

**INFLUENCE OF INSTITUTIONAL INTERVENTIONS ON ADOPTION INTENSITY
OF ECOLOGICAL FARMING AMONG HOUSEHOLDS IN KIAMBU COUNTY,
KENYA**

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the Master of Science Degree in Agricultural and Applied Economics of Egerton University**

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DECLARATION AND RECOMMENDATION

Declaration

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

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DEDICATION

I dedicate this thesis to my lovely parents, my husband Gideon Sang, my daughter Milan, and my son Mark, for their unwavering support and love throughout my academic journey.

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ABSTRACT

The ecological farming system is an alternative agricultural system that integrates local knowledge into food production. It has the ability to ensure the whole agricultural and food systems are economically viable, socially just, and culturally sensitive. Through a variety of interventions and policy formulations, institutions play a crucial role in affecting the effectiveness and intensity of the adoption of ecological techniques. However, there is a dearth of thorough empirical research that shows a connection between current institutional initiatives and the level of adoption of ecological agricultural practices. Therefore, this study focused on analysing institutional interventions influencing the intensity of adoption of ecological farming. In addition, the study determined the factors influencing awareness of ecological farming and, finally, conducted an analysis of the effect of adoption on farm income. The study used multistage sampling to collect data from 320 households in Kiambu County. A generalised Poisson regression, a generalised ordered logit, and a multinomial endogenous switching regression model were used to analyse the three objectives, respectively. According to the results, awareness was found to be high (91%). Moreover, awareness was influenced by age, household size, drought and floods, soil erosion, perceptions of benefits, group membership, and information sources. Further, according to the generalised Poisson regression results, access to markets, training, information sources, extension contacts increased the likelihood of a farmer adopting ecological farming practices at higher intensity by 50.1%, 50.9%, 4.3%, and 38.7%, respectively. Finally, this study identified six bundles of various combinations that were used by households. A comprehensive package that included compost manure, mulching, crop diversification, integrated pest management (IPM), and minimum tillage increased farm income by 9.2%. Households using the said package had the highest gain in farm income. Also, using a package consisting of compost manure, crop diversification, and IPM, and the one consisting of compost manure, mulching, crop diversification, and IPM, increased farm income by 2.5% and 1.3%, respectively. Considering the results, this study calls for policy interventions that encourage multi-stakeholder partnership arrangements to facilitate farmers' linkages to eco-friendly markets. Again, there is a need to enhance knowledge dissemination through tailored agricultural extension services and regular training forums. Also, establish policies that incentivise the comprehensive adoption of all ecological farming practices package. This would enhance household welfare through increasing farm income.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABN	African Biodiversity Network Agriculture
AFSA	Alliance for Food Sovereignty in Africa
AGNES	The African Group of Negotiators Experts Support
ANAK	Alliance of Networks in Agroecology Kenya
ANT	Actor-Network Theory
ASTGS	Agricultural sector Transformation and Growth Strategy
BIBA Kenya	Biosafety Biodiversity Association of Kenya
BvAT	Biovision Africa Trust
CABI	Centre for Agriculture and Biosciences International
CNS-FAO	The Swiss FAO National Committee
COSDEP	Community Sustainable Development Empowerment Programme
CSA	Climate Smart Agriculture
CSAEA	College of Sustainable Agriculture for East Africa
EAC	East African Community
FAO	Food and Agriculture Organization of the United Nations
GHGs	Greenhouse gases
HLPE	High Level Panel of Experts on Food Security and Nutrition
ICE	Institute for Culture and Ecology
ILEIA	Centre for Information on Low External Input and Sustainable
IPES-FOOD	International Panel of Experts on Sustainable Food Systems
IPM	Integrated Pest Management
KALRO	Kenya Agriculture and Livestock Research Organization
KBioC	Kenya Biodiversity Coalition
KCOA	Knowledge hub for Organic Agriculture
KIOF	Kenya Institute of Organic Farming
KNBS	Kenya National Bureau of Statistics
KOAN	Kenya Organic Agriculture Network
MoALD	Ministry of Agriculture and Livestock Development
NCPD	National Council for Population and Development
NGOs	Non-Governmental Organizations

OCA	Organic Consumer Alliance
PELUM	Participatory Ecological Land Use Management
SCOPE	Schools and Colleges Permaculture
SDG	Sustainable Development Goals
SRI	Sustainable Rice Intensification
SSN	Seed Savers Network
UN	United Nations
WFP	World Food Programme
WWF	World Wildlife Fund

CHAPTER ONE

INTRODUCTION

1.1 Background information

The conventional agricultural model has dominated the farming landscape over the years globally. The conventional system is corporate-controlled and heavily relies on chemical inputs, high-yielding crop and animal varieties, input-intensive monocrops, and little or no ground following. The World-Wide Fund for Nature (WWF) and the High-Level Panel of Experts on Food Security and Nutrition (HLPE) indicate several negative outcomes of the conventional farming model. They include widespread environmental degradation, biodiversity losses, high greenhouse gas (GHG) emissions, persistent hunger, diet-related diseases, broadened social inequalities among actors, and livelihood stresses for farmers around the world (HLPE, 2019; Orozco-Meléndez & Paneque-Gálvez, 2022; WWF, 2021). Despite all the stated problems associated with conventional farming systems, most governments and industry lobbying groups continue to offer massive support for conventional approaches due to their ability to improve production. This implies that conventional approaches are more concerned with just one component of food security, which is food availability. However, social movements are calling for the adoption of alternative agricultural systems that focus on achieving all six aspects of food security, namely availability, access, utilisation, stability, agency, and sustainability (HLPE, 2020).

The ecological farming system is an alternative agricultural system that integrates local knowledge into food production and provides a better relationship between agriculture and the environment and between the food system and society. In this study, ecological farming is conceptualised as a system of producing food that forgoes the use of agrochemical inputs and instead relies on ecological systems, biodiversity, and cycles adapted to local living conditions, ensuring the whole system is economically viable, socially just, and environmentally friendly (Florian *et al.*, 2020; Jurjescu, *et al.*, 2021). Embracing ecological farming implies that farming households would rely on the use of compost, animal and farmyard manure, intercropping, crop rotation, crop and livestock integration, cover crops and mulching, mixed cropping, agroforestry, minimum or zero tillage, ridging, bush fallows, and integrated pest management on their farms (Agrisud, 2020; Akanmu *et al.*, 2023; Paracchini *et al.*, 2020).

The study considers only five ecological practices. First off is crop diversification, which is key to addressing population growth, climate change, and environmental degradation. The

system involves promoting crop diversity through multiple cropping, intercropping, planting varieties or mixtures that are regionally adapted, and crop rotation. The second practice is mulching, which benefits soil health and biodiversity by maintaining soil moisture, inhibiting weed growth, and controlling soil structure. Third, integrated pest management practices tackle issues related to ecosystems, biodiversity, human health, and the environment. The fourth practice is compost manure, a less-costly alternative to chemical fertilisers for resource-constrained farmers that increases soil fertility and crop production by reusing local resources. The last practice is minimum tillage, which conserves the soil by reducing soil disturbances and increasing water use efficiency.

Ecological farming techniques have been used by farmers over the years; however, in today's agriculture, they are used in ways to provide sufficient food for a growing world population while conserving biodiversity and the ecosystem services on which agriculture depends and ensuring social justice and economic viability for farmers (Mouratiadou *et al.*, 2024). The ecological practices align with the three operational principles for sustainable food systems, which are to improve resource efficiency, strengthen resilience, and secure social equity and responsibility (HLPE, 2019). In ecological farming, the production of healthy and safe food for local people is a key concern. Consumers are increasingly concerned about food safety and prefer to purchase food that is produced through environmentally friendly farming methods (Gundala & Singh, 2021). This shift in perception has led to increased demand for eco-friendly products, consequently giving rise to green grocery stores and supermarkets stocking eco-friendly products, and organic restaurants that incorporate organic menus.

The need to ensure a sufficient food supply for an expanding population while preserving the sustainability of ecosystems has stoked increased interest among institutions in switching from conventional to more sustainable agriculture methods, particularly ecological farming. However, the transformation towards ecological farming still faces the challenge of unsupportive regimes, including multinational corporations and governments. Corporate actors play a central role in making decisions about the future of food systems. By so doing, they have managed to influence policy, research, and trade in supporting the industrial farming and food system, which disregards environmental and social externalities, hindering the development of sustainable food systems (IPES-Food, 2023). Additionally, most governments have failed to support ecological farming adequately through policies and programs. For instance, the portion of the public budget allocated

to the agriculture sector is shared out unevenly across the different sub-sectors. Fund allocation tends to favour the industrial farming system, the same system that is believed to have contributed to climate change, environmental degradation, and social inequalities (AFSA, 2020). This makes it difficult to implement sustainable farming approaches, such as ecological farming.

In Kenya, small-scale farming is mostly rainfed, so climate change poses a great threat to food production. According to the National Council for Population and Development [NCPD] (2019), about 14.5 million individuals in Kenya are below the food poverty line. Also, in 2022, the World Food Programme reported that 4.4 million people in Kenya were acutely food insecure (WFP, 2022). Further, agricultural production in Kiambu County has been declining mostly due to land degradation, poor access to agricultural inputs, crop and livestock diseases, and climate change. Farmers are addressing the challenges by adopting conservation agriculture, climate-smart agriculture, and sustainable land management practices (MoALF, 2021). According to Karuga (2022), some of the practices mostly incorporated by farmers in Kiambu county include cover cropping, intercropping, leguminous cropping, minimum tillage, crop rotation, mulching, organic manure use, integrated crop-livestock systems, agroforestry, biopesticides, and land terracing.

The uptake of ecological farming in Kiambu County is enabled by multi-stakeholder governance initiatives, whereby institutions devise institutional interventions to increase farmers' capacity to use eco-system-based practices. The institutional interventions mainly offered to farmers in Kiambu County include research and extension, capacity building, market links, early warning systems, financial and credit services, agro-inputs, technology and technology transfer, and disease surveillance (MoALF, 2021). Despite the much efforts from various institutions, there is a significant gap in the literature concerning the effectiveness of civil society interventions in promoting the adoption intensity of ecological farming. Therefore, there is a pressing need to investigate and document the effectiveness of civil society interventions in promoting the adoption of ecological farming practices. Such research will provide valuable insights into how these efforts can be enhanced and integrated with institutional support to facilitate a more effective transition to a sustainable food system.

1.2 Statement of the problem

The conventional system is a resource-intensive, corporate-led agricultural system that has caused massive negative outcomes for the environment and society. To continue integrating the conventional farming system in a resource-constrained world with corporate-controlled farming

and food systems is not a viable option to deliver sustainable agricultural and food systems that are much needed to achieve food security, protect the environment, and empower societies. In Kenya, agricultural production is characterised by resource-poor farmers facing challenges like degraded natural resources, unpredictable rainfall, and inaccessibility to expensive fertilizers and pesticides. The challenges above increase smallholder farmers' vulnerability to food insecurity and malnutrition. Therefore, farmers turn to innovations such as ecological farming that use locally accessible inputs and are appropriate for particular ecological conditions. The widespread adoption of ecological farming practices is essential for promoting environmental health and ensuring food security among farmers yet, farmers are using such farming practices within unsupportive institutional frameworks and policy regimes.

Institutions, including multinational corporations and governments, are not always supportive of ecological farming and may actively encourage other, non-ecological alternatives. Few large corporate actors in the agricultural sector play a central role in making decisions about the future of food systems. They have influenced policy, research, and trade in supporting the industrial farming and food system, disregarding environmental and social externalities. Also, most governments have failed to support ecological farming adequately through policies and programs. For instance, the portion of the public budget allocated to the agriculture sector is shared unevenly across the different sub-sectors. Fund allocation tends to favour the industrial farming system, which has continued to contribute to climate change, environmental degradation, and social inequalities. In response to the said challenges, civil society organizations have stepped in to promote the adoption of ecological farming practices. They are pushing back the conventional agriculture narrative and devising interventions to enhance the adaptive capacity of farmers. They improve access to information, extension services, credit, markets, inputs, and infrastructure. While institutional interventions are making a substantial impact, there is limited empirical research evaluating how these interventions affect the intensity of ecological farming adoption and the economic outcomes of adoption in Kenya. This study aims to fill that gap.

1.3 Objectives

1.3.1 General objective

Increasing household welfare through the uptake of ecological farming practices among households in Kiambu County.

1.3.2 Specific objectives

- i. To identify factors affecting awareness of ecological farming among households in Kiambu County.
- ii. To determine the institutional interventions that influence the adoption intensity of ecological farming among households in Kiambu County.
- iii. To determine the effect of ecological farming on farm income among households in Kiambu County.

1.4 Research questions

- i. What factors determine awareness of ecological farming practices among households in Kiambu County?
- ii. Which institutional interventions influence adoption intensity of ecological farming practices among households in Kiambu County?
- iii. Does uptake of ecological farming affect farm income among household in Kiambu County?

1.5 Justification of the study

Ecological farming practices have the ability to balance food production, environmental conservation, and social inclusion. Small-scale farming in Kenya is heavily dependent on rainfall. Thus, with massive land degradation and the effects of climate change, smallholder farmers often face the risk of not producing enough food. Taking up ecological practices would require farmers to use fewer synthetic fertilisers and chemical inputs and rely on locally available inputs, as well as diversify crops, which increases the chances of better yields (HLPE, 2019). According to the County Integrated Development Plan (CIDP) of Kiambu for the 2022–2023 period, the county government of Kiambu has been at the forefront of promoting sustainable agricultural practices all around the county. County directorates have promoted sustainable land management, agro-forestry seedlings, and on-farm water harvesting techniques (Kiambu County, 2021).

Ecological farming could help realise the food and nutrition security agenda according to the Big Four Agenda and the Agricultural Sector Transformation and Growth Strategy (ASTGS), as well as the National Food and Nutrition Security Policy. The ASTGS aspires to provide food for all through agricultural transformation (ASTGS, n.d.). On the other hand, the National Food and Nutrition Security Policy aims to ensure that all Kenyans have access to enough nutritious food, both in terms of quantity and quality, at all times to meet their needs for optimum health

(Republic of Kenya, 2011). Consequently, the two policy agendas contribute to the Big Four agenda of achieving 100% food and nutrition security. Moreover, adopting ecological farming would contribute to achieving Kenya's Vision 2030 by increasing productivity and household income, thus contributing to the economic pillar. Also, using locally available resources and diversifying food would contribute to the social pillar.

According to East African Community (EAC) Vision 2050, the regional goal under the "natural resources and environment management" pillar is to realise effective natural resource and environmental management and conservation with enhanced value addition. This goal is set to be achieved by encouraging the use of resources sustainably, promoting a green economy for sustainable development and poverty reduction, and adapting to climate change (EAC, 2015). Similar aspirations and goals are espoused in the AU Agenda 2063, along with the 2030 Agenda for Sustainable Development. For example, ecological practices would help achieve SDG 12, which calls for all stakeholders to embrace sustainable production by using resources efficiently and sustainable consumption by reducing global waste.

The findings from this study provide empirical evidence that inform policymakers on intervention strategies and policies that would improve resource allocation towards promoting and scaling up ecological farming and subsequently increasing productivity while conserving the environment. Furthermore, this study is useful to the education fraternity as it contributes to the existing body of knowledge.

1.6 Scope and limitation of the study

The study focused on determining the institutional interventions influencing the adoption intensity of ecological farming practices among farmer households in Kiambu County. The task involved establishing whether the different interventions initiated by institutions influenced the intensity of the adoption of ecological farming practices. This study further established whether the uptake of ecological farming affects households' farm income. The study was limited to farmer households in the Lari sub-county and covered a total of two wards situated within the sub-county. This study was challenged by the limited literature available on ecological farming in Kenya, creating an information challenge for the study.

1.7 Definition of terms

Awareness: refer to household knowledge and demonstrated understanding with regard to ecological farming.

Conventional farming system: is associated with heavy reliance on chemical inputs, high-yielding crop and animal varieties, input-intensive mono-crops, and less or no ground following during agricultural production.

Ecological farming: it as a system of producing food that forgoes the use of agrochemical inputs and instead relies on ecological systems, biodiversity, and cycles adapted to local living conditions, ensuring the whole system is economically viable, socially just, and environmentally friendly (Florian *et al.*, 2020; Jurjescu, *et al.*, 2021).

Farm income: Refers to the money generated by a household from on-farm (crops and livestock) operation.

Household: is defined as a person or a group of persons residing in the same compound, answering to the same head of the household and pooling and sharing resources for common provisions such as food and house rent (KNBS, 2015).

Institutional interventions: They are set of activities designed to better support, and enhance the capacity of farming household or act as incentive for uptake of ecological farming practices.

Institutions: They are organizations or a network of actors at different scales within which changes are generated and spread.

Sustainability: refers to “the long-term ability of food systems to provide food security and nutrition in a way that does not compromise the economic, social and environmental bases that generate food security and nutrition for future generations” (HLPE, 2020).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this section, the literature of previous studies on sustainable farming, particularly ecological farming, was reviewed. Several studies have been conducted on ecological farming, most of which focused on awareness and the drivers and barriers to the adoption of ecological farming across different scales. However, this literature review focused on factors affecting the level of awareness of agricultural innovations as well as the institutional environment and its role in influencing the adoption of sustainable farming techniques. Furthermore, the literature on the adoption of sustainable farming practices was investigated to understand their effect on improving household welfare. Based on the reviews, the knowledge gaps in the body of literature that this study attempted to fill were identified. Ultimately, a theoretical framework, random utility theory, that served as the foundation for this study was introduced, and a conceptual framework was provided.

2.2 Current state of agriculture

The global agriculture and food systems have failed to meet the world's demand for food. In 2022, it was estimated that an average of 735 million people in the world suffered from hunger (FAO *et al.*, 2023). The world's state of food insecurity is exacerbated by the challenges arising from uneven demographic expansion, threats posed by climate change, mounting pressures on natural resources, increased incidences of pests and diseases, rising inequalities, and the intensification of natural disasters. Therefore, in the future, the global agricultural and food systems should not only be more resilient to crises, but also more equitable and inclusive, empowering and respectful, regenerative, healthy and nutritious, as well as productive and prosperous for all (HLPE, 2020).

In Kenya, agriculture is an important economic sector. Despite this, the country still faces the challenge of food insecurity. The small-scale farming system is particularly rainfed; thus, rainfall variability brought about by climate change negatively affects agricultural production. To add to this, increased incidences of pests and diseases result in major crop and livestock losses, hence causing hunger (Karina & Mwaniki, 2011). Also, population pressure and land fragmentation have intensified, leading to a decrease in land available for cultivation and hence

affecting food production. These challenges increase smallholder farmers' vulnerability to food insecurity and malnutrition.

There is a growing interest among farmer organisations, the government, learning and research institutions, civil society organisations, and other development practitioners in transitioning from conventional production systems towards more sustainable production systems. The ecological farming system is increasingly gaining recognition as a suitable system with the ability to improve productivity, stability, sustainability, and equity.

2.3 Definition of ecological farming and the principles

Ecological farming has been defined differently in many studies over time. For instance, ecological farming has been defined by O'Flaherty (2000) as those production practices that consider the local ecology and use the ecosystem for food production without interfering with its ability to regenerate. Magdoff (2007) defines it as "farming that involves building the strengths of natural ecosystems into agroecosystems purposely disturbed to produce food and fibre." Killebrew *et al.* (2009) define ecological farming as a holistic approach that seeks to produce food by relying on natural processes and local resources rather than external inputs while taking into consideration environmental and social outcomes. Tirado (2015) defines ecological farming as a fair and systemic agricultural approach that is concerned with ecological benefits, economic viability, societal benefits, and respect for the culture of the local people while producing food. Altieri and Nicholls (2005) define ecological farming as a system that eliminates the use of agrochemical inputs and instead relies on ecological interactions and synergisms for food production and ensures the whole system is economically viable, socially just, and culturally sensitive. Ecological farming is an approach that maintains biodiversity while producing food using economically, socially efficient, and environmentally friendly farming practices, improving the quality of life for the entire society (Florian *et al.*, 2020). Jurjescu *et al.* (2021) defined ecological farming as a system of producing food that forgoes the use of chemical inputs and instead relies on ecological systems, biodiversity, and cycles adapted to local living conditions, ensuring benefits to the environment and promote fair relations and a good quality of life for all involved.

