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# Moderating effect of biodiversity conservation on the relationship between agroforestry practices and productivity of smallholder farmers in Mt. Elgon, Kenya.

Loyatum, Antonious
*Strathmore Business School*
*Strathmore University*

# MODERATING EFFECT OF BIODIVERSITY CONSERVATION ON THE RELATIONSHIP BETWEEN AGROFORESTRY PRACTICES AND PRODUCTIVITY OF SMALLHOLDER FARMERS IN MT. ELGON, KENYA

**ANTONIOUS LOYATUM**

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## DECLARATION

**DECLARATION**

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Antonious Cherop Loyatum

**Approval**

The thesis of Antonious Cherop Loyatum was reviewed and approved by the following:

Prof. Simon Wagura Ndiritu

Director and Associate Professor

Strathmore University Business School/ Strathmore Agri-Food Innovation Center

## ABSTRACT

Agroforestry, practiced on over 1 billion hectares globally, represents 28% of agricultural land area and offers potential solutions to smallholder farmers' challenges, including soil degradation, low productivity and climate variability. Despite its extensive adoption, there is limited statistical evidence quantifying the impact of agroforestry practices and biodiversity conservation on farm productivity. This study sought to address this gap by examining the relationship between agroforestry practices, biodiversity conservation and productivity in Mt. Elgon Sub-County, Kenya. Specifically, the study aimed to analyze the effects of agroforestry types, implementation scale and utilization of extension services on productivity. Additionally, it evaluated how biodiversity conservation moderated the relationship between agroforestry practices and productivity. The research was underpinned by three theories: the Theory of Agroforestry Systems, which explains the ecological and economic synergies of integrated farming systems; the Resource Dependence Theory, emphasizing farmers' reliance on external and natural resources; and the Theory of Planned Behavior, which accounts for farmers' attitudes and intentions in adopting agroforestry. A pragmatist research philosophy guided the study, focusing on actionable insights for addressing real-world challenges. A concurrent triangulation research design was employed, combining qualitative and quantitative methods to ensure robust findings. The study targeted smallholder farmers practicing agroforestry in Mt. Elgon Sub-County, Kenya, estimated at 16,283 households. A sample size of 384 farmers was determined using Fisher's formula, with participants selected through stratified random sampling across geographical zones and purposive sampling for key informants to ensure comprehensive representation of agroforestry practices. Data was collected through questionnaires and key informant interviews from a stratified random sample of smallholder farmers in Mt. Elgon Sub-County. Quantitative data was analyzed using SPSS Version 27, employing descriptive statistics and multiple linear regression, while qualitative data underwent content analysis. The findings revealed that the type of agroforestry system significantly influenced farm productivity, with more diverse systems showing greater benefits. Expanding the scale of agroforestry implementation had the strongest positive impact on productivity, demonstrating the advantages of wider adoption. Access to extension services contributed moderately to productivity gains, particularly when combined with other factors. Most notably, biodiversity conservation played a crucial moderating role, enhancing the positive relationship between agroforestry practices and productivity, especially when implemented at larger scales and supported by extension services. The research recommended that farmers should be supported with targeted interventions to enhance the scale and effectiveness of agroforestry implementation. This study contributes to policy frameworks and extension programs, supporting sustainable agricultural practices and biodiversity management in the region.

Keywords: Agroforestry Practices, Biodiversity Conservation, Smallholder Productivity, Sustainable Agriculture, Mt. Elgon Kenya.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ASALs | Arid and Semi-Arid Areas |
| FAO | Food and Agriculture Organization |
| IRB | Institutional Review Board |
| KACP | Kenya Agricultural Carbon Project |
| NACOSTI | National Commission for Science, Technology and Innovation |
| RDT | Resource Dependence Theory |
| SBS | Strathmore Business School |
| SDGs | Sustainable Development Goals |
| TPB | Theory of Planned Behaviour |

## DEFINITION OF TERMS

**Agroforestry Practices**: Agroforestry practices involve integration of trees and shrubs into agricultural landscapes to enhance productivity, sustainability and environmental benefits. These practices include alley cropping, silvopasture, riparian buffer strips and windbreaks, aiming to create diverse, multi-functional landscapes that support both agricultural production and ecosystem services (Ahmad et al., 2023).