The definition of ecological farming has evolved over time and has extended its focus from on fields and farms to encompass all the ecological, sociocultural, technological, economic, and political dimensions of food systems (HLPE, 2019). This study adopts the definition by Florian *et al.* (2020) and Jurjescu *et al.* (2021). This is because the authors have incorporated the ecological,

economic, and socio-cultural aspects in their definitions. Therefore, ecological farming in this study is conceptualised as a system of producing food that forgoes the use of agrochemical inputs and instead relies on ecological systems, biodiversity, and cycles adapted to local living conditions, ensuring the whole system is economically viable, socially just, and environmentally friendly (Florian *et al.*, 2020; Jurjescu, *et al.*, 2021).

FAO developed a framework of ten elements that would guide countries as they transition towards sustainable food systems to achieve multiple SDGs. The ten elements are categorised into three groups. Firstly, ecological characteristics include diversity, synergies, efficiency, resilience, and recycling. Secondly, social characteristics include the co-creation and sharing of knowledge, human and social values, culture, and food traditions. Finally, enabling political and economic environments include responsible governance, circular economy, and solidarity economy” (FAO, 2018b; CNS-FAO, 2021). Later, HLPE (2019) devised a set of 13 principles that conform with the FAO's ten elements (Wezel *et al.*, 2020). They include “recycling, input reduction, soil health, animal health, biodiversity, synergy, economic diversification, co-creation of knowledge, social values and diets, fairness, connectivity, land and natural resource governance, and participation” (HLPE, 2019). Broadly, the 13 principles capture the three operational principles for sustainable food systems, which are to improve resource efficiency, strengthen resilience, and secure social equity and responsibility. The term ‘ecological farming’ used in this study follows the 13 principles for determining the sustainability of a given agricultural practice, input, or management decision in the agricultural system.

2.4 Ecological farming practices

In farming communities, attempts are being made to incorporate ecological farming practices. The drivers and barriers to the adoption of ecological farming practices have been identified in several studies. The barriers include a lack of social awareness regarding organic products, lack of financial support from the government, a lack of scientific knowledge, expertise, and experience regarding practices different from those currently in use, higher labour requirements, a lack of increased market value for the products, the complexity and incompatibility of the practices, resistance to change. On the other hand, the motivating factors have been identified as the availability of government support, a favourable cultural environment, perceived benefits, the availability of information about the experiences of other farmers, good agronomics,

and limited income sources (Paracchini *et al.*, 2020; Polonio Punzano *et al.*, 2021; Zazu & Manderson, 2021).

Some of the most commonly mentioned ecological practices in literature are compost, animal and farmyard manure, intercropping, crop rotation, crop and livestock integration, cover crops and mulching, mixed cropping, agroforestry, minimum or zero tillage, ridging, bush fallows, and integrated pest management (Agrisud, 2020; Akanmu *et al.*, 2023; Paracchini *et al.*, 2020). The Kenyan policy document has included eco-friendly practices such conservation agriculture, agroforestry, SLM, growing indigenous crops that can withstand drought, water harvesting, livestock management, and integrated soil fertility management (Leippert *et al.*, 2020). These methods are thought to boost resilience and agricultural productivity. This study takes into account five ecological practices, including mulching, integrated pest management, crop diversification, and the use of compost manure.

2.4.1 Minimum tillage

Minimum tillage (MT) is a sustainable farming practice that limit soil disturbance only to planting stations while leaving the rest of the soil undisturbed (Adam & Abdulai, 2023). In a study by He *et al.* (2021), minimal tillage is conceptualised as a tillage method that follows the principle of reducing soil tillage. The study notes that minimum tillage discourages the use of a plough, reduces the tillage procedure to avoid destroying the soil structure, hence greatly reducing soil, wind, and water erosion. This system has been promoted for its soil conservation benefits. The long-term benefits of minimum tillage are to reduce soil disturbances and improve soil fertility, while the short-term benefit is to increase water use efficiency.

In southern and eastern Africa countries, the area under the application of no-till systems is still small. This is because most farmers have no knowledge of no-till systems. According to Jena (2019), only 15% of Kenya's high-potential agricultural zone actually practised minimum tillage. Furthermore, the authors also discovered that minimum tillage did not increase yields but did slightly increase adopters' gross margins. The results also showed that for adopters, the impact of minimum tillage labour savings was the most significant welfare-enhancing effect. In a different study, Osewe *et al.* (2020) confirmed that the introduction of minimum tillage enhanced the welfare of smallholder farmers in southern Tanzania. The adoption of minimum tillage, specifically, had a positive effect on per capita net crop income and labour demand. Also, Adam

and Abdulai (2023) showed that adoption of minimum tillage significantly decreased households food insecurity and labour demand.

2.4.2 Crop diversification

Crop diversification is the process of fostering crop diversity by growing more than one crop in an area. It is achieved through multiple cropping, intercropping, planting varieties or mixtures that are regionally adapted, and crop rotation (Barman *et al.*, 2022). The benefits of using a number of diversification strategies outweigh those of using just one of them (Beillouin *et al.*, 2019). Crop diversification is a crucial sustainable agriculture strategy that can be used to address population growth, climate change, environmental degradation, and shifting consumer habits (Sonawane *et al.*, 2022). It can increase productivity, sustainability, and the supply of eco-system benefits. Additionally, smallholder farmers used crop diversification on their farms as a strategy for risk reduction, nutritional improvement, consumption, and commercial needs (Dessie *et al.*, 2019).

According to Kemboi *et al.* (2020), diversification strategies such as crop rotation and intercropping (agroforestry) are linked to improvements in soil quality, yields, and biodiversity. Appiah-Twumasi and Asale (2022) affirm the importance of crop diversification in increasing food access and reducing the food insecurity experienced by households. Douyon *et al.* (2022) found out that smallholder farmers in Mali adopted crop diversification in order to increase agricultural production as well as mitigate the adverse effects of climate change on crop yields, which improved food and nutritional security. Similarly, Derso *et al.* (2021) found that crop diversification had a positive and significant effect on household food security. Despite the highlighted benefits of crop diversification, few farmers in Sub-Saharan Africa diversify their agricultural practices. This is due to institutional limitations and difficulties accessing agricultural inputs, equipment, and other production factors. Therefore, the government should support the development of agricultural policies that support the transition from non-diversification to crop diversification (Dembele *et al.*, 2018). This can be achieved by creating guaranteed access to inputs and subsidies on agricultural input resources, with smallholder farmers receiving priority.

2.4.3 Composting

The widespread land degradation and threats of climate change have posed a challenge to achieving food security, especially for smallholder farmers who rely on the availability of natural resources for their livelihood. Land degradation is common in Africa. About 46% of the total land

area is degraded, mainly due to, population increase, wars and conflicts that have resulted in larger refugee camps, improper soil management, deforestation, shifting agriculture, insecurity regarding land tenure, variances in climate, and inherent qualities of fragile soils in various agroecological zones (AGNES, 2020). Soil fertility can be improved by applying inorganic fertilisers; however, due to the high prices of chemical fertilisers, poor farmers are unable to acquire them. Compost manure is a readily available and less-costly alternative to chemical fertilizers.

Composting is the controlled conversion of degradable organic products and wastes into stable products with the aid of microorganisms (Ayilara *et al.*, 2020). It is a component of sustainable agriculture practices that re-uses readily available local or farm resources. The common composting methods used by farmers include, firstly, the traditional composting method. This type of composting process relies on naturally occurring fungi and bacteria to break down biodegradable materials. Secondly, the vermicomposting method involves decomposing organic waste into organic manure using earthworms (mostly the red wiggler). Finally, there is a new concept of composting that uses black soldier fly (BSF) larvae for the bioconversion of organic materials into organic fertilizer. The regular use of compost manure improves the physical and chemical properties of soil cultivation by increasing porosity, aggregate stability, organic content, water-holding capacity, and the macro and micronutrients available for plant uptake as well as reducing bulk density consequently leading to improved plant growth and increased crop productivity (Ho *et al.*, 2022).

2.4.4 Integrated pest management

Pests and diseases are problems affecting agricultural production worldwide. An estimated 20–40% of crop yield globally is lost to pests and diseases (CABI, 2023). Pests and diseases affect the quality and quantity of harvested yields. This has contributed to food insecurity and financial losses incurred by farmers. To control pests and diseases, farmers have used chemical pesticides on their farms. The pesticides are quite expensive, hence unsustainable for resource-constrained farmers; they also pose a threat to human health and the environment. Alternative methods that control pests and disease in a sustainable manner have been developed. Integrated Pest Management (IPM) is one such alternative.

IPM as a sustainable, science-based approach that employs biological, cultural, physical, and chemical techniques to identify, manage, and reduce pest risks, focusing on environmental and human health benefits (Dara, 2019). The issues of human health, environment, ecosystems,

and biodiversity have become great concerns in agricultural production. IPM has the ability to reduce chemical dependency, preserves beneficial organisms, and nurtures resilient ecosystems. Also, it offers economic benefits like cost-effective strategies, enhanced yields, and sustained agricultural longevity (Rashwin & Sanjeeth, 2023). However, IPM adoption is hindered by a lack of supportive policies, social and psychological factors, extension methods, and training in developing countries. By stepping up farmer training, bolstering public-private partnerships, and creating climate-resilient methods, IPM has the potential to successfully transform pest management and ensure sustainable food production and global food security (Sharma, 2023).

2.4.5 Mulching

In Sub-Saharan Africa (SSA), agriculture production is rainfed. About 97% of the moisture needed by crops comes from the soil, which mainly stores water from rainfall (Lampsey, 2022). Climate change has led to increasing global temperatures and unpredictable and irregular seasonal rainfalls, thus failing to meet the crop moisture needs required for higher yield production. It is important that water in rain-fed agriculture is used efficiently and effectively through interventions that conserve soil water. One such intervention is mulching.

Mulching offers farmers an opportunity to minimize the effects of drought, water loss, and soil erosion on crop production (Madin *et al.*, 2024). Mulching is a technique that helps conserve the soil moisture by limiting runoff and soil loss, reducing evaporation, and managing soil temperature (Iqbal *et al.*, 2020). Additionally, mulching enhances the nutrients status of soil, suppresses the weeds in crop plants, and remove the residual effects of pesticides, fertilizers, and heavy metals, and improve the aesthetic value of landscapes and economic value of crops (El-Beltagi *et al.*, 2022). The benefits of mulching mainly demonstrate its effectiveness in enhancing soil health and biodiversity, which is a fundamental goal of sustainable farming.

2.5 Institutions and ecological farming

2.5.1 Introduction

The implementation of ecological farming is challenged by several institutional settings that favour conventional agriculture and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition notes that policies, corporate structures, education systems, consumer habits, and investment in research have not fully adjusted to accommodate a sustainable farming system (HLPE, 2019). Therefore, an enabling environment that would offer guidance and

support to institutions transforming the farming system is needed. Despite the unfavourable institutional environment, social movements all around the world are promoting ecological farming approaches as methods that can achieve sustainable food system transformation. Substantial progress has been made in the number of publications released by civil society organisations, academic institutions, and international development organisations. Also, in recent years, policies specifically designed to support eco-system-based practices have emerged in a few countries including Argentina, Brazil, France, India, Nicaragua, Senegal, and Uganda (MoALD, 2023).

2.5.2 The role of institutions in influencing a transition toward ecological farming

Farmers' capacity to implement and sustain ecologically based practices can be enhanced by institutions. Institutions offer incentives in the form of extension services, market linkages, infrastructure development, agricultural research and development, information services, credit, input support, and training. Therefore, farmers who have access to such institutional resources gain the right skills and information, access to markets, financing channels, and inputs, thus prompting the uptake and intensification of ecological practices. However, the farmers' geographical locations might make it more difficult for them to access these resources. Therefore, the study incorporated a location variable to capture the difference in the interventions accessed and farm income.

Transforming a conventional system into an ecological system requires system redesign. Farmers must redesign both their production system and their commercialization system, as well as develop new knowledge on practices adapted to local conditions (Ryschawy *et al.*, 2019). Therefore, interventions and support from actors, practitioners, and civil society are fundamental in shifting resources away from conventional approaches that are disempowering, synthetic input-intensive, and harmful to the environment and ensuring the full potential of ecological farming is realised. In a study conducted by VanGelder and Varghese (2017), the authors examined how a Mexican farmers' organisation or cooperative was promoting ecological farming. They reported that their role in creating a space for dialogue and knowledge exchange stimulated an ecological transition.

According to Ryschawy *et al.* (2019), actors can act in favour or against a transition towards ecological farming with no regard for their influence on farmers. The authors identified two types of actors influencing farmers' decisions to transition or not to ecological farming. On

one hand, they identified central actors comprising supply chain actors, input suppliers, and standard advisors who were not in favour of ecological farming. For example, enterprises commercialising inputs were, in particular, shown to develop barriers to ecological practices as they were opposed to autonomy in inputs. Despite the central actors not necessarily being in favour of agroecology, they were found to play a key role in farmers' decisions to transition or not to ecological farming. This is because farmers interact with them when purchasing inputs or during marketing. On the other hand, they identified peripheral actors comprising progressive advisors, agri-chambers, progressive farmer groups and cooperatives, and organic farmer unions. The mentioned actors acted in favour of ecological farming and greatly influenced farmers' decisions to transition or not to ecological farming since the farmers relied on their advice.

Castella *et al.* (2022) explored the role of an innovation system in the reconfiguration of agricultural practices towards sustainability in Laos. They examined the role of actor networks in enabling ecological innovation using insights from the Actor-Network Theory (ANT). The innovation system was a network of actors involving a diversity of individuals (for example, farmers, traders, and experts) and organisations (for example, cooperatives, rural development agencies, and teaching and research institutions) that mainstream ecological principles and practices to enhance agroecosystems' resilience. The study focused on analysing seven innovation systems that were active between 2005 and 2020 in the northern uplands of Laos. It found that the scope of interventions gradually evolved towards increased involvement of a larger range of service providers along the value chains, civil society, and policymakers. Further, the results indicated that the focus of interventions shifted from pull activities like technical innovations and capacity building of research and development and extension agents to push activities such as market innovations, policy advocacy, and infrastructure development. The study implied that maintaining flexibility and agility in innovation systems was a key element of success and impact in the context of the uncertainty inherent to ecological innovation. Therefore, activities coming from within and between networks are essential for scaling ecological innovations.

Over the past two decades, some countries have been recognised to have achieved considerably high success in terms of transitioning to agroecology. One of those countries is Cuba, which has been highly successful in achieving a large-scale transition away from conventional production. Nelson *et al.* (2008) conducted a case study to explore the role of government and other national institutions in the shift away from conventional agriculture, particularly with regard

to how national policies were implemented and their effect at the farm level. The evidence gathered on 12 farms in San Jose' de las Lajas, as well as through farm visits and key informant interviews across the country, indicated that the ecological model of production has received conscious support at the level of agricultural research, development, extension, and policy. The authors argued that the ecological transition was largely led by research institutes, non-state organisations, and the Cuban government, which have all contributed to the institutionalisation of ecological farming in both policy and practice. However, even though most farmers have adopted ecological farming, the degree to which they have internalised ideas about sustainable agriculture is still considerably low.

2.5.3 Institutional environment in Kenya

Private actors, farmer organisations, the Kenyan government, learning and research institutions, and civil society organisations have promoted ecological practices in Kenya. The Kenyan government has established different development programmes to increase productivity, deliver food and nutrition security, reduce social inequality, and minimise biodiversity loss (Karuga, 2022). They include Kenya Vision 2030, the Kenya Climate-Smart Agriculture Strategy, the Climate Change Act, and the Big Four Agenda (Leippert *et al.*, 2020). Recently, the government has also drafted the National agroecology for food system transformation strategy, 2024 – 2033. The strategy provides coordination mechanism to agroecology actors to transform food and agricultural systems holistically, focusing on social, cultural and economic dimensions.

Kenyan institutions are making notable progress in promoting ecologically-based farming. For example, the Alliance of Networks in Agroecology Kenya (ANAK) and the Participatory Ecological Land Use Management (PELUM) Association of Kenya are the main networks of actors promoting ecological farming through advocacy and policy influence, networking, capacity development, and information and knowledge sharing. In a publication by PELUM (2022), the ANAK network promotes agrobiodiversity, ecosystem services, and agroecology in Kenya. It comprises the African Biodiversity Network (ABN), Biosafety Biodiversity Association of Kenya (BIBA Kenya), Kenya Organic Agriculture Network (KOAN), Organic Consumer Alliance (OCA), Participatory Ecological Land Use Management (PELUM Kenya), Schools and Colleges Permaculture (SCOPE-Kenya), and Biovision Africa Trust (BvAT). These networks of actors promote a range of ecological practices, including crop diversification, integrated pest

management, compost/farmyard/animal manure, agroforestry, cover crops, crop residual utilisation, and minimum tillage, among others (Paracchini *et al.*, 2020).

Further, ecological farming practices are knowledge-intensive; efforts to raise awareness and disseminate knowledge on ecological farming to farmers and other stakeholders are therefore inevitable. Several knowledge hubs have been created separately and independently across the country. According to AgriProFocus (2020), some of the key knowledge centres in Kenya are the Agroecology (AE) Hub in Kitale, the College of Sustainable Agriculture for East Africa (CSAEA), the Seed Savers Network (SSN), the Knowledge Hub for Organic Agriculture (KCOA), the Catholic-led Multi-Agency Initiative, the Global Advocacy Project 2017-2020, and the Kenya Institute of Organic Farming (KIOF).

Lari sub-county has received immense support from stakeholders, either individually or in collaboration, to promote ecological approaches. For example, the Institute for Culture and Ecology (ICE) has promoted ecological approaches for farmers in the Lari Sub-County of Kiambu County for over 12 years. Moreso, farmers have been trained in the techniques of farming indigenous vegetables and made aware of the nutritional importance of consuming them by organisations such as KALRO and the National Gene Bank of Kenya (PELUM, 2022). COSDEP is another active organisation in Lari subcounty. It offers training services to smallholder farmers on organic farming and advocates for sound ecological farming techniques.

Public policy guides the specific roles and agendas of different actors and promotes agricultural development, private actors, and donor interests (Leippert *et al.*, 2020). At the county level, several counties including, Muranga, Kiambu, Vihiga, Busia, Kakamega and Elgeyo Marakwet, have either developed or are in the process of developing agroecology policies or strategies (MoALD, 2023). Institution such as PELUM and ICE are specifically working with Kiambu County government on an agroecology policy draft for the county (Karuga, 2022). Despite the remarkable influence institutions have on ecological farming, the literature has not widely documented the effectiveness of institutional interventions on the adoption of ecological farming. Therefore, this study aims at filling that gap.

2.6 Determinants of farmers' awareness of agricultural innovations

Ecological farming is knowledge-intensive (Emeana *et al.*, 2021), and access to information on the basic concept of ecological practices and their potential benefits and risks is paramount for their adoption. Training farmers raises awareness regarding that particular

technology. Nevertheless, awareness among farmers is not always a guarantee that they will automatically adopt and apply the technology (Dennis *et al.*, 2013). Other existing barriers and farmers' perceptions about risky technologies also determine adoption. While knowledge is an important variable in determining adoption, the different dissemination channels used to disseminate information to farmers have a bigger influence on technology adoption and sustained use (Mauceri *et al.*, 2005). In the studies conducted by Amudavi *et al.* (2009), Murage *et al.* (2012), Nyasimi *et al.* (2017), and Shariff *et al.* (2013), face-to-face interactions, field days, government extension workers, researchers, traditional experts, seed companies, neighbours and family members, radio, agricultural shows, religious groups, and farmer groups were the main sources of information for farmers. The channels were effective in transferring information to enhance the diffusion of technology in their study areas. Additionally, a study by Lai Ngunyen *et al.* (2020) underscores the importance of group organisation in promoting learning among farmers. They deduced that most farmers learned about sustainable farming and organic farming practices, making use of the local resources, reducing chemical inputs to protect the environment, water use efficiency, and climate change adaptation through interactions and/or training provided by the group.

Different studies have looked into the determinants of awareness of different agricultural innovations. One such study is that of Cherotich and Kaur (2023), which identified the socio-economic characteristics that affect GAP awareness among vegetable farmers in Nakuru, Kenya. The study results indicated that gender, level of education, leased land, income, and training were socio-economic factors influencing awareness among vegetable farmers in Nakuru, Kenya. Mehmood *et al.* (2022) used a Probit model to evaluate the relationship between the farmers' awareness of climate change and socioeconomic characteristics. They found age, education level, farming experience, farmer knowledge, land ownership, off-farmhouse income, extension access, and information access to be the variables influencing climate change awareness.

In another study, Sedhai *et al.* (2022) assessed the perception of farmers towards Good Agricultural Practices (GAP) and factors affecting awareness of GAP among mandarin growers. They reported that extension contact and participation in GAP training were found to be the factors affecting awareness of GAP among farmers in Gulmi, Nepal. Further, Joshi *et al.* (2019) revealed that education and training significantly influenced awareness of GAP among banana growers in Chitwan, Nepal. According to Rahman *et al.* (2022), respondent age, average family income,

income from the crop, farming experience, adoption of inclusive agribusiness techniques, easy access to extension services, and distance from farm to industrial zone were the influencing factors of farmers' awareness of environmental degradation in Bangladesh. In a different study, Ouko *et al.* (2023) found that farming experience, distance to the feed source, and knowledge about existing fish feeds positively and significantly impacted the awareness of black soldier fly larvae (BSFL) meal, while average income earned negatively and significantly influenced awareness.

Ullah *et al.* (2022) stressed that extension contact, income from agriculture, and access to credit positively affect the farmers' awareness of extension-suggested wheat varieties in Pakistan, whereas their education and household sizes negatively affect their awareness. Also, a study conducted by Raza *et al.* (2023) on factors affecting the awareness and adoption level of improved olive cultivation practices by olive growers showed that education, the number of olive trees, and motivation to grow olive trees had a highly positive and significant relationship with the level of awareness about olive cultivation practices. In another study, Daberkow and McBride (2003) indicated that operator education and computer literacy, full-time farming, and farm size positively influenced the awareness of precision agriculture, while age had a negative influence. Additionally, Ayuya *et al.* (2011) revealed that age, gender, education level, group membership, existence of tree farming, and contact with extension services influenced the awareness level of smallholder forest carbon projects.

Most studies on determinants of farmers' awareness have covered a wide range of topics. The majority of existing studies have only considered household characteristics, socio-economic factors, and institutional factors as determinants of awareness of agricultural technologies. However, little attention is given to perceptions, farm characteristics, and climate shock variables. This study differs from existing studies in that it includes the later variables as determinants of awareness. Moreover, most of the studies mentioned above have approached awareness as a binary outcome variable and have used the binary logit and probit models to determine the factors affecting awareness. This study analysed awareness as an ordered outcome using a generalised ordered logit model to account for the violation of the parallel line regression assumption.

2.7 Determinants of adoption intensity of agricultural technologies/practices

Along with awareness, farmer households differ in their ability to adopt and maintain established ecological practices. The transition to ecological farming varies from farmer to farmer depending on local ecological conditions and local socio-economic circumstances, institutional

factors, as well as farmers' individual needs and aspirations (ILEIA, 2006; Mekuria *et al.*, 2022). Additionally, perceptions of ecological intensification also influence the adoption of ecological farming (Benitez-Altuna *et al.*, 2021). Farmers only adopt practices that they perceive to be beneficial, especially in terms of yields and income. On the other hand, farmers hesitate to adopt ecological practices if they perceive them to be risky. Coulibaly *et al.* (2019) reported that increased crop yields and farm income, the availability of natural resources and labour, and training determined the adoption of ecological practices in the Sudano-Sahelian Zone. Additionally, Gomarasca (2012) identified socio-cultural factors, namely social cohesion, participation, political compromise, gender equality, inter-generational relationships, peasant habits and traditions, peasant pride, education, and individual personality, that greatly influence the decision to adopt ecological practices or not.

According to Epule and Bryant (2016), socio-demographic factors that influence adoption include farmer years of experience, farm income, level of education, and availability of family labour. In a different study, Mahama *et al.* (2020) conducted a study to determine the factors that account for the adoption intensity of soybean production technologies among farmers in northern Ghana. The results from a generalised Poisson regression model showed that age, education, extension visits, mass media through radio, and risk perception were significant and positive factors influencing the adoption intensity of soybean production technologies among farmers in northern Ghana. Contrarily, farming experience, distance to the input market, cropping system, household extension method, and access to credit had a significant but negative influence on adoption intensity.

Further, Mthethwa *et al.* (2022) used a Poisson model to estimate the factors that influence the intensity of smallholder maize farmers' CSA practices. They reported that drought had a significant and positive impact on CSA intensification, while marital status had a negative but significant effect. A different study was conducted in Uganda on the adoption patterns and intensity of multiple banana technologies. The findings showed that adoption intensity was influenced by household size, total area under bananas, soil fertility status, ecological location, household membership in a farmer group, access to formal sources of credit, and input and output markets in major towns in Uganda (Kiconco *et al.*, 2022).

In another study, Musafiri *et al.* (2022) conducted a study to assess the determinants of joint adoption and the intensity of CSA adoption in Western Kenya. The results revealed that arable

land size, livestock ownership, and constant soil erosion were significant and positive determinants of adoption intensity, and gender and soil fertility were negative but significant determinants of adoption intensity.

Ghimire *et al.* (2015) looked into various aspects of the adoption of the improved maize variety (IMV) by farm households in Central Nepal. Livestock assets, group membership, extension services, access to seeds, and varietal-specific traits (yield potential and pest resistance) all had a positive and significant association with adoption intensity. On the contrary, farm size and distance to the market had a negative effect.

Upendram *et al.* (2023) examined how access to four institutional resources, namely, membership in producer groups, extension contact, weather information, and training, influenced smallholder rice producers' adoption intensity for climate change adaptation practices. The study results revealed that all four institutional resources significantly and positively influenced the adoption intensity of climate change adaptation practices among smallholder rice producers.

Oyetunde-Usman *et al.* (2021) used an ordered Probit model to identify the drivers of the intensity of adoption of sustainable agricultural practices. It was found that age, household size, extension, household wealth status, and production shock significantly and positively influenced the adoption intensity of sustainable agricultural practices. However, education, gender, and distance to the market had a negative influence on adoption intensity. Similarly, Muzira *et al.* (2021) used an ordered probit model and reported that age, education level, hired labour, possession of small ruminants, and enhanced market linkage positively influenced farmers' likelihood to invest in two or more soil fertility management and conservation innovations.

Rahman *et al.* (2022) used a two-limit Tobit model to identify factors that influence the adoption intensity of drought-tolerant rice varieties. They found out that training, having access to a mobile phone and television, and good health conditions positively influenced adoption intensity, while membership in a group had a negative influence. Kassa *et al.* (2021) determined the intensity of adoption of the improved faba bean cultivars in the central highlands of Ethiopia. Their results showed that livestock holding and access to market information were the factors that significantly and positively influenced the intensity of adoption.

In a different study, Awuni *et al.* (2018) used a zero-inflated Poisson regression model to look into the rate at which rice farmers adopted new agricultural technologies. The author postulated that adoption intensity had a significant and positive association with location (region),

household extension method, mobile phone access, access to research and extension, access to agriculture credit, household size, and the gender of the farmer. On the contrary, access to agricultural information through demonstration fields and radio, formal education, membership in farmer-based organisations (FBOs), and access to trainings had a negative but significant association with adoption intensity.

Further, Pedzisa *et al.* (2015) employed a Poisson regression model to analyse the intensity of adoption of conservation agriculture by smallholder farmers in Zimbabwe. The results indicated that education, agro-ecology zone, non-governmental input support, and extension support had a positive and significant impact on adoption intensity, while household size had a negative and significant impact.

2.8 Effect of ecological farming practices

Farmers are more likely to adopt multiple ecological practices if they perceive them to enhance productivity, manage pests and disease, improve soil fertility, and easily adapt to local ecological conditions (Ochola *et al.*, 2013). Adoption of ecological farming practices at the farm level can contribute positively to the food security and wellbeing of smallholder farmers (Milheiras *et al.*, 2022). It can also contribute to positive income and labour outcomes on farms with a strong peer support network and access to diverse markets (Stratton *et al.*, 2021).

In another study, Paracchini *et al.* (2020) affirmed that ecological practices positively contribute to food security, particularly due to improved yields and a better economic situation for producers. The study depicts those improved yields as a result of using organic fertilisers such as manure or compost, diversified crop systems, and soil quality management practices such as mulching, intercropping, and longer, more diversified crop rotations. Adopting ecological practices has proven to be a positive contributor towards achieving the food security and nutrition of households in low and middle-income countries (Bezner Kerr *et al.*, 2021).

Further, VanGelder and Varghese (2017) note that farmers who were using ecological farming reported positive results. The benefits included increased yields, a decrease in production costs, healthier soils, and crops that are more likely to withstand ecological shocks like drought or frost. A review by Palomo-Campesino *et al.* (2018) explored the connection between ecological practices and ecosystem services. The authors reported that ecological practices are generally more effective than conventional ones in supplying a wider variety of ecosystem services. Therefore,

ecological practices have the potential to provide an environmentally sustainable alternative to conventional agricultural management.

In addition, Karuga (2022) notes that through ecological farming farmers' networks, women and youth empowerment, knowledge dissemination, and sharing increased. Further, the author reports that farmers recorded a good to average increase in on-farm productivity, wealth creation, food security, nutrition, mitigation of climate change, and environmental conservation. These positive changes were associated with ecological practices such as diversification, local trading, connectivity, local-based innovations, agroforestry, minimum tillage, integrated pest management (friendly biopesticides, mixed cropping), manuring, and biogas production. The performance of ecological practices has not been widely documented, but these are a few cases showing that ecological practices have beneficial outcomes for humans and nature.

2.8.1 Effects of multiple sustainable agricultural practices on farmers welfare

Huong *et al.* (2023) investigated the economic effects of adopting sustainable agricultural practices (SAPs), namely crop diversification and conservation agriculture, in Vietnam. Their results confirmed that, whereas adoption of single SAP raised agricultural income, adoption of both practices brought better benefits than single SAP adoption.

Teklewold *et al.* (2013) studied farmers' choice of combination of SAPs (cropping systems diversification, conservation tillage, and modern seed) and the impacts of their adoption on maize income, agrochemicals, and family labour use in rural Ethiopia. The results further affirmed that adoption of SAPs increases maize income, and the highest payoff is achieved when SAPs are adopted in combination rather than in isolation.

Ngango and Nkurunziza (2021) evaluated the effects of three interdependent sustainable agricultural intensification practices on maize yields and income. These practices included crop residue retention, minimum tillage, and maize-legume diversification. The study results reveal that the adoption of a combination of sustainable agricultural intensification practices increases maize yields, maize income, household total expenditure, and household food expenditure. The policy implications of this study were for the government and development partners to provide innovative extension services to encourage the adoption of multiple sustainable practices.

Abdallah *et al.* (2021) investigated the effects of multiple adoptions of sustainable agricultural practices (SAPs) on farm income and food security among rural households in Africa. These SAPs included intercropping with nitrogen-fixing crops, zero tillage, residue incorporation,

and animal manure. The findings revealed that adoption of one or two SAPs significantly reduced farm income and food security, while adoption of three or more SAPs in combination significantly increased farm income and food security. The study concluded that improvement in household welfare would be realised when the appropriate packages of SAPs are combined by households in Africa.

In a different study conducted in northern Ghana, adoption of soil and water technologies positively and significantly increased farm income for households (Abdulai & Huffman, 2013). Baiyegunhi *et al.* (2022) explored the effect of adopting complementary improved maize varieties and crop diversification on smallholder maize farmers' welfare in Ogun State, Nigeria. Welfare was measured by productivity and net farm income. The results revealed that farmers who adopted crop diversification and improved maize varieties in combination or in isolation realised increased maize productivity and net farm income per hectare.

The aforementioned studies have considered risk reduction strategies like crop diversification and soil and water conservation technologies such as minimum tillage, crop residue retention, and the use of animal manure. However, the existing studies have not given pest and disease management strategies much attention. Therefore, this study differs from other studies in that it incorporates integrated pest management as one of the ecological practices. Furthermore, evidence has shown that the adoption of a combination of sustainable practices has much greater benefits for welfare compared to the adoption of a single practice. However, there is a shortage of empirical evidence about the economic impact of adopting different ecological practices packages in many parts of Kenya. Therefore, this study intends to inform policymakers of the different combinations of ecological practices that greatly contribute to farm income and enable them to design effective financing and extension strategies to encourage adoption of these ecological practices. The study follows various surveys conducted by the KNBS, including the Kenya Integrated Household Budget Survey (KIHBS), whereby they categorize income into specific ranges to analyse poverty levels and household welfare.

2.9 Theoretical framework

2.9.1 Theory of planned behaviour

The theory of planned behaviour developed by Ajzen (1991) explains that attitude towards a behaviour, subjective norms with respect to the behaviour, and perceived control over the behaviour are components that predict behavioural intentions. The theory of planned behaviour

could provide an understanding of the behaviours and decision-making processes of farmers regarding adopting and implementing ecological farming practices. Attitudes represent an individual's positive or negative evaluation of a behaviour (Mutyasira *et al.*, 2018). Attitudes can be influenced by beliefs and perceptions about the costs and benefits of a behaviour, consequently influencing the intention of performing the behaviour. Farmers who have positive attitudes towards ecological farming are more likely to adopt them.

A subjective norm refers to an individual's perception of social pressure to perform a particular behaviour. Social pressure may come from internal sources such as the community, family members, and relatives, or from external sources such as agricultural advisors, NGOs, and government policies (Atta-Aidoo *et al.*, 2022). Positive subjective norms, such as support from NGOs and governments, encourage farmers to adopt ecological farming practices. Therefore, social influence plays a significant role in the decision-making process of farmers on whether or not to adopt ecological farming practices. Perceived behavioural control relates to individual perceptions of their ability to perform a behaviour (Pierrette Coulibaly *et al.*, 2021). Individuals' ability to adopt a behaviour is influenced by access to resources and opportunities, such as knowledge and skills. Consequently, an individual's ability can enable or hinder the intention to perform a behaviour. Farmers who have access to knowledge, skills, and other resources are more likely to adopt ecological farming.

2.9.2 Random Utility Theory

The study takes on the random utility theory framework. Following Greene (2012), according to this theory, the i^{th} farming household chooses between alternative ecological farming practices n and only chooses to adopt one ecological farming practice if the expected utility is higher than its non-adoption. Expected utility has been defined by Davis *et al.* (1997) as the weighted sums obtained by adding the utility values of outcomes multiplied by their respective probabilities. The utility of adopting n^{th} ecological farming practice by the i^{th} farming household is given by U_d and U_m otherwise. Therefore, the net utility of adopting the n^{th} practice is:

$$B_{in} = U_d - U_m > 0 \quad (1)$$

The net utility is represented by a latent variable (Y_{in}^*) as shown below:

$$Y_{in}^* = \beta_n X_i + \varepsilon_i \quad Y_i = 1 \text{ if } Y_{in}^* > 1 \text{ and } Y_i = 0 \text{ if } Y_{in}^* \leq 0 \quad (2)$$

Where, Y_{in} is the observed adoption behaviour of the i^{th} farmer household adopting n^{th} ecological farming practice, X_i is vector of explanatory variables, β_n vector of coefficient, ε_i is a

multivariate normally distributed error term, and n , in the context of this study represents the ecological farming practices: compost manure, integrated pest management, crop diversification, minimum tillage, and mulching.

2.10 Conceptual framework

The conceptual framework illustrates the interaction of the various variables that influence households' decision-making processes. Socioeconomic factors and household characteristics such as age, education, gender, farming experience, involvement in off-farm activities, and membership in producer groups or cooperatives may influence household awareness of ecological farming practices. Moreso, farmer perceptions on the risks and benefits of ecological farming, farm characteristics, namely, farm size, soil erosion, slope, and shocks such as drought, floods, pests, and diseases, could motivate households to search for information on ecological farming practices, influencing awareness. The adequacy of information received by farmers could be influenced by the information sources, which subsequently determine awareness. Households that are aware could adopt ecological practices or not.

Furthermore, farmers adopt different combinations of ecological farming practices as a package. The adoption of different packages is influenced by socio-economic factors that include age, gender, education, off-farm activities, household size, farming experience, membership in a producer group or cooperative, as well as farm characteristics, farmer perceptions, and shocks. Moreso, institutions encourage the adoption of ecological practices through different interventions. The interventions commonly include training, information provision, extension services, market linkages, infrastructure, and input support. Institutional interventions influence the number of ecological practices households take up. Finally, households adopt ecological practices on their farms as a package. The adoption of bundles of ecological practices is likely to change the farm income.

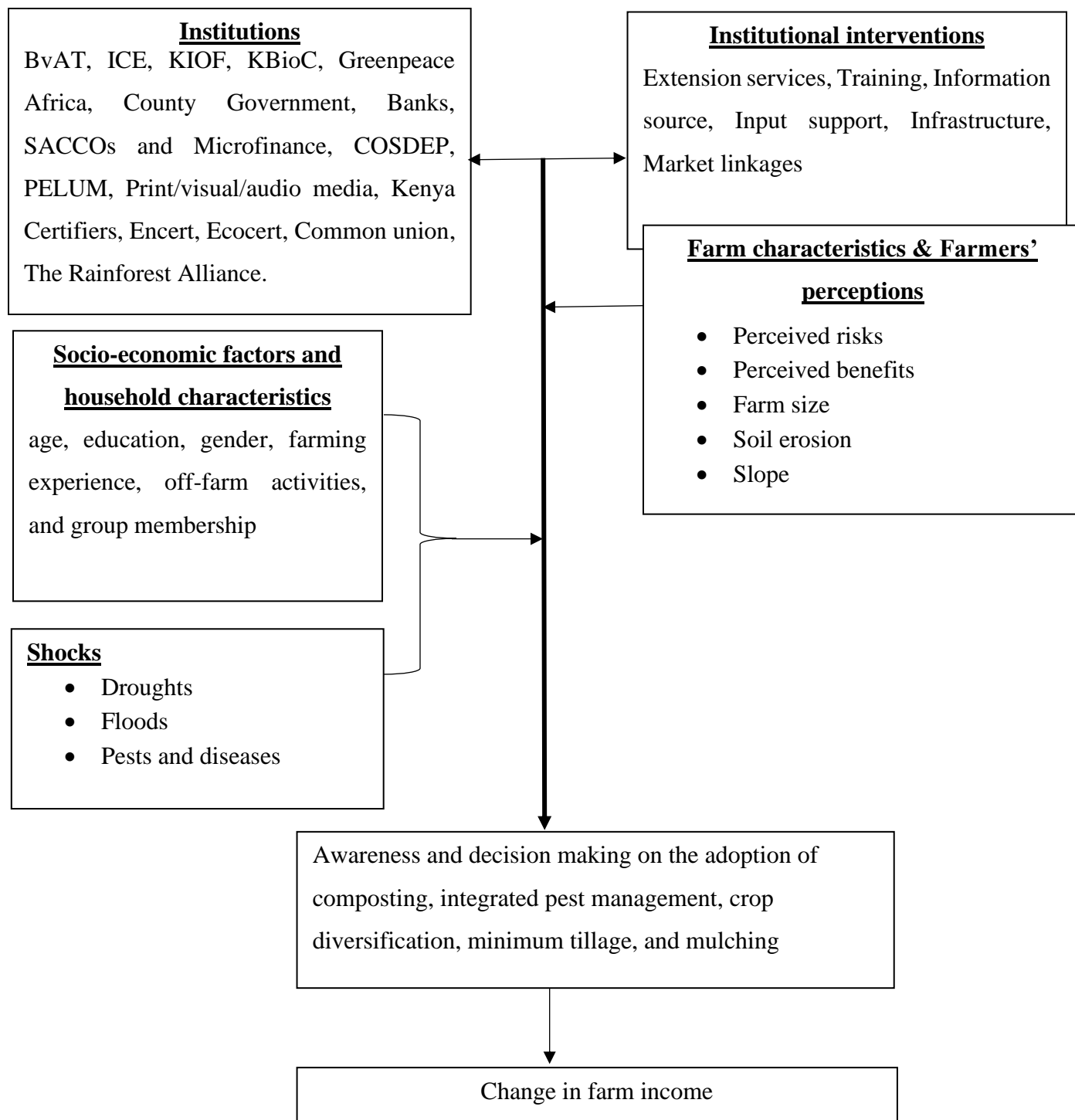


Figure 1: Conceptual framework

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter first presents the study area, research design, sample size determination, sampling procedure, data collection techniques, and type of data collected. This is followed by the analytical framework representing empirical models for analysing factors influencing awareness of ecological farming, institutional interventions influencing adoption intensity of ecological farming practices, and finally, the effect of adoption of ecological practices on farm income.