**Biodiversity Conservation**: Biodiversity conservation refers to the management and protection of ecosystems, species and genetic diversity to prevent the loss of biological resources. This includes strategies and practices designed to maintain and restore the variety of life forms, their habitats and their ecological functions (Swallow et al., 2020).

**Extension Services**: Extension services are support systems that provide education, resources and assistance to farmers to improve their agricultural practices. These services aim to disseminate knowledge, promote innovative practices and increase the general productivity and sustainability of farming systems, including agroforestry (Kinyili et al., 2020).

**Productivity**: Productivity in the context of agroforestry refers to the output or yield of agricultural and forestry products per unit of land. It encompasses both the quantity and quality of produce generated from agroforestry systems, focusing on sustainable and efficient production and improved household income (Castle et al., 2021).

**Scale of Agroforestry Implementation**: The scale of agroforestry implementation refers to the extent and intensity at which agroforestry practices are adopted and practiced, ranging from small-scale individual farm plots to large-scale, landscape-level interventions. The scale of implementation can significantly influence the effectiveness and sustainability of agroforestry practices (Telwala, 2023).

**Smallholder Farmers**: Smallholder farmers are individuals or families that farm small plots of land, typically less than 5 acres and rely primarily on family labour for production. These farmers typically practice subsistence agriculture but may also produce crops for local markets. Their farming activities are often characterized by low input and output levels and significant reliance on agroecological principles (Duffy et al., 2021).

**Type of Agroforestry**: Types of agroforestry include silvopastoral (livestock and trees), agrosilvicultural (crops and trees) and agrosilvopastoral (crops, livestock and trees) systems. Each type integrates different components of agriculture and forestry to optimize land use and resource efficiency (Korir et al., 2022).

## DEDICATION

I dedicate this research project to my family for their encouragement and unwavering support throughout my journey.

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I extend my heartfelt gratitude to God for His constant guidance and blessings throughout this journey. I am deeply thankful to my mother and sister for their unwavering support, encouragement and sacrifices that have shaped my path. Special appreciation goes to my husband and son, whose companionship and positivity have been a source of strength and motivation. I am indebted to my esteemed colleagues at Strathmore Business School for their valuable insights and collaborative spirit. Additionally, I would like to express my sincere thanks to my university supervisor for their guidance and expertise, which have been instrumental in shaping this work. Lastly, I appreciate my classmates for their solidarity and shared learning experiences, which have enriched my academic journey.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the Study

Smallholder agriculture is critical to global food security, yet it faces persistent productivity challenges. Worldwide, smallholders manage approximately 500 million farms, producing over 50% of the global food supply, but many operate on degraded land with limited access to resources (Kassa, 2022). Globally, agricultural productivity among smallholders has stagnated or declined in many regions due to unsustainable practices, soil degradation and climate change. Studies estimate that yield gaps, which are the difference between actual and potential productivity, average between 20% and 60% for key crops like maize and rice (Mukhlis et al., 2022). This crisis disproportionately affects vulnerable populations, with an estimated 80% of people living in extreme poverty residing in rural areas dependent on agriculture (Homann-Kee et al., 2023; Kassa, 2022).

### 1.1.1 Agroforestry Practices

Agroforestry practices, which involve the deliberate integration of trees with crops and/or livestock on the same land unit, are globally recognized for their ecological and economic benefits. Around the world, agroforestry has gained attention as a sustainable land-use system capable of improving food production, enhancing biodiversity and addressing the adverse effects of climate change. Research by Alifa et al. (2024) highlights how integrating trees with crops and livestock enhances soil fertility, water retention and microclimate regulation, leading to yield increases of up to 30% in some regions. In Latin America, agroforestry has been successfully deployed to reduce deforestation and sequester carbon while maintaining food output (Willmott et al., 2023). In Southeast Asia, particularly in Indonesia and the Philippines, agroforestry has enabled farmers to adopt climate-smart practices that build resilience to extreme weather and sustain livelihoods in ecologically fragile zones (Alifa et al., 2024). Despite these successes, the global uptake of agroforestry remains uneven due to differences in policy environments, land tenure systems and technical knowledge.

Regionally, in Sub-Saharan Africa, where over 70% of the population depends on smallholder farming for food and income (Homann-Kee et al., 2023), agroforestry plays a vital role in enhancing productivity and ecological resilience. Countries like Zimbabwe and Burkina Faso have recorded higher household incomes, improved food security and healthier ecosystems among smallholders who integrate trees into their farming systems (Kinyili et al., 2020). In arid and semi-arid lands (ASALs) of the region, agroforestry is increasingly viewed as a tool for reversing land degradation and combating desertification (Kassa, 2022). However, the pace of adoption is still constrained by challenges such as inadequate extension services, lack of financing and cultural preferences for conventional cropping systems.

In Kenya, where smallholder farmers constitute approximately 75% of the agricultural workforce, agroforestry has been promoted as a key strategy for sustainable agriculture and rural development. The government, through institutions such as the Kenya Forestry Research Institute (KEFRI), has supported the dissemination of agroforestry technologies including tree planting on farms, alley cropping and boundary planting. These efforts have targeted regions experiencing soil depletion, erratic rainfall and declining farm productivity. Nevertheless, the adoption of agroforestry in Kenya is often hindered by insecure land tenure, fragmented extension systems and limited farmer awareness about long-term benefits (Korir et al., 2022).

Locally, Mt. Elgon in Bungoma County provides a compelling context for agroforestry implementation due to its highland ecosystem, fertile volcanic soils and historical reliance on agriculture. The region is ecologically rich but vulnerable to soil erosion, deforestation and unsustainable land-use practices. Several agroforestry interventions have been piloted in Mt. Elgon, focusing on the use of nitrogen-fixing species such as *Sesbania*, *Calliandra* and *Grevillea robusta* to improve soil health and provide fodder and fuelwood. Despite observable benefits in certain areas, the adoption of agroforestry remains uneven. Factors such as limited technical support, lack of coordinated community participation and insufficient integration of indigenous knowledge systems have constrained its widespread application. There is a critical need to investigate how context-specific agroforestry practices can be scaled up to improve productivity and support biodiversity conservation in Mt. Elgon.

Despite the growing body of literature on agroforestry, several critical research gaps persist, particularly concerning smallholder farmers in specific regions like Mount Elgon, Kenya. Globally, agroforestry has been recognized as a sustainable land management strategy, yet much of the research has focused on its environmental benefits, such as carbon sequestration and soil fertility improvement, with less emphasis on its direct impact on smallholder productivity (FAO, 2020; Homann-Kee et al., 2023). While studies from regions such as Southeast Asia and Latin America highlight the role of agroforestry in improving rural livelihoods (Alifa et al., 2024; Willmott et al., 2023), localized studies in African contexts, particularly in Kenya, remain limited. The lack of region-specific data creates a significant gap in understanding how diverse agroforestry systems interact with local ecological, social and economic factors to affect productivity.

### 1.1.2 Productivity of Smallholder Farmers

Globally, smallholder farmers, those cultivating less than two hectares, produce over one-third of the world's food supply, yet their productivity remains significantly constrained (FAO, 2021). Productivity, defined as output per unit of land or input, varies widely due to factors such as soil degradation, limited access to inputs, climate variability and inadequate extension services. In regions like South Asia and Latin America, innovations including the use of nitrogen-fixing trees such as *Sesbania* and *Calliandra* have improved soil fertility, thereby boosting crop yields by over 25% (Mukhlis et al., 2022). Despite these advances, yield gaps persist due to fragmented landholdings, poor infrastructure and weak policy support.