3.2 Study area

Kiambu County was purposively chosen for the study because several institutions have taken the initiative to popularise ecological farming in the county. Further, the Lari sub-county was purposively selected since it is one of the areas where several projects have been implemented by organisations individually or in collaboration to promote ecological approaches, as agricultural productivity has been faced with a myriad of challenges. Lari sub-county is one of the 12 sub-counties in Kiambu County. It is subdivided into five wards that include Lari/Kirenga, Kijabe, Kamburu-Kamuchege, Kinale, and Nyanduma wards. According to KNBS (2019), the census report indicated that the number of households in the Lari sub-county is 38,592, with an average household size of 3.5. It further indicated that Lari covers a total area of 432.3 km². Lari is located in the Upper Highland Zone of Kiambu County and lies at an altitude of 1,800–2,550 metres above sea level. The altitude greatly influences the climate in the region, in particular the rainfall, which averages at 1500 mm/year, and the temperature, which ranges from 20.1°C to 34°C. The area experiences long rains in the months of March to May and short rains in October and November.

The majority of the residents depend on small-scale farming, with the average size of the land being 0.8 hectares. They grow cash crops such as tea, coffee, horticulture, and cut flowers for export. Further, they produce food crops such as maize, bananas, beans, potatoes, and vegetables. On the other hand, livestock production is also an income-generating activity. Mostly, the residents practice dairy farming based on zero grazing due to land scarcity and population growth. Additionally, they keep goats, sheep, and poultry. Bee farming is practised on the drier side of the region between Ndeiya and Karai. The forest covers large parts of Lari and acts as an important community asset by providing forest products including water, herbal medicine, building materials, fodder for livestock, fuel wood, a water catchment area, and leisure space (Mwangi,

2014). Although the main soils in Lari sub-county are clay soils, it still has good loam soils that are known for vegetable production. Soil fertility is maintained through the application of both inorganic and organic fertilisers.

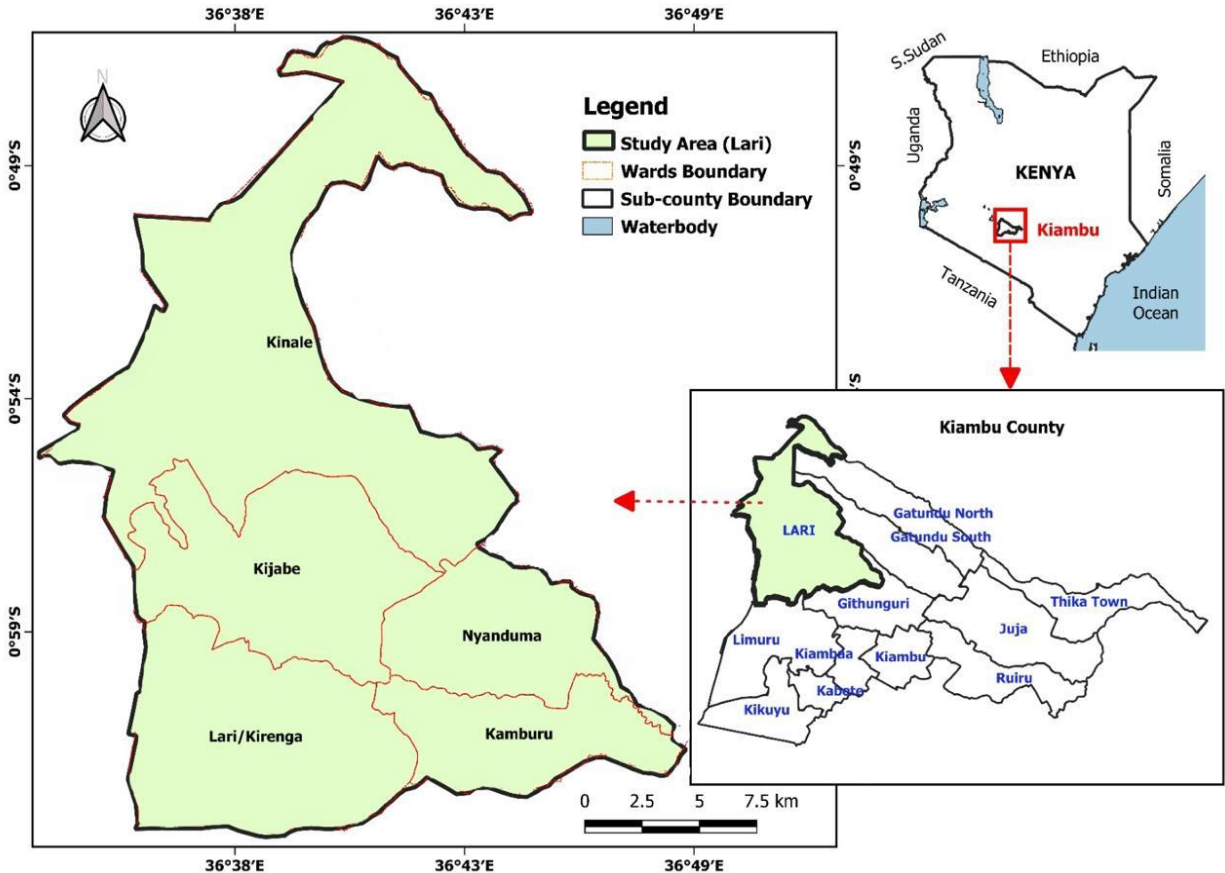


Figure 2: Map of the study area.

Source: Geography Department, Egerton university (2022).

3.3 Research design

The study adopted a survey research design. With the help of this methodology, it was possible to draw conclusions that are statistically significant regarding how institutional interventions influence the intensity of ecological farming practices among farmer households in Kiambu County.

3.4 Sample size determination and sampling procedure

The required sample size was determined using a formula for sample size determination as described by Kothari (2004). Since the proportion of the population was not known, the formula

assumed that 50% of the population (households) possessed major attributes of interest for the study.

$$n = \frac{z^2 pq}{e^2} \quad (3)$$

Where; n = Sample size; Z= is the standard variation given confidence coefficient of $\alpha = 0.05$, p = proportion of the population containing the attribute of interest, p= 0.5, q = 1-p, e is the allowable margin of error or degree of precision which is 0.054(5.4%), Z= 1.93.

$$n = \frac{1.93^2(0.5)(0.5)}{0.054^2} = 319.35 \quad \text{: This was approximated to 320 households.}$$

This study picked 5.4% as the allowable margin of error which gave the exact desired sample size that was representative of the population and also fit the available funds and time.

The sampling frame included farmer households in the Lari sub-county. A multi-stage sampling procedure was used for the selection of respondents. It was done as follows: in the first stage, Lari was purposively selected for the study because of the high involvement of institutions promoting the adoption of ecological farming in the sub-county. The second stage involved purposively selecting two wards namely, Kamburu and Lari/Kirenga wards, that had received the most interventions from different organisations. In the third stage, a list of villages was obtained from the organisations that promote agroecological activities in the area and systematic random sampling was used to select six villages which include Kagaa, Kamburu, Gatwamba, Kirenga, Githirioni, and Lari villages. Lastly, systematic random sampling was used to select the households to be interviewed from the selected villages. The distribution of the sampled households from the different villages across the two wards are as shown in Table 3. 1

Table 3. 1: Distribution of respondents across each ward and villages

Wards/Villages	Total
Kagaa village	70
Kamburu village	90
Gatwamba village	40
Sampled households from Kamburu ward	N=200
Kirenga village	42
Githirioni village	27
Lari village	51
Sampled households from Lari/Kirenga ward	N=120

This study collected data from both primary and secondary sources. Primary data was sourced through interviews with the help of a semi-structured questionnaire (Appendix 1) that was administered to farmer households. Secondary data was sourced from publications on ecological and sustainable farming, including but not limited to reports, journal articles, newsletters, online databases, and unpublished data. This data was used to supplement the primary data. Further, interviews with key informants were conducted to understand the challenges, opportunities, and initiatives for enhancing the uptake of agroecological farming. The study considered government departments, non-governmental organisations, and the private sector as crucial informant groups. Unstructured questions (Appendix 2) were used to collect qualitative data from the key informants, which was used to supplement the quantitative data.

3.5 Analytical framework

Objective 1: To identify factors affecting awareness of ecological farming among households in Kiambu County.

The first objective was to identify the determinants of awareness among farmer households in Kiambu County. The outcome variable was household awareness of ecological farming. The dependent variable was measured as household knowledge and demonstrated understanding with regard to ecological farming. Farmers knowledge was conceptualised as household familiarity with ecological farming practices, that is, if they had heard about ecological farming practices. On the other hand, understanding was conceptualised as demonstrated skills by the farmers with regard to ecological farming. Awareness was categorised into three groups.

Farmers categorised under outcome 3 (advanced awareness) had to demonstrate they had knowledge of ecological practices as well as demonstrate understanding of the same. Therefore, farmers falling under this group had heard of at least one practice and also indicated that they used at least one of the practices on their farms. On the other hand, farmers who had heard of any one practice but indicated they did not use it on their farms were deemed to have basic awareness (outcome 2). Basic awareness was conceptualised as farmers having knowledge of ecological practices without demonstrating understanding of the practices. Finally, those who had not heard of any ecological practice were regarded as unaware (outcome 1). This is because they showed no knowledge of ecological farming practices.

Since the outcome variable was regarded as an ordered response with three categories. A generalised ordered logit model was selected to identify factors affecting household awareness of

ecological farming among households in the study area. The probability of the household being in either of the three categories was estimated as a linear function of the vector of covariates and a set of cut-offs. The probability of observing the i^{th} awareness within a range of cut-offs is given as:

$$\Pr(\text{Outcome}_j = i) = \Pr(k_{i-1} < \beta_1 X_{1j} + \beta_2 X_{2j} + \dots + \beta_k X_{kj} + \varepsilon_j \leq k) \quad (4)$$

Where:

$\beta_1, \beta_2,$ and $\beta_k,$ indicate the coefficients that are associated with the independent variables, $X_1, X_2,$ and X_k are the independent variables, k represents the last variable, j represents the possible outcome (awareness), $\varepsilon_j,$ is the error term which assumes a logistic distribution.

The standard ordered logit model could be used to estimate equation 4. However, this model could not be used because of its' restrictive parallel line assumption. The standard ordered logit model assumes that there is equal parameterization in the model since the coefficient β estimates are the same across the j categories. For the generalised ordered logit, Williams (2016) indicates that there is relaxation of the parallel lines assumption and allows one or more parameter estimates to differ across the j categories of the ordered outcome. According to Williams (2006), the generalized ordered logit model is written as below:

$$P(Y_i > j) = f(X\beta_j) = \left[\frac{\exp(\alpha_j + X_i\beta_j)}{1 + \exp(\alpha_j + X_i\beta_j)} \right] \quad j = 1, 2, \dots, M - 1, \quad (5)$$

The probability that Y can take a value ranging between 1 and 3, where three is the maximum is written as shown:

$$P(Y_i = j_1) = 1 - f(X_i\beta_1) \quad (6)$$

$$P(Y_i = j_2) = f(X_i\beta_{1-1}) - f(X_i\beta_j) \quad j=2, \dots, M-1 \quad (7)$$

$$P(Y_i = j_3) = f(X_i\beta_{3-1})$$

β_j are vectors of the independent variables while i and j respectively denote the household and the categories of the awareness. The variables used in the generalized ordered logit model are described in Table 3. 2

Table 3. 2: Description of variables used in generalized ordered logit models

Variable	Description	Expected sign
<u>Dependent variable</u>		
Awareness	1= Unaware ; Farmers who had not heard of any ecological practice 2= Basic awareness ; farmers who had heard of at least one practice but did not use the practice/s on their farms 3= Advanced awareness ; famers who had heard of at least one practice and were using the practice/s on their farms.	
<u>Independent variables</u>		
Age	Age of the decision maker (discrete)	+/-
Gender	Gender of the household head dummy (1=male, 0=female)	+/-
Education	Household's years of schooling (discrete)	+/-
Farming experience	Years of farming experience (discrete)	+/-
Off-farm activities	If a household is involved in other activities outside farming? 1=Yes, 0= No (dummy)	+/-
Household size	Size of the household (discrete)	+/-
Farm size	The total size of land under cultivation in acres (continuous)	
Pests and diseases	If household has experienced yield losses due to pests or diseases? 1=Yes, 0= No (dummy)	+/-
Risk	If a household perceives not using chemical inputs would reduce quantity and quality of output. 1=Yes, 0= No (dummy)	
Soil erosion	Severity of soil erosion on the cultivated land 1= very/moderately severe, 0= not severe (categorical)	+/-

Droughts and floods	If household has experienced yield losses due to drought and floods? 1=Yes, 0= No (dummy)	+/-
Benefits	If a household thinks that ecological practices contribute to the coverage of the household food's needs and additional income? (dummy) 1=Yes, 0= No	+/-
Membership	If household belongs to a producer group/cooperative 1=Yes, 0=No (dummy)	+
Information source	Household major source of information on ecological farming 1= NGO extension staff, 2= Government extension staff, 3= Media, 4= Other farmers/traditional knowledge (categorical)	+

Objective Two: To determine the institutional interventions that influence the adoption intensity of ecological farming among households in Kiambu county.

The objective is to look into how institutional interventions influence the intensity of ecological farming in the study area. The adoption intensity of ecological farming is higher if the farming household utility gained from taking up multiple ecological farming practices is greater than using one or a few practices. The dependent variable for this objective was the number of ecological farming practices each household uses. Therefore, the dependent variable was a count variable that was used to measure the intensity of adoption. This study follows other empirical studies that have employed count data models to explain the adoption intensity of various agricultural practices.

Some existing studies have employed Poisson regression for the analysis of count data. The Poisson regression model assumes the variance of the dependent variable equals its' mean; a condition known as equi-dispersion. However, in most empirical studies, the count data show differences in mean and variance, whereby the variance could be greater than the mean, overdispersion, or the variance could be less than the mean, under-dispersion. In such cases, using Poisson regression for modelling count data yields biased standard errors and inconsistent parameter estimates. Therefore, models that are able to deal with under-dispersion or overdispersion should be employed.

The dependent variable in this study exhibited under dispersion. Thus, the study employed a generalised Poisson regression (GP) model to estimate the relationship between adoption intensity and access to one or more institutional resources. The GP is an extension of the standard Poisson regression model that assumes count data has a Poisson distribution (Greene, 2012). The GP relaxes the equidispersion assumption by introducing a dispersion parameter that allows for overdispersion or underdispersion. Following Mahama *et al.* (2020) and Famoye (1993), the adoption intensity of ecological practices, Y_i , was assumed to follow a generalised Poisson distribution, thus the probability mass function (PMF) was specified as below:

$$f(y_i) = pr(Y_i = y_i) = \left(\frac{\lambda_i}{1+\alpha\lambda_i} \right)^{y_i} \frac{(1+\alpha y_i)^{y_i-1}}{y_i!} \exp \left[\frac{-\lambda_i(1+\alpha y_i)}{1+\alpha\lambda_i} \right], y_i = 0,1,2, \dots \quad (7)$$

The mean and variance of the GP random variable Y_i are as shown below (Harris *et al.*, 2012):

$$\text{Mean } (\mu)=E(Y_i) = \frac{\theta_i}{1-\delta}; \text{ Variance } (Y_i) = \frac{\theta_i}{(1-\delta)^3} = \frac{1}{(1-\delta)^2} E(Y_i) = \phi E(Y_i) \quad (8)$$

$\phi = \frac{1}{(1-\delta)^2}$ represents the dispersion factor. When $\delta=0$, there is equi-dispersion, and if $\delta > 0$ or $\delta < 0$ we have overdispersion and under-dispersion respectively.

The institutional interventions that were considered in the study were extension contacts, market linkages, training, access to infrastructure, access to input support, and access to reliable sources of information. They were all hypothesised to positively influence households' decisions to adopt more ecological practices. On the other hand, farmer and farm characteristics were included as part of the explanatory variables but were used as control variables. They included age, gender, household size, farming experience, education, farm size, land tenure, soil erosion, slope, effect of CA, demand, and location. Description of variables used in the Generalized Poisson regression are shown in Table 3. 3.

Table 3. 3: Description of variables used in the Generalized Poisson regression

Variable	Description	Expected sign
<u>Dependent variable</u>		
Adoption intensity	Total number of ecological farming practices	
<u>Independent variables</u>		
Age	Age of the decision maker (discrete)	+/-
Gender	Gender of the household head dummy (1=male, 0=female)	+/-
Education	Household's years of schooling (discrete)	+/-
Farming experience	Household years of farming experience (discrete)	+/-
Household size	Size of the household (discrete)	+/-
Farm size	The total size of land under cultivation in acres (continuous)	+/-
Land tenure	If the household owns the land (categorical) (1=owned with title deed, 2=Inherited without title deed, 3=Leasehold, 4=Borrowed from family/friends, 5=Community/government land)	+/-
Slope	The slope of land under cultivation (categorical) 1= very/fairly steep, 0= not steep	+/-
Soil erosion	Severity of soil erosion on the cultivated land (categorical) 1= very/moderately severe, 0= not severe	+/-
Demand	If a how household perceive the demand for ecologically produced food is 1=high, 2= average 3= low (categorical)	+/-
Effect of CA	How household perceives the effect of using conventional agriculture? (categorical) 1= Bad, 2=Good, 3= Not sure	+/-

Training	If a household has attended a workshop/forum/conference on farming in the last year? (dummy) 1=Yes, 0=No	+
Extension	Number of contacts with extension officer per year (discrete)	+
Information source	Household major source of information on ecological farming (categorical) 1= NGO extension staff, 2= Government extension staff, 3= Media, 4= Other farmers/traditional knowledge	+
Market	If a household has been able to access eco-friendly markets for ecologically produced products (dummy) 1=Yes, 0=No	+
Input support	If a household has received inputs to promote uptake of ecological farming? (dummy) Yes=1, 0=No	+/-
Infrastructure	The distance from the farm to the nearest tarmac road (continuous)	+
Location	Household location (categorical) 1= Kamburu 0= otherwise	+/-

Objective Three: To determine the effect of ecological farming on farm income among farmer households in Kiambu County.

To achieve the objective, this study used the multinomial endogenous switching regression model (MESR), in line with the studies by Bourguignon *et al.* (2007) and Teklewold *et al.* (2013). Uptake of ecological farming practices is non-random, and self-selection might occur. We treat the adoption of ecological farming practices as an endogenous variable. This is because some unobservable factors, such as the farmer's preferences, management skills, motivation, and innate ability, which influence the farm household's decision to take up ecological farming practices or not, could also influence farm income. Unobserved factors are heterogeneous across farming households (Siddiqua *et al.*, 2019). One method commonly used, especially where self-selection bias occurs, is the Propensity Score Matching (PSM) method. However, the PSM approach only

accounts for observed factors (Abdallah *et al.*, 2019). Thereby, employing MESR helps overcome the problems of selection bias and endogeneity brought about by observed and unobserved heterogeneity (Ahmadzai & Morrissey, 2023). For instance, MESR estimates in this study provide insights into how the endogeneity and switching behaviours affect the relationship between the set of explanatory variables for specific technology choices and farm income. The MESR model is estimated in two stages:

In the first stage, this study employed the multinomial regression model to determine the factors influencing households' decisions to adopt ecological farming practices or not. In this case, the responses are unordered and have more than two outcomes; hence, a multinomial logit or probit model can be used. The multinomial probit model (MNP) has some practical limitations since it requires the evaluation of multiple integrals of the normal distribution and makes maximum likelihood infeasible for more than about five alternatives (Greene, 2012; Wooldridge, 2011). Thus, a multinomial logit model (MNL) will be used. The MNL was used to capture the impact of independent variables on the likelihood of being in any of the identified categories relative to the reference category. Given the five ecological practices considered by the study, this study ended up with seven bundles for empirical estimations.

In the case of this study, we assume that households adopt a combination of those practices that help them maximise their revenues. Thus, for a farmer household, i , to choose a combination of practices, n , over any other alternative combination, m , can be illustrated as $m \neq n$. This illustration shows that combination n provides greater expected revenues than any other available alternative. It is a latent variable and represents the expected revenue that a household derives from adopting a set of ecological farming practices, n . The latent variable is determined by observed household, socio-economic, and plot characteristics (X_i) and unobserved characteristics as shown below (Green, 2012).

$$U_{in}^* = X_i\beta_{in} + \varepsilon_{in} \quad (9)$$

Where X_i is observed exogenous variables (household, plot and socio-economic characteristics) and ε_{in} is unobserved characteristics. Assuming the error terms are identically and independently Gumbel distributed, the probability that a household, i , takes up a combination of practices, n , can be estimated using a multinomial logit regression model (McFadden, 1973);

$$P_{in} = Pr(\varepsilon_{in} < 0|X_i) = \frac{\exp(X_i\beta_n)}{\sum_{m=1}^n \exp(X_i\beta_m)} \quad (10)$$

In the second stage, ESR was used to estimate the effect of using ecological practice on farm income. we came up with the outcome equation (farm income) conditional on whether a farm household takes up ecological farming or not. The base category was indicated as $n = 1$ (non-adoption). For the remaining set of practices ($n = 2 \dots k$) at least one ecological practice was used. The farm income equation for each possible regime n will be as follows:

$$\text{Regime 1: } Y_{1i} = \alpha_1 Z_i + \mu_{1i} \text{ if } i = 1 \quad (11)$$

$$\text{Regime n: } Y_{ni} = \alpha_n Z_i + \mu_{in} \text{ if } i = n \quad (12)$$

Y_i represents the farm income for the i^{th} farmer household; Z_i is a vector of exogenous variables; α_1 and α_n are parameters to be estimated; μ_{1i} and μ_{in} are the error Terms.

The farm income of the i^{th} household (Y_i) is observed only if one of the possible ecological farming practices combinations is used. Some unobservable factors which influence the farm household decision to take up ecological farming practices or not, could also influence farm income. Thus, the error term of the decision equation, ε_{in} and the outcome equation, μ_{in} are non-zero, and ordinary least squares (OLS) estimates will not be consistent (Setsoafia *et al.*, 2022). Endogenous switching regression (ESR) corrects the problem of unobserved selection bias using the inverse Mill's ratios/selectivity term of the alternative choices (Bourguignon *et al.*, 2007; Teklewold *et al.*, 2013). The selectivity term is as expressed below:

$$\lambda_n = \sum_{m \neq n}^n \rho_n \left[\frac{\hat{\rho}_{im} \ln(\hat{\rho}_{im})}{1 - \hat{\rho}_{im}} + \ln(\hat{\rho}_{in}) \right] \quad (13)$$

Where ρ is the correlation coefficient of ε_{in} and μ_{in} . In the multinomial choice setting, there are $n-1$ selectivity terms, one for each alternative set of practices (Teklewold *et al.*, 2013). The inverse Mills ratio is then added into the linear outcome equations as shown below;

$$\text{Regime 1: } Y_{1i} = \alpha_1 Z_i + \sigma_1 \lambda_1 + v_{1i} \text{ if } i = 1 \quad (14)$$

$$\text{Regime n: } Y_{ni} = \alpha_n Z_i + \sigma_n \lambda_n + v_{ni} \text{ if } i = n$$

Where; σ is the covariance between ε_{in} and μ_{in} , and v_{ni} is the error term with an expected value of zero.

Estimation of Average Treatment Effects

The farm income of the i^{th} household (Y) is observed only if one of the possible ecological farming practices combinations is used. Some unobservable factors that influence the farm household decision to take up ecological farming practices or not could also influence farm income. Thus, the error term of the decision equation and the outcome equation are non-zero, and

ordinary least squares (OLS) estimates will not be consistent (Setsoafia *et al.*, 2022). The following equations were used to calculate the predicted outcomes for adopters under observed conditions and counterfactual conditions (if adopters do not adopt):

Farm income for farming households that adopts ecological farming practices as observed in the sample

$$E(Y_{i2}|i = 2) = Z_i\alpha_2 + \sigma_2\lambda_2 \quad (15)$$

$$E(Y_{in}|i = n) = Z_i\alpha_n + \sigma_n\lambda_n \quad (16)$$

Farm income for farming households had they decided not to adopt ecological farming practices (counterfactual)

$$E(Y_{i1}|i = 2) = Z_i\alpha_1 + \sigma_1\lambda_2 \quad (17)$$

$$E(Y_{i1}|i = n) = Z_i\alpha_1 + \sigma_1\lambda_n \quad (18)$$

The average treatment effect on treated (ATT), which is the difference between the expected values of the outcome equation 15 and 17, represents the influence of adoption on farm income among farming household.

$$E[Y_{i2}|i = 2] - E[Y_{i1}|i = 2] = Z_i(\alpha_2 - \alpha_1) + \lambda_2(\sigma_2 - \sigma_1) \quad (19)$$

Table 3. 4: Description of variables used in the Multinomial Endogenous Switching Regression Model (MESR)

Variable	Description	Expected sign
<u>Dependent variable</u>		
Farm income	The gross income that household gets from farming activities per year in Kenyan shillings (continuous)	
<u>Independent variables</u>		
Age	Age of the decision maker (discrete)	+/-
Gender	Gender of the household head dummy (1=male, 0=female)	+/-
Education	Household years of schooling (discrete)	+
Household size	Number of people in a household (discrete)	+/-
Farming experience	Household years farming experience (discrete)	+/-
Off-farm activities	If a household is involved in other activities outside farming (dummy) 1=Yes 0=No	+/-
Farm size	The size of land under cultivation in acres (continuous)	+
Soil erosion	Severity of soil erosion on the cultivated land (categorical) 1= very/moderately severe, 0= not severe	+/-
Slope	The slope of land under cultivation (categorical) 1= very/fairly steep, 0= not steep	+/-
Droughts and floods	If household has experienced yield losses due to drought and floods? (dummy) 1=Yes, 0= No	+/-
Effect of CA	How household perceives the effect of using conventional agriculture? (categorical) 1= Bad, 2=Good, 3= Not sure	+/-
Membership	If household belongs to a producer group/cooperative (dummy) 1=Yes, 0=No	+

Location	If household is located in Kamburu ward=1 and 0 if otherwisel	+/-
Credit	If household access credit (dummy) 1=Yes, 0=No	+/-

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings of the study. The chapter starts with a brief description of the variables to be used in the empirical models. This is followed by the results of the analysis of the factors determining awareness of ecological farming, along with institutional interventions influencing the adoption intensity of ecological farming practices. Lastly, the results of the multinomial endogenous switching regression model on the effect of adoption of ecological farming practices on farm income are presented.

4.2 Summary statistics of independent variables

The summary statistics of the variables used in the analysis are summarised in Table 4. 1 and Table 4. 2. The descriptive statistics results for the continuous variables are shown in Table 4. 1. The results indicated that the average age of farmers was 50 years. Households that adopted ecological farming practices were younger compared to their counterparts. The average age for adopters was 50 years, while that of non-adopters was 53 years. Older farmers are less likely to adopt ecological farming practices since they are reluctant to change the methods of farming they have used for years. The mean household size of the sampled farmers was 4.2, while the mean for adopters and non-adopters was 4.33 and 3.68, respectively. The mean difference in household size between adopters and non-adopters was significant at the 1% level. This implies that the households that adopted ecological farming practices had more family members.

The mean number of years in school for adopters (10.56 years) was less compared to that of non-adopters (11.20 years). This is an indication that households that spent more years in school were not adopting ecological farming practices. The mean number of years of farming experience was 19.70 years. Adopters had more years of farming experience. Further, the mean difference in the number of extension contacts between adopters and non-adopters was statistically significant at the 1% level. This could be attributed to the fact that households that were in contact with extension agents were able to acquire the knowledge and skills to adopt ecological farming practices.

Road networks are important indicators of infrastructure development in rural areas. The average distance from the household to the nearest tarmac road was 3.31 km. For adopters of ecological farming, they appeared to be further from the tarmac road (mean distance of 3.34 km),

while non-adopters seemed to be closer to the tarmac road (mean distance of 3.19 km). This could be explained by the fact that households located close to the tarmac are more likely to allocate land to other activities not related to farming. Additionally, land available for farming was scarce in the study area due to other competing land-use activities. Farm size was averaging 1.04 acres. Those who adopted had a mean farm size of 1.01 acres, while non-adopters had a mean farm size of 1.19 acres. This result implies households with small plots of land have adopted ecological farming.

Table 4. 1: Descriptive statistics for continuous variables

Variables	Description	All	Adoption	Non- adoption	t-value
		Mean	Mean	Mean	
Age	Age of the household head (HH) in years	50.23(12.75)	49.71(12.82)	52.66(12.21)	1.578
Household size	Number of people in a household	4.22(1.62)	4.33(1.63)	3.68(1.48)	-2.751***
Education	Number of years of education of the HH	10.67(2.98)	10.56(2.90)	11.20(3.30)	1.454
Farming experience	Years of farming experience of the HH	19.70(11.86)	19.81(12.06)	19.18(10.97)	-0.364
Farm size	Size of land under cultivation in acres	1.04(1.30)	1.01(1.30)	1.19(1.30)	0.952
Extension	Number of contacts with extension officer per year	3.76(5.51)	4.43(5.81)	0.61(1.45)	-4.881***
Infrastructure	The distance from the farm to the nearest tarmac road	3.31(4.61)	3.34(4.62)	3.19(4.61)	-0.211

Note: Figures in brackets denotes standard deviations. ***, **, * denotes statistical significance at 1%, 5% and 10% level.

The descriptive statistics results for the categorical variables are shown in Table 4. 2. The results depict that male-headed households were more likely to adopt ecological practices (53.41%) compared to female headed households (46.59%). Most female-headed households are

constrained from adopting ecological farming practices due to a lack of access to productive resources such as land. This is consistent with Paudel *et al.* (2020), who reported gendered differences in the adoption of agricultural technology. Moreover, there was a statistically significant difference at the 1% level between farmers who belonged to a group and those who did not. Farmers who belonged to a farmer group were more likely to adopt ecological farming practices. Farmers belonging to a group are able to learn from their peers as well as enhance their skills through farm demonstrations.

Among the adopters, 23.11% have access to eco-friendly markets, while 76.89% do not. The association between market access and the adoption of ecological farming was statistically significant at the 1% level. Eco-friendly markets offer a premium price for produce, hence attracting farmers. Perception of a technology is key when it comes to its adoption. There were more households (88.00%) that perceived ecological farming to have benefits in terms of yield and income. The association between perception of the benefits and adoption of ecological farming was statistically significant at the 1% level. This could be explained by the fact that farmers only adopt technologies that they believe will improve their welfare.

Among the adopters and non-adopters, 31.00% had received training on ecological farming while 69.00% had not. Training had a statistically significant association with adoption of ecological farming practices at 1% level. According to Constantine *et al.* (2020), trained farmers can easily shift to a more sustainable farming system and are more ready to take the risks associated with changing production technologies as compared to non-trained farmers. Furthermore, the mean difference between source of information averages was statistically significant at 1% level. Most farmers who adopted, accounting for 65.53%, received their information from institutions comprising of, NGOs extension staff, government extension staff, media, and other private companies. This result suggests that having reliable sources of information could encourage adoption.

Most farmers that adopted were from Kamburu ward. Also, among the sampled households, 63% stated they had experienced yield loss due to drought and floods. However, the number of non-adopters was higher than that of adopters. This implies losses from droughts and floods discourage farmers from using alternative farming practices such as ecological farming practices.

Table 4. 2: Descriptive statistics for categorical variables

Variables		All	Adoption	Non-adoption	χ^2
		%	%	%	
Gender	Male	52.50	53.41	48.21	0.500
	Female	47.50	46.59	51.79	
Location	Kamburu	62.50	65.15	50.00	4.525**
	Lari-Kirenga	37.50	34.85	50.00	
Off farm activities	Yes	60.94	40.15	33.93	0.752
	No	39.06	55.85	66.07	
Slope	Very/fairly steep	47.19	49.24	37.50	2.556
	Not steep	52.81	50.76	62.50	
Soil erosion	Very/moderately severe	15.31	17.42	5.36	5.188**
	Not severe	84.69	82.58	94.64	
Drought and floods	Yes	62.81	58.71	82.14	10.859***
	No	37.19	41.29	17.86	
Pests and diseases	Yes	84.69	84.09	87.50	0.414
	No	15.31	15.91	12.50	
Risk	Yes	27.19	24.24	41.07	6.610***
	No	72.81	75.76	58.93	
Effect of CA	Bad	75.94	81.06	51.79	21.669***
	Good/Not sure	24.06	18.94	48.21	
Demand	High	52.81	55.30	41.07	3.755*
	Average/low	47.19	44.70	58.93	
Benefits	Yes	88.44	76.79	90.91	9.012***
	No	11.56	23.21	9.09	
Input support	Yes	18.13	21.97	0.00	15.027***
	No	81.87	78.03	100.00	
Market	Yes	19.38	23.11	0	15.987***
	No	80.62	76.89	100.00	
Credit	Yes	60.63	65.53	37.50	15.206***
	No	39.38	34.47	62.50	

Training	Yes	30.94	37.50	0.00	30.407***
	No	69.06	62.50	100.00	
Information source	Institutions	60	65.53	33.93	19.224***
	Farmers	40	34.47	66.07	
Membership	Yes	51.50	57.58	23.21	21.841***
	No	48.44	42.42	76.79	
Land tenure	Owned with title	50.31	47.73	62.50	4.033**
	Otherwise	49.69	52.27	37.50	

***, **, * denotes statistical significance at 1%, 5% and 10% level.

4.3 Summary statistics of dependent variables

The farmers who were aware accounted for 91% of the sampled households, while 9% of the respondents had not heard of ecological farming practices (unaware). Out of the 91%, approximately 82.81% of the sampled households were grouped as having advanced awareness. The remaining 8.13% were for farmers with basic awareness.

The ecological farming practices are summarised in Table 4. 3. Among the farming practices, compost manure was the most adopted practice (78.44%), followed by crop diversification (66.88%), and minimum tillage was the least used practice (11.25%). The intensity of ecological farming practices adoption is illustrated in Table 4. 4 and the distribution of adopters and non-adopters in the different villages across the two wards is shown in Table 4. 5. In the context of this study, we considered a farmer as an adopter if they used at least one of the five ecological farming practices, namely, composting, mulching, crop diversification, IPM, and minimum tillage. On the other hand, non-adopters were farmers that had not adopted any of the above-mentioned ecological farming practices.

According to Table 4. 4 the rate of adoption of ecological farming is very high, with adopters accounting for 82.50% and non-adopters for 17.50%. Among the adopters, 9.69% were using a single practice while 5.94% were using all five practices. The majority of households were using three practices, accounting for 30.94% of the respondents. As indicated in Table 4. 5, between the two wards, Kamburu had a higher number of households that had adopted ecological farming practices accounting for 65.15% of the total adopters. Additionally, out of the sampled households, the number of non-adopting households were equal across the two wards.

Table 4. 3: Ecological farming practices

Ecological practices	Frequency	Percentage
Use of compost manure	251	78.44
Crop diversification	214	66.88
Mulching	120	37.50
Integrated pest management	116	36.25
Minimum tillage	36	11.25

N=320

Table 4. 4: Intensity of ecological farming practices adoption

Number of ecological practices adopted	Frequency	Percentage
0	56	17.50
1	31	9.69
2	70	21.88
3	99	30.94
4	45	14.06
5	19	5.94
Mean adoption	2.3219	
Variance	2.1061	

N=320

Table 4. 5: Distribution of adopters and non-adopters across each ward and villages

Wards/Villages	Number of respondents	
	Adopters	Non-adopters
Kamburu ward	172	28
Kagaa village	56	14
Kamburu village	88	2
Gatwamba village	28	12
Lari/Kirenga ward	92	28
Kirenga village	34	8
Githirioni village	12	15
Lari village	46	5

Ecological farming practices are adopted in bundles of various combinations by households. To come up with different bundles, the study grouped the practices using joint probability distribution. Given the five ecological practices considered in this study, there were 31 possible ecological farming practices bundles, as shown in Table 4. 6. Out of the possible 31 bundles, only 20 were adopted by the sampled households. Notably, those bundles with fewer observations, less than ten respondents, were dropped. To emphasize further, the bundle combining mulching and compost manure still had few observations (13 respondents). Thus, it was merged with the bundle combining mulching, compost manure, and crop diversification and analysed as one group. Therefore, this study ended up with seven bundles for empirical estimations that included non-adopters.

The farmers who did not use any bundles accounted for 17.5% of the sampled farmers. The bundle comprising compost manure, crop diversification, and integrated pest management was used by 15.31%. Only 19 households (5.94%) used all the ecological practices. Adopting a bundle consisting of all ecological practices was low because most farmers were not using minimum tillage on their farms. Out of the 320 sampled households, only 36 were using minimum tillage.

Table 4. 6: Specification of bundles of various ecological farming practices combinations

Choice	Ecological farming packages	M	C	D	T	P	Frequency	Percentage
1	Non-adoption						56	17.50
2	CDP		✓	✓		✓	49	15.31
3	CD		✓	✓			46	14.38
4	MCD	✓	✓	✓			43	13.44
5	MCDP	✓	✓	✓		✓	36	11.25
6	C		✓				23	7.19
7	MCDTP	✓	✓	✓	✓	✓	19	5.94
8	MC	✓	✓				13	4.06
9	D			✓			6	1.88
10	CDTP		✓	✓	✓	✓	6	1.88
11	CP		✓			✓	5	1.56
12	CT		✓		✓		4	1.25
13	MD	✓		✓			3	0.94
14	MCDT	✓	✓	✓	✓		3	0.94
15	CDT		✓	✓	✓		2	0.63
16	MCP	✓	✓			✓	2	0.63
17	DP			✓		✓	1	0.31
18	MDP	✓		✓		✓	1	0.31
19	MCT	✓	✓		✓		1	0.31
20	CTP		✓		✓	✓	1	0.31
21	MDTP	✓		✓	✓	✓	0	0
22	MCTP	✓	✓		✓	✓	0	0
23	P					✓	0	0
24	M	✓					0	0
25	DT			✓	✓		0	0
26	TP				✓	✓	0	0
27	MT	✓			✓		0	0

28	MDT	✓	✓	✓	0	0	
29	MTP	✓		✓	✓	0	0
30	DTP		✓	✓	✓	0	0
31	MP	✓			✓	0	0
Total						320	100

Note: M denotes Mulching, C composting, D crop diversification, T minimum tillage, P integrated pest management.

4.4 Factors affecting awareness of ecological farming

4.4.1 Pre-diagnostic tests

The study considered fourteen independent variables to influence awareness of ecological farming practices. All the independent variables used in the regression model were tested for multicollinearity. The variance inflation factor (VIF) was used to test for multicollinearity. As a rule of thumb, a VIF value greater than the critical value of 10 indicates that multicollinearity is a major problem. The average VIF was found to be 1.28, ranging from 2.08 to 1.03, as shown in Appendix 3. None of the explanatory variables showed a significant correlation, suggesting the absence of multicollinearity in the model. Also, a pairwise correlation test was used to test the linear relationship among the categorical explanatory variables used in the model. The results are presented in Appendices 5 and 6. The values ranged from 0.0002 to 0.4340, which are below the acceptable threshold of 0.5. This confirms that there was no strong correlation among the categorical explanatory variables.

Further, a Breusch-Pagan test was used to test the presence of heteroscedasticity and the results are shown in Appendix 4. They show the probability chi-square was 0.0000, which is less than 0.05; thus, we rejected the null hypothesis that the variance is constant among residues and concluded that heteroscedasticity is present in the data. To account for this problem, we reported robust standard errors (RSE).