In Africa, where approximately 33 million smallholder farms contribute up to 80% of the continent's food production, low productivity remains a pressing concern. These farmers typically face challenges such as nutrient-depleted soils, unpredictable rainfall, pests and limited market access. Agroecological approaches, including agroforestry, have shown promise in improving productivity while conserving the environment. For instance, in countries such as Malawi and Ghana, the integration of multipurpose tree species into farming systems has enhanced crop output and soil quality. However, adoption remains patchy due to the absence of scalable financing models, inadequate research-extension linkages and socio-cultural barriers (Homann-Kee et al., 2023).

In Kenya, smallholder farmers form the backbone of the agricultural sector, contributing over 75% of total agricultural output. Yet, their productivity remains below both regional and global benchmarks (Korir et al., 2022). Key challenges include low input use, poor soil health, fragmented land tenure systems and limited adoption of sustainable practices. While government and non-governmental efforts have promoted agroforestry and conservation agriculture, the impact has been uneven, partly due to limited outreach and inconsistent policy implementation. As a result, staple crops such as maize, beans and potatoes still yield below their potential, affecting food security and income generation at the household level.

Locally, in Mt. Elgon, Bungoma County, smallholder farmers dominate the agricultural landscape, relying heavily on crops like maize, beans and potatoes. The region is characterized by fertile volcanic soils and high rainfall, which offer significant potential for enhanced agricultural productivity. However, local farmers grapple with a range of challenges including deforestation, soil erosion, limited access to quality seeds and fertilizers and inadequate agricultural extension services. Although agroforestry interventions have been introduced to improve soil fertility and reduce land degradation, their uptake remains limited. Addressing these constraints through context-specific productivity-enhancing strategies such as the incorporation of nitrogen-fixing trees, improved extension support and local seed systems could significantly improve yields and strengthen household food security in Mt. Elgon.

Empirical studies underscore the potential of agroforestry to enhance smallholder productivity. For example, Korir et al. (2022) report that the incorporation of nitrogen-fixing trees in Kenyan smallholder farms increased maize yields by 20-50%, while Kinyili et al. (2020) highlight the role of agroforestry in improving soil fertility and water retention, particularly in arid and semi-arid regions of sub-Saharan Africa. Similarly, a study by Mukhlis et al. (2022) in Zimbabwe showed that smallholder farmers practicing agroforestry experienced a 30% rise in overall farm productivity compared to those relying on monoculture systems. However, the variability in these results points to the importance of local ecological and socio-economic conditions, necessitating more targeted research to understand the full potential of agroforestry in specific regions.

### 1.1.3 Biodiversity Conservation

Globally, biodiversity conservation, the protection, sustainable management and restoration of biological diversity, is critical for maintaining ecosystem resilience, food security and climate stability. The loss of biodiversity has accelerated over recent decades due to habitat destruction, pollution, overexploitation and climate change. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) warns that over one million species face extinction, undermining ecosystem services like pollination, water regulation and disease control. Agroforestry systems, which combine tree cover with agriculture, are increasingly recognized as a nature-based solution that enhances biodiversity while sustaining agricultural livelihoods.

Studies in Latin America and Southeast Asia have shown that such systems support greater species richness and habitat connectivity compared to conventional agriculture (Willmott et al., 2023).

In Africa, where biodiversity hotspots such as the Congo Basin and the Eastern Afromontane region are under growing pressure, biodiversity conservation is both a challenge and a necessity. Land-use changes driven by agricultural expansion, charcoal production and logging have contributed to forest fragmentation and species decline. However, evidence from countries like Uganda, Ethiopia and Cameroon shows that agroforestry can mitigate biodiversity loss by creating ecological corridors, preserving soil organisms and enhancing carbon storage (Kassa, 2022). These landscapes support both endemic and migratory species, which are vital for ecological balance and local economies. Yet, the success of such interventions depends on supportive policy environments, community participation and long-term incentives.

In Kenya, biodiversity conservation is enshrined in national policy frameworks such as the National Biodiversity Strategy and Action Plan and Vision 2030. Kenya hosts diverse ecosystems, from coastal wetlands to montane forests, which are under pressure from land conversion, overgrazing and unsustainable harvesting. Agroforestry has gained prominence as a strategy for reconciling conservation and development goals. Initiatives in areas such as Kakamega Forest and the Mau Complex have demonstrated how integrating trees into farming systems can protect critical habitats and enhance resilience. Nonetheless, gaps in enforcement, weak local institutions and competing land uses continue to hamper biodiversity conservation efforts at scale.