4.4.2 Model specification test

This study adopted the generalised ordered logit. Specifically, it employed the partial proportional odds model. This is because it was possible to relax the parallel regression assumption only for the variable where it was violated. Thus, in this case, the Gologit2 model relaxed the parallel regression assumption for the variable drought and floods while maintaining it for the rest of the variables.

4.4.3 Empirical results

The results of the generalised ordered logit estimates are shown in Table 4.7 below. The model's chi-square (χ^2) value of 70.05 and the loglikelihood ratio of -145.910 indicate that all the variables in the model significantly influence the awareness of ecological farming practices at 1% level of significance. The pseudo R² value of 0.2108 means that the model explains around 21.08% of the farmers' awareness of ecological farming practices, implying that the model fits the given data 21.08% percent of the time. The results from the Gologit2 model indicated that household size, group membership, information source, and perception of benefits, as well as soil erosion, positively influenced the likelihood of farmers being aware of ecological farming practices, while age, and drought and floods had a negative influence.

Age negatively influences awareness of ecological farming practices. This could be attributed to the fact that as people age, they are less likely to be exposed to new experiences and information, leading to lower awareness. Age was significant at 10% the level. This result corroborates those of Daberkow and McBride (2003), who reported that age negatively affected the probability of awareness of precision agriculture. Contrary to this is the finding of Raza *et al.* (2023) who found age to have a positive relationship with the level of awareness of olive cultivation practices.

Household size was positively associated with awareness at the 1% level of significance. This implies that households with a larger number of family members tend to be aware of ecological farming practices. A possible explanation could be that larger households have more members who may actively engage in external engagements and thus gather information about ecological farming and increase awareness. Similarly, Mashi *et al.* (2022) found household size to be a significant and positive factor influencing the levels of farmers' awareness of climate-smart agricultural practices. However, Ullah *et al.* (2022) and Grovermann *et al.* (2023) report that larger household sizes were associated with a lower likelihood of awareness.

Perception of the benefits was positively and significantly associated with awareness of ecological farming practices at the 1% significance level. Households that perceived farming without chemical inputs as contributing to achieving households' food needs and income were more likely to be aware of ecological farming practices. This implies that farmers who believe that ecological farming is associated with positive outcomes are more likely to pay attention to it and become increasingly aware of the practices.

Contrary to the findings by Grovermann *et al.* (2023), this study found that drought and floods negatively influenced awareness at the 1% significance level. Farmers who have experienced crop failure due to drought and floods are less likely to be aware of ecological practices. A possible explanation is that droughts and floods lead to potential crop and income losses, increasing the risks and uncertainties for farmers. Since farmers are rational producers, they prioritize short-term benefits, such as increasing yields and income, over long-term benefits, such as environmental conservation. Therefore, they choose to continue using conventional farming methods as they perceive them to be capable of offering more stable yields and income. Thus, they are less likely to be aware of alternative farming methods. Climate information is crucial to the decision-making process in farm production and execution. The surveyed households reported having limited access to early warning systems and meteorological data, which hinders farmers from making well-informed decisions in the face of climate variability. Therefore, to increase awareness and the willingness of smallholder farmers to adopt ecological farming, it is necessary to address the climate information gaps.

Soil erosion was positive and significant at the 10% level. Households that experienced severe soil erosion were more likely to be aware of ecological farming practices. This could be attributed to the fact that excessive soil erosion causes nutrient depletion through the loss of top soil, hence leading to decreased crop yields. Therefore, farmers seek alternative farming practices such as mulching and the use of compost manure, that could help minimise soil erosion, protect the quality of the soil, and improve soil fertility as well.

Information sources positively and significantly influenced households' awareness of ecological farming practices. It was significant at the 1% level. Most households (60%) mentioned they acquired their information from institutions, including NGOs and government extension staff, while the remaining 40% sourced their information from the media (10%) and other farmers (30%). This result postulates that farmers who had access to reliable sources of information were more likely to obtain the right information to better understand the practices and, hence, have a stronger awareness of ecological farming practices. Nonetheless, despite extension staff acting as a significant source of information in the study area, the results show that farmers have limited access to extension services. A similar result was reported by Mehmood *et al.* (2022), who found that farmers with proper sources of information are more aware of climate change.

Group membership positively and significantly influences the likelihood that households are aware of ecological farming practices at the 5% level. Group membership creates a social network platform where members have a chance to access knowledge about ecological farming through trainings and farm demonstrations. Moreso, farmers who participate in a group share their experiences and exchange ideas about new innovations, which can increase the likelihood of household awareness of ecological farming practices. This result is consistent with that of Ayuya *et al.* (2011), who found that group membership has a positive influence on awareness. On the other hand, the study notes that almost half of the surveyed households, accounting for 48%, were not members of any existing farmer groups hence missed on the opportunity of learning from their peers.

Table 4.7: Generalised ordered logit model results on factors influencing farmers' awareness of ecological farming practices

Awareness	Coef.	RSE	P> z
Unaware			
Gender	-0.197	0.357	0.580
Age	-0.031	0.018	0.087*
Household size	0.283	0.102	0.006***
Education	-0.116	0.082	0.155
Farming experience	0.029	0.023	0.210
Farm size	-0.029	0.158	0.856
Soil erosion	1.842	0.964	0.056*
Drought and floods	-0.215	0.494	0.663
Information source	1.039	0.420	0.013**
Membership	1.129	0.406	0.005***
Benefits	1.468	0.388	0.000***
Off-farm activities	0.478	0.427	0.264
Pests and diseases	0.227	0.423	0.592
Perception on risk	-0.555	0.363	0.126
_cons	1.753	1.541	0.255
Basic awareness			
Gender	-0.197	0.357	0.580
Age	-0.031	0.018	0.087*
Household size	0.283	0.102	0.006***
Education	-0.116	0.082	0.155
Farming experience	0.029	0.023	0.210
Farm size	-0.029	0.158	0.856
Soil erosion	1.842	0.964	0.056*
Drought and floods	-1.068	0.395	0.007***
Information source	1.039	0.420	0.013**
Membership	1.129	0.406	0.005***
Benefits	1.468	0.388	0.000***

Off-farm activities	0.478	0.427	0.264
Pests and diseases	0.227	0.423	0.592
Perception on risk	-0.555	0.363	0.126
_cons	1.471	1.506	0.329

Number of observations = 320

Wald chi2(14) = 70.05

Prob > chi2 = 0.0000

***, **, * denotes statistical significance at 1%, 5% and 10% level. Advanced awareness category was used as the base category.

4.5 Determining the institutional interventions that influence the adoption intensity of ecological farming

4.5.1 Preliminary tests

Multicollinearity is a major problem in regression analysis, with many explanatory variables. To test for the possibility of multicollinearity, the study used the variance inflation factor (VIF). The result from the test presented in Appendix 9 indicated that multicollinearity was not a major problem since the captured mean VIF was 1.43. Likewise, the results of the pairwise correlation test of the categorical variables shown in Appendices 10 and 11 indicate no serious linear relationship. This is because the pairwise correlation coefficients were within the 0.5 threshold in all cases. Further, the Breusch-Pagan test was conducted to detect possible heteroscedasticity in the model. The probability chi-square was 0.2248, hence not statistically significant, indicating that the variance is constant among residues and concluding that heteroscedasticity is absent in the data.

4.5.2 Model specification tests

The mean and variance of the outcome variable for this objective (ecological farming practices) are shown in Table 4. 4: Intensity of ecological farming practices adoption above. The mean is 2.32 and the variance is 2.11, implying the mean and variance are not equal. However, this is not an optimal way of investigating dispersion in the data. Therefore, we estimated both the Standard Poisson and Generalised Poisson models, compared the parameter estimates of these models and goodness of fit measures, and finally justified the modelling by testing the dispersion parameter.

The estimates from standard Poisson and generalised Poisson (GP) regression models are presented in Table 4.8 below. A goodness of fit test for the two models reveals that the AIC and BIC for GP are less than standard Poisson. Also, the log-likelihood values are greater for the GP model. Due to these reasons, the GP model was regarded as a better model that describes the data compared to the standard Poisson model. Further, we investigated the presence of dispersion in the data. Following Long and Freese (2001), we compared the two likelihood ratio chi-squares values, that is, the likelihood ratio static value of 37.48 with the tabulated value of 3.84 obtained from the chi-squared table with 1 df. With this result, the null hypothesis that there is zero dispersion in the data was rejected, and we concluded that the generalised Poisson regression is appropriate for analysing the count data.

4.5.3 Empirical results

The results presented in Table 4.8 also include the marginal effects estimates from the generalised Poisson regression model. The results reveal that out of the eighteen independent variables, eleven significantly influenced the adoption intensity of ecological farming practices. Age was negative and significant at the 1% level. Increasing age by one year would decrease the use of multiple ecological farming practices by 2.1%. This implies that older farmers were less likely to use more ecological practices compared to younger farmers. A possible explanation for this is that as people age, they have established farming methods and may be less willing to change. Contrary to this are the results of Mahama *et al.* (2020) and Muzira *et al.* (2021), who reported age to positively influence adoption intensity.

Education had a significant but negative association with adoption intensity at the 1% level. This could be attributed to the fact that more educated farmers might be more focused on growing their careers than actively engaging in ecological farming. In this case, due to the close proximity of the study area to the country's capital, educated people moved to the city and got involved in other forms of livelihood, leaving those with low levels of education back in the village to practice farming. The finding is consistent with that of Awuni *et al.* (2018), who found education to have a negative influence on the adoption intensity of improved agricultural technologies.

Gender was negatively associated with adoption intensity at the 10% level of significance. This means women were less likely to use more ecological practices compared to men. This could be explained by the socio-economic and cultural settings that favour men over women. More often than not, women are assigned traditional roles such as caregiving; they have limited access to

productive resources; and they have limited decision-making powers. Due to the aforementioned reasons, women could be discouraged from actively engaging in ecological farming practices. This finding is inconsistent with that of Awuni *et al.* (2018), who found the gender of the farmer to be positively associated with adoption intensity.

Household size was positively correlated with adoption intensity at the 10% significance level. The study results imply that households with more family members increased the likelihood of intensifying ecological farming. This could be attributed to the fact that larger households are motivated to adopt more ecological farming practices in order to meet their household food consumption requirements. This finding confirms the finding of Kiconco *et al.* (2022) that household size positively influences the adoption intensity of banana technologies in Uganda. However, Pedzisa *et al.* (2015) found a negative association between household size and the adoption intensity of conservation agriculture.

Farming experience had a positive influence on adoption intensity at a significant level of 5%. Adding one more year of farming experience increased the likelihood of adopting multiple ecological farming practices by 1.6%. To explain this, farmers with more years of experience tend to have a long-term perspective on farming. They have a better understanding of the benefits that sustainable farming practices provide for their land and environment. Thus, they tend to adopt multiple ecological farming practices to serve their long-term goals. This result corroborates the result of Negera *et al.* (2022) that farming experience is positively correlated with climate-smart agriculture adoption intensity. Contrarily, Tafese (2016) reported a negative association between farming experience and adoption intensity.

Additionally, perception of demand was significant and positively associated with adoption intensity at the 1% level. Farmers who perceived the demand for ecologically produced foods as high increased the likelihood of adopting more ecological practices by 34%. A possible explanation for this is that as market demand for organic and sustainable products increases, farmers are motivated to adopt more ecological farming practices to meet market demand and capture premium prices for their produce. Most of the surveyed households stated that the middlemen preferred their farm produces, but they were unwilling to pay a premium price for the them.

The perception of the effect of conventional agriculture was found to positively and significantly influence the intensity of ecological farming at the 1% level. Farmers who perceived

that the use of synthetic fertilizers and pesticides had negative consequences for the soil, climate, and human health had a 78% probability of adopting ecological practices on a larger scale. To explain this result, farmers prioritised the use of ecological farming practices since they were tailored to their specific local conditions, readily available, and friendly to human health. On the flip side, close to 25% of the surveyed farmers did not agree that the use of synthetic fertilisers and pesticides had negative consequences for the soil, climate, and human health. This calls for campaigns to educate producers on the negative effects of using chemical inputs on the soils and human health.

In line with Mahama *et al.* (2020), this study found a significant and positive association between extension contact and adoption intensity at the 1% significance level. An additional visit from the extension officer increased adoption intensity by 4.3%. This result affirms the important role played by extension agents in providing information, hands-on training and demonstrations, and guidance needed to promote the adoption of agricultural practices. The presence of ICE and COSDEP NGOs in the study area increased households' chances of having contact with extension agents. The NGOs and government extension officers visit farmers to disseminate knowledge on ecologically sound initiatives for producing food. However, this study notes a significant extension gap that could be attributed to the high extension staff-to-farmer ratio in Kenya. The extension-farmer ratio was 1:2000 according to the 2012 National Agricultural Sector Extension Policy (NASEP) report, falling short of the internationally recommended ratio of 1:400. The low staffing levels in both public and private extension service providers remain the biggest challenge to reducing the high extension staff-to-farmer ratio.

In this study, access to the market was found to have a significant and positive association with adoption intensity at the 1% level. The results show that access to eco-friendly markets increases the intensity of adoption by 50.1%. A possible explanation for this result is that institutions such as supermarkets, restaurants, and consumers themselves have created a demand for ecological products. The anticipation of higher sales volumes and better prices acts as an incentive for households to take up ecological farming practices at a higher intensity. However, access to eco-friendly markets is still a challenge for most farmers. Evidently, 81% of the surveyed farmers sold their farm produce to buyers who do not pay premium prices for the produce, such as brokers and local markets. Most interventions nationally have focused their efforts towards sustainable production, but only a few focus on developing eco-friendly markets as well as market

linkages for producers with consumers. This finding is in tandem with Kiconco *et al.* (2022), who reported that access to urban output markets positively and significantly influenced the adoption intensity of banana technologies in Uganda.

The study found that farmer access to training on ecological farming had a significant and positive association with adoption intensity at the 1% significance level. According to the findings of this study, farmers who had attended training had a 50.9% higher chance of adopting more ecological practices. This suggests that the more extensive and comprehensive the training is, the higher the level of adoption. A plausible explanation is that farmers who had attended workshops, conferences, or forums such as field days gained a better understanding of the benefits, successes, and challenges of ecological farming and thus a higher likelihood of adopting more ecological practices effectively. This study noted that the surveyed farmers mostly received training on production and little or no training on marketing. The key gaps in the training of farmers remain a challenge in ensuring a sustainable transformation of the farming and food systems. Similarly, Rahman *et al.* (2022) show that training positively influences the adoption intensity of drought-tolerant rice varieties.

The major information source variable was positive and significant at the 1% level. Further, the findings indicated that those who accessed their information from institutions had a 38.7% higher likelihood of a greater level of adoption intensity compared to those who received their information from other farmers. This could be attributed to the fact that NGOs, government, and private companies' extension staff are experts, and farmers tend to perceive them as trusted and credible sources of information. The finding agrees with Rodthong *et al.* (2020), confirming a positive association between access to information and the intensity of adoption. This finding further underscores the importance of addressing the extension gap in order to fully realise the dissemination of information on ecological practices.

Table 4.8: Standard Poisson and Generalised Poisson regression models results on institutional interventions influencing households' adoption intensity of ecological farming practices

Variables	Standard Poisson		Generalised Poisson		
	Coefficient	SE	Coefficient	SE	dy/dx
Location	-0.017	0.100	-0.018	0.072	-0.040
Gender	-0.105	0.079	-0.091*	0.058	-0.195*
Age	-0.011**	0.005	-0.010***	0.003	-0.021***
Education	-0.033**	0.014	-0.032***	0.010	-0.070***
Household size	0.042*	0.023	0.030*	0.017	0.065*
Farming experience	0.008*	0.005	0.007**	0.003	0.016**
Slope	0.059	0.088	0.052	0.065	0.112
Soil erosion	0.016	0.112	0.029	0.083	0.062
Farm size	0.006	0.030	0.005	0.021	0.012
Demand	0.174**	0.082	0.159***	0.059	0.340***
Effect of CA	0.427***	0.105	0.401***	0.075	0.780***
Input support	0.029	0.099	0.009	0.074	0.019
Market	0.240**	0.105	0.218**	0.077	0.501***
Infrastructure	-0.000	0.010	0.001	0.007	0.002
Training	0.254***	0.090	0.227***	0.066	0.509***
Extension	0.021***	0.007	0.020***	0.005	0.043***
Information source	0.191**	0.097	0.184***	0.071	0.387***
Land tenure	-0.062	0.084	-0.052	0.062	-0.112
_constant	0.653**	0.313*	0.687***	0.232	
Log likelihood	-507.77		-489.03		
AIC	1053.53		1018.05		
BIC	1125.13		1093.42		
Dispersion (δ)			-0.326		

Likelihood-ratio test of $\delta=0$: $\chi^2(1) = 37.48$ Prob $\geq\chi^2 = 0.0000$; dy/dx denotes marginal effects, ***, **, * denotes statistical significance at 1%, 5% and 10% level.

4.6 Effect of ecological farming practices on farm income

4.6.1 Preliminary tests

The results of the variance inflation factor (VIF) test are presented in Appendix 14. The VIF ranged from 1.06 to 2.06, and the mean VIF was 1.31. Following this result, we concluded multicollinearity was not a problem for our analysis. Similarly, the pairwise correlation analysis (Appendix 15) showed the absence of a serious linear relationship among the categorical explanatory variables. Likewise, the results from the Breusch-Pagan test (Appendix 16) reported a probability chi-square of 0.6054, which is greater than 0.05. Therefore, we did not reject the null hypothesis that the variance is constant among residues and conclude that heteroscedasticity is absent in the data.

4.6.2 Determinants of choice of specific ecological farming packages

The parameter and marginal effects estimate of the determinants of choice of ecological farming practice packages from the multinomial logit model are shown in Table 4.9 and Table 4.10 below. Age was negative and significant at the 1% level. Increasing age by one year would decrease the use of mulching, compost manure, and crop diversification packages by 0.8%. A possible explanation for this could be due to the fact that a practice such as mulching is labour-intensive, requiring healthy, risk-bearing, and energetic individuals. Hence, the package may be unattractive to older farmers. This result corroborates with that of Baiyegunhi *et al.* (2022), who found that farmer's age was negative and statistically significant with all the alternative packages of improved maize varieties and crop diversification.

Household size was positively and significantly correlated with the adoption of compost manure and crop diversification at the 1% level. Larger family sizes had 3.80% higher chances of choosing a combination of compost manure and crop diversification. A plausible assumption is that households with more family members have higher food needs. A package combining the use of compost manure and crop diversification can help households meet their food needs by increasing crop production. This aligns with the finding of Teklewold *et al.* (2013), who reported that a strong positive correlation existed between family size and adoption of a combined package including cropping systems, diversification, conservation tillage, and modern seed adoption in Ethiopia.

Off-farm activities were significant at the 1% level. Households that were involved with off-farm activities increased the probability of adopting mulching, compost manure, and crop

diversification package by 12.2%. As argued by Setsoafia *et al.* (2022) and Abdulai and Huffman (2013), participation in off-farm activities could earn farmers additional income that enables them to invest in innovative technologies such as sustainable agricultural practices. On the other hand, it decreased the probability of choosing a package consisting of all ecological farming package by 10.1%. This finding alludes to the fact that participation in off-farm activities diverts time and money away from agricultural activities; hence, fewer resources are available for facilitating adoption of agricultural technologies. This is a similar notion to that of Amsalu and de Graaff (2007), who found farmers' engagement in off-farm activities negatively and significantly influenced adoption of agricultural technologies.

Farming experience had a negative and significant association with the adoption of a package consisting of all ecological practices at the 5% level. Adding one year of experience decreased the likelihood of adopting a combination of all ecological practices by 0.4%. This suggests that farmers with many years of experience may have established farming practices that work for them and may be hesitant to change their methods of farming. This corroborates the finding of Mahama *et al.* (2020) that farming experience is negatively correlated with the adoption of improved soybean production technologies. However, farming experience was positively and significantly correlated with the adoption of a combination of mulching, crop diversification, and composting at the 1% level. Further, an additional year of farming experience increased the probability of choosing the mulching, crop diversification, and composting package by 1.1%. This implies that farmers with more years of farming experience gather enough knowledge and information over the years that allows them to easily adapt to new innovations. This finding conforms with that of Awuni *et al.* (2018), who found that farming experience positively influences the adoption of improved agricultural technologies.

Farm size was positively and significantly associated with the adoption of composting and crop diversification package and a combination of all five ecological practices at the 5% and 1% level, respectively. Further, increasing the size of cultivated land by one acre increases the likelihood of choosing MCDTP and CD by 3.6% and 3.9%, respectively. This is possible because having a larger farm allows farmers to adopt larger packages of ecological practices. This result is compatible with that of Huong *et al.* (2023), who argue that farmers with larger farm sizes benefit from economies of scale by adopting multiple practices at a time. On the other hand, farm size was negative and significant at the 5% level. An increase in the size of cultivated land by one acre

decreased the use of composting, crop diversification, and IPM package by 6.98%. A possible explanation could be that farmers may find it challenging to implement this package due to the technical expertise required and also the complexity of managing composting, diverse crops, and integrated pest management operations on a larger land area. Therefore, any additional land is dedicated to other farming methods. Similarly, Wekesa *et al.* (2018) found that farm size had an inverse relationship with the use of sustainable agricultural practices packages.

The variable drought and floods had a positive and significant influence on the adoption of a package combining compost manure, crop diversification, and IPM and composting only at the 5% significance level. Households that experienced yield loss due to drought and floods increased the use of CDP and C by 9.7% and 12.1%, respectively. This is plausible, as farmers adopt these practices to reduce production losses brought about by droughts and floods. Floods are likely to cause an increase in pests, and they can also significantly alter the level of plant-available nutrients in the soil. Farmers manage the mentioned problems by applying compost manure and using IPM practices. Also, crop diversification can help manage drought stress by planting crops that can withstand local climatic conditions. Similar to this finding is that of Mthethwa *et al.* (2022), who found drought conditions positively influenced the adoption of multiple climate-smart agricultural practices. On the other hand, drought and floods had a negative and significant influence on the adoption of a package combining all five ecological practices at the 1% level. That is, households that had experienced yield loss due to drought and floods were less likely to adopt a package combining all five practices by 15.6%. A possible explanation could be that a switch to ecological practices may induce a change in perceived income risks. Reducing external inputs for instance, lesser reliance on pesticides often results in higher perceived production risks leading to non-adoption of larger packages of ecological farming practices. Similar to this are the findings of Teklewold *et al.* (2013), which show waterlogging and drought stress negatively influence the adoption of sustainable agriculture practice packages.

Group membership was significant at the 1% level and positively influenced the adoption of MCDP, while it negatively influenced the adoption of CD packages. Belonging to a group increased the likelihood of adopting MCDP by 21.4%. This could be attributed to the benefits of social capital, such as exposure to training, sharing information, and credit access. Therefore, farmers who belonged to producer groups were able to adopt a larger package of ecological practices. On the other hand, membership in a group decreased the likelihood of adopting CD by

14.8% at the 1% level. A possible reason is that some of the producer groups had goals focused more on other activities than farming. Similarly, Awuni *et al.* (2018) reported a significant and negative relationship between group membership and adoption of agricultural technologies.

Credit access had a positive association with the use of composting and crop diversification package at the 1% significance level. Farmers who could access credit were more likely to use the aforesaid package by 15.2%. This is plausible, as access to credit enables farmers to cover farm production costs. This result is consistent with that of Wekesa *et al.* (2018), who reported credit access had a significant and positive influence on the adoption of climate-smart agricultural technology packages. On the other hand, credit access was negatively and significantly correlated with the adoption of the MCDP package at the 5% level. Having access to credit decreased the likelihood of using the MCDP package by 8.8%. Choosing to use larger packages of ecological practices may increase the risks and uncertainties with regard to potential crop failure arising from increased pressure from pests and market uncertainties associated with crop diversification. Therefore, the acquired credit is mostly invested in other production practices or non-farm activities. Similarly, Mahama *et al.* (2020) found an inverse relationship between access to credit and the adoption of multiple agricultural technologies.

Adoption of composting, crop diversification, and IPM was higher among households that perceived conventional agriculture to have harmful effects. Soil degradation, low food production, high cost of chemical inputs, pesticide residues in crops, and unpredictable weather were significant concerns for farmers in the study. Farmers adopted farming practices that could restore degraded soils while increasing production of healthy food. Compost manure and IPM were used to replace chemical fertilisers and pesticides while crop diversification was used as a risk mitigation strategy against crop and income loss.

The results further indicate that households in the Kamburu ward had a higher probability of adopting larger packages than in the Kirenga ward. This result could be attributed to more NGOs offering extension services and input support to farmers from the Kamburu ward.

Table 4.9: The MNL model parameter and marginal effects estimates of the determinants of choice of ecological farming practices packages

Variables	MCD		CD		CDP	
	Coefficient (SE)	dy/dx	Coefficient (SE)	dy/dx	Coefficient (SE)	dy/dx
Location	0.445(0.529)	0.006	-0.406(0.532)	-0.066	0.048(0.547)	-0.042
Gender	-0.003 (0.484)	-0.001	-0.561(0.499)	-0.070*	0.081(0.507)	0.007
Age	-0.076(0.028)	-0.008***	-0.037(0.028)	-0.001	-0.004(0.025)	0.004*
Household size	0.277(0.157)	-0.001	0.546(0.171)	0.038***	0.248(0.160)	-0.003
Education	-0.154(0.089)	0.005	-0.152(0.096)	-0.005	-0.163(0.094)	-0.006
Experience	0.080(0.028)	0.011***	0.013(0.028)	-0.000	-0.014(0.028)	-0.004*
Farm size	-0.114(0.219)	-0.002	0.242(0.167)	0.039**	-0.579(0.307)	-0.068**
Drought and floods	-1.346(0.537)	-0.039	-1.163(0.547)	-0.040	-0.312(0.590)	0.097**
Membership	1.842(0.523)	0.000	0.236(0.549)	-0.148***	2.175(0.541)	0.051
Off-farm activities	0.602(0.513)	0.122***	-0.071(0.538)	-0.003	-0.480(0.543)	-0.052
Credit	0.836(0.519)	-0.023	2.201(0.575)	0.152***	1.199(0.535)	0.036
Slope	0.608(0.540)	0.015	0.059(0.577)	-0.057	0.682(0.566)	0.017
Soil erosion	1.316(0.867)	0.023	1.284(0.912)	0.046	1.339(0.889)	0.039
Effect of ca	2.455(0.578)	0.049	1.442(0.542)	-0.058	3.317(0.735)	0.174**
Constant	-0.038(1.846)		-0.714(2.000)		-2.537(2.025)	

***, **, * denotes statistical significance at 1%, 5% and 10% level.

Table 4.10: The MNL model parameter and marginal effects estimates of the determinants of choice of ecological farming practices packages continuation

Variables	MCDTP		MCDP		C	
	Coefficient (SE)	dy/dx	Coefficient (SE)	dy/dx	Coefficient (SE)	dy/dx
Location	0.693(0.816)	0.001	2.463(0.899)	0.182***	-1.048 (0.625)	-0.084**
Gender	0.632(0.768)	0.028	0.171(0.600)	0.007	0.313(0.558)	0.025
Age	-0.020(0.038)	0.001	-0.025(0.033)	0.001	-0.028(0.031)	-0.000
Household size	0.078(0.231)	-0.011	0.424(0.187)	0.015	0.174(0.188)	-0.005
Education	-0.074(0.141)	0.003	-0.127(0.113)	0.000	-0.131(0.111)	-0.002
Experience	-0.073(0.050)	-0.004**	0.033(0.035)	0.001	-0.011(0.034)	-0.002
Farm size	0.620(0.304)	0.036***	-0.363(0.307)	-0.021	-0.019(0.201)	0.007
Drought and floods	-4.695(1.056)	-0.156***	-2.078(0.667)	-0.063*	0.997(0.874)	0.121**
Membership	2.856(0.830)	0.029	4.481(0.878)	0.214***	1.588(0.593)	-0.019
Off-farm activities	-2.268(0.997)	-0.101***	0.098(0.668)	0.029	-0.238(0.630)	-0.011
Credit	1.634(0.796)	0.033	0.023(0.630)	-0.088**	1.324(0.602)	0.028
Soil erosion	1.946(1.136)	0.025	2.228(0.962)	0.082*	-0.661(1.286)	-0.112
Slope	1.095(0.857)	0.026	0.524(0.690)	-0.010	1.504(0.642)	0.077**
Effect of CA	4.202(1.250)	0.083*	2.709(0.770)	0.007	1.435(0.608)	-0.027
Constant	-3.502(2.894)		-5.916(2.541)		-1.665(2.273)	

***, **, * denotes statistical significance at 1%, 5% and 10% level.

4.6.3 Average adoption treatment effects for the ecological farming practices packages

In the second stage, an ordinary least squares (OLS) regression model was used to estimate the effect of each combination of ecological practices on households' farm income. The self-selection bias from the first stage was taken care of at this stage. However, for purposes of brevity, we did not report the results from the OLS regression. The main focus was to estimate the treatment effects.

Table 4.11 reports the treatment effects of the adoption of a combination of ecological practices on farm income. To estimate the average treatment effects for households that used ecological practices, the farm income of farm households that adopted ecological practices packages (observed scenario) was compared with the farm income of farm households that had not adopted them (counterfactual scenario). The values of ATTs are presented in

Table 4.11 below, showing that a household is better off if ATT is positive and worse off if it is negative.

The results revealed that a package consisting of all ecological practices (mulching, compost manure, crop diversification, minimum tillage, and integrated pest management) had a positive impact on farm income. The impact magnitudes of adopting all five ecological farming practices are larger than those of adopting four practices and below. Specifically, adoption of MCDTP increased farm income by 9.2%. Farmers who chose to adopt compost manure, crop diversification, and integrated pest management (CDP) had income gains as well. Further, the use of a combination of mulching, compost manure, crop diversification, and integrated pest management (MCDP) was statistically significant at the 10% level. The ATT for the aforementioned package was positive, implying that farm income increased for the households that used that package.

However, the use of packages combining compost manure and crop diversification only (CD), and one that consists of mulching, compost manure, and crop diversification (MCD) reduced farm income by 1.7% and 2.8%, respectively. This means the adopters of the aforementioned packages would be better off in the counterfactual scenarios (non-adoption). On the other hand, the package including only compost manure was not statistically significant. Nonetheless, the results show a negative ATT, suggesting that households that used only compost manure were worse off.

Table 4.11: Treatment effects of ecological practices adoption on farm income

Ecological farming practices categories		Adoption status		Average treatment effects
		Adopting	Not-adopting	
MCDTP	Adopters	12.953	11.863	ATT=1.090***
	Non-adopters	11.662	11.923	ATU=-2.600***
	Level effects	1.291***	-0.060	1.030
CDP	Adopters	12.254	11.953	ATT=0.301***
	Non-adopters	11.957	11.938	ATU= 0.020
	Level effects	0.296*	0.015	0.316
MCDP	Adopters	12.282	12.125	ATT=0.157*
	Non-adopters	12.813	11.950	ATU=0.863***
	Level effects	-0.531***	0.175***	0.332
C	Adopters	11.855	12.034	ATT=-0.179
	Non-adopters	11.343	12.004	ATU=-0.662***
	Level effects	0.512	0.030	-0.149
CD	Adopters	11.801	12.004	ATT=-0.203**
	Non-adopters	11.872	12.029	ATU= -0.157***
	Level effects	-0.071	-0.025	-0.228
MCD	Adopters	11.801	12.140	ATT=-0.339***
	Non-adopters	11.779	12.039	ATU= -0.260***
	Level effects	0.022	0.101**	-0.238

***, **, * denotes statistical significance at 1%, 5% and 10% level

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The overall objective of this study was to document the role of institutional interventions in enhancing the transition to increased farm income based on the uptake of ecological farming practices among households in Kiambu County. The specific objectives were to identify factors affecting awareness of ecological farming, to determine the institutional interventions that influence the adoption intensity of ecological farming, and to determine the effect of ecological farming adoption on farm income among farmer households in Kiambu County. Primary data was collected from 320 households in Lari subcounty using semi-structured questionnaires. Further, the study employed a generalised ordered logit model, a generalised Poisson regression model, and a multinomial endogenous switching regression model to analyse the three objectives.

5.2 Conclusions

- i. Awareness among farmers was found to be high (about 91%). The results show a positive relationship between group membership and awareness of ecological farming. This result points out the importance of social capital in enhancing the diffusion of information. Also, awareness is positively influenced by factors such as soil erosion and perceptions of the benefits of ecological practices, indicating that visible issues and perceived advantages drive interest and knowledge about sustainable methods. Additionally, the positive association between awareness and access to information signify the importance of institutions as reliable sources of disseminating information on ecological farming. On the other hand, age, drought and floods negatively influenced awareness.
- ii. Institutional interventions found to significantly and positively influence the adoption intensity of ecological farming practices in this study were extension contacts, access to eco-friendly markets, access to training, and access to information. The positive influence of extension contact on adoption intensity suggests that agricultural extension services are crucial for promoting ecological farming practices. Effective extension services facilitate the transfer of knowledge, provide practical advice, and offer ongoing support to farmers. Similarly, the significant role of training accessibility in increasing adoption intensity underscores the necessity of educational initiatives that provide farmers with the skills and

expertise needed for ecological farming. The impact of access to information on adoption intensity imply that relevant and up-to-date information from institutions supports farmers in making decisions about ecological farming practices. Furthermore, the results signify the importance of creating economic incentives for farmers to adopt ecological practices. Access to markets that value and pay a premium for eco-friendly products encourages farmers to adopt multiple ecological farming methods.

- iii. The study also found that households that used a full package of ecological practices (mulching, crop diversification, integrated pest management, use of compost, and minimum tillage) had the highest gross farm income gain per year. The adoption of the comprehensive package was significantly influenced by, farming experience, off-farm activities, farm size, perceptions of the effects of conventional agriculture, and drought and floods. The results indicate the significant role of larger farm sizes in encouraging the adoption of a comprehensive package suggesting the need to enforce land use planning laws that discourage further agricultural land fragmentation. Similarly, the correlation between households' perceptions of the effect of conventional agriculture and increased adoption of the comprehensive package underscores the need to establish targeted information campaigns through digital platforms and extension services to educate farmers about the drawbacks of conventional agriculture and the benefits of ecological practices and dispel misconceptions. Furthermore, the results signify the importance of timely weather-related data, including rainfall amounts, time of year, and distribution, to cushion farmers from weather-related risks like drought and floods.

5.3 Recommendations

- i. County government, private institutions, and NGOs should capitalize on the factors that significantly influence awareness and design tailored knowledge dissemination programs to raise awareness among farmers. For example, related stakeholders should encourage group formation and participation among farmers since it is a crucial information network where farmers can share information and carry out farm demonstrations effectively.
- ii. This study recommends policy interventions to promote multi-stakeholder partnerships to develop eco-friendly markets, for instance by setting up stalls at the local markets that are specifically meant for farm produce farmed using eco-friendly agricultural methods. Additionally, the government should reduce the extension gap by hiring more extension

staff and creating an environment that encourages private sector and non-governmental extension provision. This would therefore guarantee that farmers receive extension visits regularly, which would allow them to intensify ecological practices. Again, public and private institutions should provide tailored agricultural advisory services that provide relevant information on ecological farming and thus help dispel misconceptions. Key gaps in their training should be addressed by reviewing their training curriculum to pay more attention to areas such as marketing and value addition. Besides, the government should allocate resources to facilitate training platforms including field days, field shows, online sharing networks, etc. to further promote knowledge dissemination offered at the community level.

- iii. This government and other partners should develop and promote weather-related advisory services that offer actionable recommendations for farmers based on real-time data. Also, the government should enforce sustainable land use laws that limit the subdivision of large agricultural plots to heighten the adoption of all five ecological practices consequently, enhance household welfare by increasing farm income.

5.4 Areas for further research

This study covered farmers motivations and decision-making processes on whether to adopt or reject five ecological farming practices; determinants of farmers knowledge and information on five ecological farming practices; and finally, the economic outcomes of adopting the five ecological farming practices. Therefore, future research could carry out a similar study with a combination of more practices. Also, future research could consider looking at the implications of gender dimensions of ecological farming practices in order to enhance inclusivity. Further, future studies could look at consumer preferences and behaviours. In particular, investigate consumer demand, attitudes, perceptions, and preferences towards ecological food products.

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APPENDICES

Appendix A: Semi-Structured Questionnaire

THE INFLUENCE OF INSTITUTIONAL INTERVENTIONS ON THE ADOPTION INTENSITY OF ECOLOGICAL FARMING AMONG HOUSEHOLDS IN KIAMBU COUNTY SURVEY QUESTIONNAIRE, 2023

INTRODUCTION

Dear respondent

You are invited to participate in a research study conducted by Emma Kamau, a Masters student from the Department of Agricultural Economics and Agribusiness Management, at Egerton University, Njoro campus. The purpose of the study is assessing the influence of institutional interventions on the adoption intensity of ecological farming practices among farmer household in Kiambu County, Lari subcounty. The results of this study are solely for academic purposes as well as informing policy makers on the interventions that can work to scale up ecological farming practices, also, they may be published in academic journals. Participation in this survey should take less than an hour. The questions that will be asked requires you to provide information on your household characteristics, assets, agricultural inputs, access to agricultural markets and credit, farm income as well as any other information that relate to agriculture production. Please note your participation in this survey is very important to us and the study. However, this is a voluntary exercise and you may choose not to participate and you may stop participating at any time without negative consequences. The information you provide will be treated strictly as confidential. Please respond to the questions as honestly as possible.

The respondent must be an individual who normally makes farm decisions in the household.

This must be the household head or the spouse

Section A: Background Information

1. Date of the interview?
2. Enumerator's name?
3. Sub-county?
4. Ward?
5. Name of the household head?

6. Name of respondent if not the household head?
7. Respondents mobile contact:

Section B: Household’s demography and socio-economic characteristics

8. Gender of the respondent/household head? 1= Male [] ; 2= Female []
9. Age of the household head/respondent in years
10. What is the size of the household?.....

*A household consists of people living under the same roof and share meals

11. How many years have you been in school?
12. What is the primary occupation of the household head?

Occupation	Tick primary occupation of the HH
Farming	
Salaried employment	
self-employment	
casual labourer on farm	
casual labourer off farm	
others, specify	

13. For how long have you been in the farming enterprise?

14. What is the ownership arrangement of the farm you are currently cultivating?

Ownership arrangement	Tick the category
Owned with title	
Owned without title	
Leasehold	
Borrowed	
Community land/Government	

15. What is the average farm income per month?

Average farm income in ksh. Per month	Tick the category
<5000	
5000-10000	
10000-20000	
20000-50000	
>50000	

16. Do you have any other sources of income besides farming?

0= No [] 1= Yes []

17. If Yes, where else do you get income from?

Sources of off-farm income	Tick the category
Rental payments	
Self-employed	
Salaried employment	

Remittances	
Pension	
Others, specify	

18. What type of labour did you mainly use in your farm for the last two seasons?
 1= Family labour []; 2=Hired labour []; 3= Both family and hired labour []
19. How many household members worked in the family farm fulltime in the last two seasons?.....

Section C: Farm/Plot characteristics and household motivating factors

20. What is the total size of land in acres is owned by the household?
 how much of that land is available for cultivation in acres?
21. How is the slope of the land you are currently cultivating?
 1= very/fairly steep [] 0= not steep []
22. What would you say about the severity of soil erosion on your land?
 1= very/moderately severe [] 0= not severe []
23. Would you say there has been a change in weather for the past 10 years in the area?
 1= Yes [] 0= No []
24. Have you experienced yield losses due to pests or diseases? 1= Yes [] 0= No []
25. Have you experienced yield losses due to drought and floods? 1= Yes [] 0= No []

Section E: Awareness

26. Please indicate if you have heard about any of these ecological practices, if **NONE**, go to **35**

Agroecological practices	Tick the practices you have heard about
Mulching	
Preparing and using compost manure	
Crop diversification	
Minimum/zero tillage	
Integrated pest management	
None	

27. Please indicate the ecological methods you used in your farm for the last two seasons? If none go to **30**

Ecological practices	Tick the practices
Mulching	
Preparing and using compost manure	
Crop diversification	
Minimum/zero tillage	
Integrated pest management	
None	

28. How would you define ecological farming?

.....