Locally, Mt. Elgon represents a vital ecological zone with high endemism and rich forest biodiversity. The region supports numerous plant and animal species, some of which are threatened due to deforestation, land degradation and agricultural encroachment. Agroforestry offers a promising pathway to conserve biodiversity in Mt. Elgon by reducing dependence on native forests for fuelwood and timber, while promoting habitat diversity on farmland. Studies show that agroforestry systems in this area can act as biological corridors, supporting species movement and enhancing ecosystem services like pollination, soil stabilization and pest control (Kinyili et al., 2020). As deforestation intensifies in Mt. Elgon, integrated approaches that combine biodiversity conservation with smallholder livelihoods are increasingly essential. This study, therefore, aimed to investigate how agroforestry can serve as a dual-purpose strategy, enhancing agricultural productivity while conserving the ecological integrity of one of Kenya's most critical biodiversity landscapes.

### 1.1.4 Study Context and Justification

Mt. Elgon was selected for this study due to its ecological significance and the unique challenges faced by smallholder farmers in the region. As a globally recognized biodiversity hotspot, Mt. Elgon hosts diverse flora and fauna, including several endemic and threatened species (Willmott et al., 2023). This makes it an ideal location for examining how biodiversity conservation moderates the relationship between agroforestry practices and farm productivity. Furthermore, the region has witnessed significant environmental challenges, such as deforestation, soil erosion and habitat degradation, which impact both agricultural productivity and ecosystem health (Kinyili et al., 2020). The study aims to provide actionable insights for promoting sustainable practices that balance productivity with conservation. Additionally, Mt. Elgon is predominantly home to smallholder farmers who rely on agriculture for their livelihoods. These farmers face challenges such as declining soil fertility, unpredictable rainfall and limited access to extension services (Willmott et al., 2023). Agroforestry is widely practiced in the region as a means of addressing these challenges, providing a relevant context for analyzing its effectiveness. The selection of Mt. Elgon ensures that the study's findings was directly applicable to a population that stands to benefit significantly from evidence-based policy and practice recommendations, thereby enhancing agricultural sustainability and biodiversity conservation in the region.

## 1.2 Statement of the Problem

Despite the recognized potential of agroforestry practices and biodiversity conservation to improve the productivity of smallholder farmers, a significant gap exists in empirical data quantifying their impact, especially in specific contexts. Globally, agroforestry is practiced on over 1 billion hectares of land, constituting approximately 28% of the agricultural land area (FAO, 2020). However, there is insufficient statistical evidence to comprehensively link agroforestry to key indicators such as agricultural productivity, carbon sequestration, biodiversity conservation and poverty alleviation. This lack of precise data hinders the ability of policymakers, researchers and practitioners to prioritize agroforestry as a transformative solution to global challenges like food insecurity, climate change and rural poverty (Homann-Kee et al., 2023; Willmott et al., 2023).

In Mount Elgon, Kenya, a region known for its ecological diversity and agricultural heritage, contextual gaps exist as localized research on agroforestry remains scarce. While studies in other parts of Kenya have demonstrated agroforestry's benefits, such as increased crop yields and improved livelihoods (Korir et al., 2022), the unique challenges and opportunities within Mount Elgon have not been adequately explored. The region faces distinct issues like deforestation, soil erosion and biodiversity loss, which complicate sustainable land management efforts. Furthermore, the interplay between agroforestry practices, biodiversity conservation and smallholder productivity in Mount Elgon has not been sufficiently examined, leaving critical knowledge gaps that impede the development of tailored interventions.

Furthermore, limited research exists on the role of biodiversity conservation in moderating the relationship between agroforestry practices and productivity. Agroforestry systems are inherently multifunctional, yet most studies fail to comprehensively examine how the integration of biodiversity conservation within these systems influences agricultural productivity and ecological sustainability (Kassa, 2022). This knowledge gap is particularly critical for regions like Mount Elgon, where biodiversity plays a pivotal role in ecosystem services, such as pollination and pest control, that directly impact agricultural outcomes.

Additionally, existing research often focuses on either qualitative or quantitative methodologies, rarely integrating the two to provide a holistic understanding of agroforestry systems. This methodological gap limits the depth and breadth of insights that can inform policies and interventions tailored to the unique needs of smallholder farmers in Mount Elgon. Addressing these research gaps is essential to unlocking the full potential of agroforestry as a sustainable development strategy and enhancing the livelihoods of smallholder farmers while conserving the region's biodiversity. This study aims to fill these gaps by analyzing agroforestry practices, biodiversity conservation and productivity in Mount Elgon Sub-County, Kenya, thereby providing evidence-based insights to inform policy and practice.

## 1.3 Research Objectives

### 1.3.1 General Objective

The main objective of the study is to determine the relationship between agroforestry practices, biodiversity conservation and productivity in Mt. Elgon Sub-County, Kenya.

### 1.3.2 Specific Objectives

The specific objectives were as follows;

i. To analyze the effect of type of agroforestry on productivity in Mt. Elgon Sub-County, Kenya.
ii. To investigate the effect of scale of agroforestry implementation on productivity in Mt. Elgon Sub-County, Kenya.
iii. To examine the effect of utilization of extension services on productivity in Mt. Elgon Sub-County, Kenya.
iv. To evaluate the moderating effect of biodiversity conservation on the relationship between agroforestry practices and productivity in Mt. Elgon Sub-County, Kenya.

## 1.4 Research Questions

The study was guided by the following research questions:

i. What is the effect of type of agroforestry on productivity in Mt. Elgon Sub-County, Kenya?
ii. How does the scale of agroforestry implementation affect productivity in Mt. Elgon Sub-County, Kenya?
iii. What is the effect of utilization of extension services on productivity in Mt. Elgon Sub-County, Kenya?
iv. What is the moderating effect of biodiversity conservation on the relationship between agroforestry practices and productivity in Mt. Elgon Sub-County, Kenya?

## 1.5 Scope of the Study

The study focused on Mount Elgon Sub-County in north-western Kenya, an area spanning approximately 35,000 hectares and home to a population of about 135,000 people (Nyberg et al., 2020). The region is characterized by a savanna climate, fertile soils and a predominantly smallholder farming system. These smallholders engage in subsistence farming, cash crop cultivation and dairy production, forming the backbone of the local agricultural economy. However, challenges such as deforestation, soil degradation and unsustainable farming practices have significantly affected agricultural productivity, reduced household incomes and contributed to environmental degradation. The study targeted smallholder farmers practicing agroforestry in Mt. Elgon Sub-County, Kenya, estimated at 16,283 households. A sample size of 384 farmers was determined using Fisher's formula. It analyzed three key dimensions of agroforestry practices: the types of agroforestry systems employed, the scale of implementation and the role of extension services in promoting these practices. Additionally, it evaluated the moderating effect of biodiversity conservation on the relationship between agroforestry practices and productivity.

A mixed-methods approach was employed, integrating both qualitative and quantitative research methodologies. This involved the collection of primary data through surveys, interviews and focus group discussions, as well as the analysis of secondary data from relevant reports and studies. The study aimed to provide a comprehensive understanding of agroforestry practices in the region, contributing to evidence-based policy formulation and sustainable development initiatives in Mount Elgon Sub-County. The study was conducted between September 2024 and April 2025.

### 1.6 Significance of the Study

The study was beneficial to the following:

#### 1.6.1 Policy Makers and Regulators

This research is of great significance for regulators and policymakers, especially in the context of Mount Elgon, Kenya, where smallholder agroforestry plays a major role. Policymakers and regulators obtained vital insights into the potential of smallholder agroforestry techniques in fostering sustainable development and livelihood improvement by exploring the environmental benefits of this type of farming. Comprehending the distinct advantages of agroforestry, such as better conservation of soil, preservation of biodiversity, heightened crop productivity and augmented household income, empowers policymakers to customize policies and regulations that facilitate and encourage the implementation of agroforestry among smallholders in Mount Elgon. Furthermore, policymakers coordinated their policies with more general objectives for environmental conservation and development by acknowledging the socioeconomic and environmental benefits of agroforestry.