29. Please indicate THREE main reasons for using ecological farming practices on your farm

Main reasons	Tick
Enhancing yield and earning additional income	
Maintaining soil moisture	
Avoid the effects of drought on farming	
Availability of organic inputs	
Controlling erosion and protecting the soil	
Support from the government and civil society	
Increased demand of ecologically produced products	
Shifting to organic farming lifestyle	
others, specify	

30. If None,

What is the main reason for not applying ecological practices?	Tick the main reasons
Insufficient knowledge/information on ecological farming	
Labour intensiveness	
Inadequate market	
Low returns	
Limited access to organic inputs	
Lack of credit access	
Lack of proper infrastructure	
others, specify	

Section D: Farmer's perception toward ecological farming

31. Do you think ecological farming is a risky investment? 1= Yes [] 0= No []

32. Do you perceive ecological farming to contribute to achieving household food's needs and additional income? 1= Yes [] 0= No []

33. How do you perceive the effects of conventional agriculture?

1=good [] 2= bad [] 3= not-sure []

34. How do you perceive the demand for ecologically farmed produce?

1= High [] 2= Average [] 3= Low []

Section F: Institutional resources

35. Do you belong to any farmers' group/cooperative? 1=Yes [] 0= No []

36. If Yes, who helped you form the group?

Institutions	Tick category
NGOs	
Agricultural department staff	
Community	
Don't know	
others, specify	

37. What activities are carried out or promoted by the group?

Activities	Tick category
Farm demonstrations	
Group marketing	
Pooling labour	
Sensitizing community	
Savings and credit	
Others, specify	

38. How many times do you receive extension services or technical advice in a year?

.....

39. Who offers the extension services and advice?

Institution	Tick category
Government extension staff	
NGOs extension staff	
Farmers' organization	
Input vendors'	
Traders/marketing agents	
Research organizations	
Others, specify	

40. How far is the main local market from the farm in Km? []

41. Which of these infrastructures are easily accessible to you?

Type of Infrastructure	Tick the ones you can access/use	What is the condition of the infrastructures?			
		Very poor	Poor	Good	Very good
Tarmac road					
Murram road					
Earth road					
Storage facilities for crops					
Processing facilities					
Rural market facilities					
Water supplies					
Others, specify					

42. What is the distance between the farm and the nearest tarmac road in Km? []

43. Are there accessible credit facilities in the area? 1= Yes [] 0= No []

44. Please indicate the accessible sources of credit in the area

Sources of credit	Tick the source/s
Relatives/ Fiends/ Shylocks	
Commercial banks	
Farmers association	
Cooperatives/ SACCO	
Others, specify	

45. What is the distance (km) from the farm to the nearest formal credit institution?

46. Do you have interest in borrowing money to use in farming? 1= Yes [] 0= No []

Note: (From this point on only those who are aware and also those who have adopted ecological practices on their farms should answer)

47. Where do you receive ecological information from?

Institutions	Tick the institution/s
Government officials	
NGOs	
Media	
Other farmers/own knowledge	
Others, specify	

48. What type of information/advice do they offer?

Type of information/advice	Tick category
Production advice	
Sources and utilisation of inputs	
Agricultural finance and credit management	
Farming as a business	
Keeping farm records	
Marketing and value addition	
Weather information	
Others, specify	

49. How often do you use the information (from source) for planning production?

1= Always [] 2= Occasionally [] 0= Not-at all []

50. Have you attended a workshop on ecological farming practices in the last two years?

1= Yes [] 0= No []

51. Did the training workshop train on any of these ecological farming practices?

Ecological practices	Tick the practices
Mulching	
Preparing and using compost manure	
Crop diversification	
Minimum/zero tillage	
Integrated pest management	

52. Did the training workshop include any of the following information?

Type of information/advice	Tick category
Production advice in regard to ecological farming practices	
Sources and utilisation of organic inputs	
Agricultural finance and credit management	

Farming as a business	
Soil and water conservation	
Early warning signs in regard to weather	
Marketing and value addition	
Others, specify	

53. Who organizes the training?

Institution	Tick category
Government extension staff	
NGOs extension staff	
Farmers' organization	
Input vendors'	
Traders/marketing agents	
Research organizations	
Others, specify	

54. Are you satisfied with the training information organizations shares with you?

1= Satisfied [] 0= dissatisfied []

55. Do you have access to eco-friendly/organic markets?

1= Yes [] 0= No [] if No go to 57

56. Which are the eco-friendly markets that you have access to?

To whom do you sell your produce to?	Tick the major market
Local markets (open air)	
urban markets (open air)	
Processing companies	
Institutions (supermarkets, schools, restaurants etc.)	
Others, specify	

57. Which is the major market for your produce?

To whom do you sell your produce to?	Tick the major market
Local markets (open air)	
urban markets (open air)	
Processing companies	
Institutions (supermarkets, schools, restaurants etc.)	
Brokers	
None	
Others, specify	

58. Has any of the following actors assisted you gain access to buyers of your products?

Institutions	Tick the institution
Private agro-companies	
Government officials	
NGOs	

What is your current job/role?

- 1 What is your view on the ecological farming of this sub-county?
- 2 What practice/s do you focus on and why?
- 3 What is the geographic coverage your organization is working with?
- 4 Are there pre-determined criteria you use to identify potential users of ecological practices?
- 5 Which types of households in Lari subcounty do you think are most likely to up take ecological farming practices? (In relation to age/gender/economic)
- 6 What kind of services do you provide to farmers in relation to ecological farming?
- 7 Do you charge a fee for services rendered to ecological farmers?
- 8 If yes, what are the average costs of the services? (Please indicate price per service and provide details if the set price is set at market price or a subsidized price)
- 9 If no, how are your services funded/supported?
- 10 (For county government) is there any budget *allocated* towards promoting ecological farming in the subcounty?
- 11 In your view, what are the livelihood changes you have observed for the household that have adopted the ecological farming?

Appendix C: VIF test results for explanatory variables in Gologit2 model

Variables	VIF	1/VIF
Age	2.08	0.480
Gender	1.10	0.906
Farming experience	2.00	0.500
Soil erosion	1.08	0.923
Education	1.41	0.709
Information source	1.30	0.769
Group membership	1.28	0.784
Drought and floods	1.17	0.854
Household size	1.03	0.973
Perceived benefits	1.06	0.947
Off-farm activities	1.20	0.836
Risk perception	1.13	0.889
Farm size	1.09	0.914
Pests and diseases	1.04	0.961
Mean VIF	1.28	

Appendix D: Heteroscedasticity test results

```
. hettest
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
```

```
Ho: Constant variance
```

```
Variables: fitted values of awareness
```

```
chi2(1) = 69.40
```

```
Prob > chi2 = 0.0000
```

Appendix E: Pairwise correlation test results for categorical variables in gologit model

Appendix F: Pairwise correlation test results for categorical variables continuation

	Pests and diseases	Risk
Pests and diseases	1.000	
Risk	0.006	1.000

Appendix G: Brant test results for ordered logit model

	Gender	Soil erosion	Drought and floods	Information source	membership	Benefits	Off-farm activities
Gender	1.000						
Soil erosion	-0.092	1.0000					
Drought and floods	0.110	-0.086	1.000				
Information source	0.036	0.135	0.032	1.000			
Membership	-0.005	0.082	-0.086	0.434	1.000		
Benefits	0.070	-0.063	0.066	0.004	-0.057	1.000	
Off-farm activities	-0.018	0.0153	-0.086	-0.039	0.084	-0.031	1.000
Pests and diseases	0.092	-0.133	0.032	-0.028	-0.065	0.009	0.003
Risk	-0.089	0.006	0.209	-0.075	-0.054	0.067	0.159

	chi2	p>chi2	df
All	16.94	0.259	14
Gender	0.95	0.330	1
Age	0.48	0.486	1
Household size	0.68	0.409	1
Education	0.02	0.898	1
Farming experience	0.85	0.357	1
Soil erosion	0.15	0.701	1
Drought and floods	6.21	0.013	1
Information source	0.00	0.984	1

Membership	0.91	0.339	1
Benefits	1.23	0.267	1
Off-farm activities	0.20	0.652	1
Farm size	1.17	0.280	1
Pests and diseases	0.97	0.324	1
Risk	0.05	0.824	1

Appendix H: Gologit2 results estimates

```
. gologit2 awareness gender age householdsize education farmingexperience soilerosion droughtandfloods informationsource membership benefits offfarmactivities farmsize pestsanddisease
> s riskperception, npl(droughtandfloods) vce(robust)
```

```
Generalized Ordered Logit Estimates      Number of obs   =      320
                                         Wald chi2(15)    =      70.05
                                         Prob > chi2      =      0.0000
Log pseudolikelihood = -145.90961      Pseudo R2       =      0.2108
```

```
( 1) [unaware]gender - [basic_awareness]gender = 0
( 2) [unaware]age - [basic_awareness]age = 0
( 3) [unaware]householdsize - [basic_awareness]householdsize = 0
( 4) [unaware]education - [basic_awareness]education = 0
( 5) [unaware]farmingexperience - [basic_awareness]farmingexperience = 0
( 6) [unaware]soilerosion - [basic_awareness]soilerosion = 0
( 7) [unaware]informationsource - [basic_awareness]informationsource = 0
( 8) [unaware]membership - [basic_awareness]membership = 0
( 9) [unaware]benefits - [basic_awareness]benefits = 0
(10) [unaware]offfarmactivities - [basic_awareness]offfarmactivities = 0
(11) [unaware]farmsize - [basic_awareness]farmsize = 0
(12) [unaware]pestsanddiseases - [basic_awareness]pestsanddiseases = 0
(13) [unaware]riskperception - [basic_awareness]riskperception = 0
```

		Robust				
awareness		Coeff.	Std. Err.	z	P> z	[95% Conf. Interval]
unaware						
gender		-.1973591	.35691	-0.55	0.580	-.8968898 .5021715
age		-.0312083	.0182133	-1.71	0.087	-.0669057 .0044891
householdsize		.2827899	.1018909	2.78	0.006	.0830875 .4824924
education		-.1162624	.0817875	-1.42	0.155	-.2765629 .0440381
farmingexperience		.0293249	.0234162	1.25	0.210	-.0165701 .0752199
soilerosion		1.841858	.9637564	1.91	0.056	-.0470703 3.730785
droughtandfloods		-.214903	.4938672	-0.44	0.663	-1.182865 .7520589
informationsource		1.038622	.4202874	2.47	0.013	.2148739 1.86237
membership		1.129437	.4055111	2.79	0.005	.3346498 1.924224
benefits		1.467615	.388134	3.78	0.000	.7068867 2.228344
offfarmactivities		.4767801	.426677	1.12	0.264	-.3594915 1.313052
farmsize		-.028687	.1578379	-0.18	0.856	-.3380436 .2806697
pestsanddiseases		-.2265634	.4225357	-0.54	0.592	-1.054718 .6015915
riskperception		-.5550918	.3628974	-1.53	0.126	-1.266358 .156174
_cons		1.753024	1.540725	1.14	0.255	-1.266742 4.772791
basic_awareness						
gender		-.1973591	.35691	-0.55	0.580	-.8968898 .5021715
age		-.0312083	.0182133	-1.71	0.087	-.0669057 .0044891
householdsize		.2827899	.1018909	2.78	0.006	.0830875 .4824924
education		-.1162624	.0817875	-1.42	0.155	-.2765629 .0440381
farmingexperience		.0293249	.0234162	1.25	0.210	-.0165701 .0752199
soilerosion		1.841858	.9637564	1.91	0.056	-.0470703 3.730785
droughtandfloods		-1.067506	.3951841	-2.70	0.007	-1.842053 -.2929598
informationsource		1.038622	.4202874	2.47	0.013	.2148739 1.86237
membership		1.129437	.4055111	2.79	0.005	.3346498 1.924224
benefits		1.467615	.388134	3.78	0.000	.7068867 2.228344
offfarmactivities		.4767801	.426677	1.12	0.264	-.3594915 1.313052
farmsize		-.028687	.1578379	-0.18	0.856	-.3380436 .2806697
pestsanddiseases		-.2265634	.4225357	-0.54	0.592	-1.054718 .6015915
riskperception		-.5550918	.3628974	-1.53	0.126	-1.266358 .156174
_cons		1.470569	1.506182	0.98	0.329	-1.481494 4.422632

Appendix I: VIF test results for explanatory variables in the GOP model

Variables	VIF	1/VIF
Age	2.26	0.443
Farming experience	2.00	0.501
Gender	1.12	0.895
Farm size	1.15	0.869

Household size	1.04	0.962
Soil erosion	1.37	0.729
Slope	1.36	0.735
Demand	1.17	0.851
Effect of CA	1.07	0.933
Land tenure	1.26	0.793
Training	1.67	0.599
Extension contacts	1.53	0.654
Information	1.54	0.651
Market	1.55	0.646
Input support	1.30	0.768
Infrastructure	1.31	0.762
Education	1.25	0.801
Location	1.57	0.637
Mean VIF	1.40	

Appendix J: Pairwise correlation test results for categorical variables in the GOP model

	Ward	Gender	Slope	Soil erosion	Demand	Effect of CA	Input support
Ward	1						
Gender	0.155	1					
Slope	0.241	0.041	1				
Soil erosion	0.132	-0.092	0.433	1			
Demand	0.095	0.122	0.116	0.176	1		
Effect of CA	0.062	0.023	-0.024	-0.045	0.127	1	
Input support	0.147	0.040	0.059	0.093	0.120	0.075	1
Market	0.228	0.080	0.115	0.147	0.236	0.180	0.039
Training	0.197	-0.014	0.072	0.128	0.077	0.076	0.282
Information source	0.224	0.036	0.005	0.135	0.135	0.107	0.285
Land tenure	-0.150	0.044	0.000	-0.098	-0.000	0.069	0.230

Appendix K: Pairwise correlation test results continuation

	Market	Training	Information source	Land tenure
Market	1			
Training	0.415	1		
Information source	0.315	0.409	1	
Land tenure	0.100	-0.038	0.031	1

Appendix L: Heteroscedasticity test results

```
. hetttest
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
```

```
Ho: Constant variance
```

```
Variables: fitted values of total
```

```
chi2(1) = 1.47
```

```
Prob > chi2 = 0.2248
```

Appendix M: Generalised Poisson regression results estimates

```
. poisson total ward gender age slope soilerosion demand effectofca farmsize inputsupport market infrastructure training extension informationsource education householdsize landtenure far
> mingexperience
```

Fitting Poisson model:

```
Iteration 0: log likelihood = -507.76817
Iteration 1: log likelihood = -507.76602
Iteration 2: log likelihood = -507.76602
```

Fitting constant-only model:

```
Iteration 0: log likelihood = -576.99459
Iteration 1: log likelihood = -575.95612
Iteration 2: log likelihood = -575.9528
Iteration 3: log likelihood = -575.9528
```

Fitting full model:

```
Iteration 0: log likelihood = -507.76602
Iteration 1: log likelihood = -490.68354
Iteration 2: log likelihood = -489.04725
Iteration 3: log likelihood = -489.02705
Iteration 4: log likelihood = -489.02705
```

```
Generalized Poisson regression      Number of obs =      320
                                   LR chi2(18) =      173.85
Dispersion = -.3262174             Prob > chi2 =      0.0000
Log likelihood = -489.02705        Pseudo R2 =      0.1509
```

	total	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
	ward	-.0184702	.0724654	-0.25	0.799	-.1604999 .1235594
	gender	-.0909392	.0578078	-1.57	0.116	-.2042403 .022362
	age	-.0098934	.0033939	-2.92	0.004	-.0165452 -.0032416
	slope	.0523539	.0645053	0.81	0.417	-.0740741 .1787819
	soilerosion	.0285924	.0825046	0.35	0.729	-.1331137 .1902985
	demand	.1594269	.0588991	2.71	0.007	.0439869 .274867
	effectofca	.4012315	.0747519	5.37	0.000	.2547204 .5477426
	farmsize	.0054452	.0214432	0.25	0.800	-.0365826 .0474731
	inputsupport	.0090158	.0738001	0.12	0.903	-.1356298 .1536614
	market	.2180709	.0768903	2.84	0.005	.0673687 .3687731
	infrastructure	.0007582	.0069811	0.11	0.914	-.0129246 .0144409
	training	.2268431	.0663277	3.42	0.001	.0968431 .3568431
	extension	.0202568	.0054823	3.69	0.000	.0095117 .0310018
	informationsource	.1838207	.0707942	2.60	0.009	.0450665 .3225749
	education	-.0324824	.0102416	-3.17	0.002	-.0525556 -.0124093
	householdsize	.0303608	.0174234	1.74	0.081	-.0037884 .0645101
	landtenure	-.0521437	.0615443	-0.85	0.397	-.1727683 .0684809
	farmingexperience	.0073999	.0033391	2.22	0.027	.0008554 .0139444
	_cons	.6869922	.2323796	2.96	0.003	.2315366 1.142448
	/atanhdelta	-.3385894	.0609149			-.4579804 -.2191983
	delta	-.3262174	.0544325			-.4284367 -.2157538

```
Likelihood-ratio test of delta=0: chi2(1) = 37.48 Prob>=chi2 = 0.0000
```

Appendix N: Heteroscedasticity test results

```
. hettest
```

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of combinations

```
chi2(1) = 0.27
```

```
Prob > chi2 = 0.6054
```





Appendix O: VIF test results for explanatory variables in MESR model

Variable	VIF	1/VIF
Age	2.06	0.484
Gender	1.12	0.893
Eductaion	1.37	0.728
Household size	1.04	0.964
Farming experience	2.00	0.501
Farm size	1.11	0.899
Off-farm activities	1.21	0.829
Drought and floods	1.12	0.893
Credit	1.16	0.861
Membership	1.10	0.910
Location	1.23	0.816
Slope	1.39	0.717
Soil erosion	1.33	0.752
Effect of ca	1.06	0.945
Mean VIF	1.31	

Appendix P: Pairwise correlation test results for categorical variables in the MESR model

	Ward	Gender	Drought and floods	Member-ship	Off-farm activities	Credit	Slope	Erosion	Effects of CA
Ward	1								
Gender	0.142	1							
Drought and floods	0.041	0.090	1						
Membership	0.166	-0.024	-0.104	1					
Off-farm activities	0.031	-0.017	-0.114	0.102	1				
Credit	0.099	-0.149	-0.070	0.124	0.141	1			
Slope	0.271	0.058	0.015	0.035	0.030	-0.098	1		
Erosion	0.142	-0.087	-0.076	0.097	0.070	-0.002	0.437	1	
Effect of ca	0.078	0.011	-0.046	0.034	-0.083	-0.106	-0.062	-0.084	1

Appendix Q: Nacosti Permit

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Appendix R: Publication abstract

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Research article

Effects of adoption of ecological farming practices on farm income in rural households: Evidence from Central Kenya

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ABSTRACT

Farmers have adopted ecological farming to overcome the adverse effects of climate change and conventional agriculture. However, the performance of ecological approaches, especially the economic outcomes of ecological practices adopted as a package, has yet to be widely documented in Kenya. This paper aims to fill this gap and generate pertinent information on the implications of adopting different ecological practices bundles on farm income. The study considers five ecological practices: crop diversification, composting, mulching, minimum tillage, and integrated pest management (IPM). This study employed a multinomial endogenous switching regression (MESR) model to capture the effect of adopting different combinations of ecological practices on farm income. The results reveal that 15.3 % of the surveyed households adopted a bundle combining composting, crop diversification, and IPM. Households that adopted a comprehensive package (comprising all five ecological practices) had the largest positive impact on farm income, increasing it by 9.2 %. This package replaces chemical inputs with locally available resources, restores degraded soils and diversifies production risks to increase food production and farm income. Farming experience, off-farm activities, farm size, perceptions of the effects of conventional agriculture, and drought and floods significantly influenced the adoption of the comprehensive package. This study's findings imply that policymakers and related stakeholders should provide timely weather-related information, enforce sustainable land use laws, and establish targeted extension services and information campaigns to heighten the adoption of all five ecological practices and enhance household welfare by increasing farm income.