#### 1.6.2 Academicians and Researchers

The study provided a foundational framework for future academicians and researchers interested in investigating the benefits of smallholder agroforestry in the context of Mount Elgon, Kenya. Comprehensive insights into the environmental and socioeconomic benefits of agroforestry practices in this region served as a valuable foundation for further research endeavours. Future academicians and researchers will leverage the findings of this study to explore additional dimensions of smallholder agroforestry, such as its long-term impacts, scalability and specific mechanisms underlying its effectiveness. Moreover, the methodology and analytical approach employed in this study served as a guide for designing similar research studies in the future, thereby contributing to the advancement of knowledge in the field of agroforestry and sustainable land management.

### 1.6.3 Community

Local communities in the Mount Elgon region of Kenya also benefited from this study. Uncovering the environmental and socioeconomic benefits of smallholder agroforestry, the findings informed community members about the potential advantages of adopting such practices. Understanding the benefits of agroforestry on soil conservation, biodiversity conservation, crop yields and household income empowered communities to make informed decisions regarding land management and agricultural practices. Additionally, the study highlighted opportunities for community engagement and participation in agroforestry initiatives, fostering a sense of accountability and ownership among locals.



## 1.7 Chapter Summary

The first chapter offers a synopsis of the research, outlining the key elements to be explored. It begins by providing a background of the study, offering insights into the concept and context of smallholder agroforestry, as well as identifying research gaps. Following this, the statement of the problem highlights the specific gap addressed by the study and its incremental contribution to existing knowledge. Subsequently, the research objectives are presented, comprising both the general objective, which mirrors the study’s title and specific objectives aimed at guiding the research process. These objectives are complemented by research questions, formulated to further elucidate the study’s focus and guide data collection and analysis. The scope of the study is then discussed, delineating the specific parameters and boundaries within which the research operated, including the geographical and temporal dimensions. Finally, the significance of the study is outlined, detailing the various stakeholders and beneficiaries who stand to gain from the research findings, ranging from policymakers and regulators to local communities and academia.

Chapter two offers a comprehensive review of the body of research on agroforestry practices, biodiversity conservation and productivity of smallholder farmers. It begins with a theoretical review, exploring the foundational theories that inform the study. This is followed by an empirical literature review, which examines existing research findings related to the key variables of the study. The chapter then identifies gaps in the current literature and concludes with a summary of the literature reviewed, a conceptual framework illustrating the relationships between the study variables and the operationalization of these variables. Chapter three outlines the methodology to be employed in the study, detailing the philosophical underpinnings, research design, population selection, sampling methods, procedures for data collection, reliability and validity of instruments, data analysis techniques, ethical considerations and a summary of the chapter.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This chapter offers a comprehensive review of the body of research on agroforestry practices, biodiversity conservation and productivity of smallholder farmers. It begins with a theoretical review, exploring the foundational theories that inform the study. This is followed by an empirical literature review, which examines existing research findings related to the key variables of the study. The chapter then identifies gaps in the current literature and concludes with a summary of the literature reviewed, a conceptual framework illustrating the relationships between the study variables and the operationalization of these variables.

## 2.2 Theoretical Review

This study drew upon three foundational theories. Firstly, the theory of agroforestry systems elucidates the integration of trees with crops and/or livestock, highlighting how this amalgamation can boost agricultural productivity and fortify ecosystem resilience. Secondly, resource dependence theory was employed to analyze the relationships between stakeholders involved in agroforestry initiatives, emphasizing how the control and access to resources such as knowledge, funding and support affect the implementation and sustainability of agroforestry practices. The theory of planned behaviour delved into the determinants of farmers' adoption of agroforestry practices, emphasizing the impact of perceived behavioural control, subjective norms and attitudes on their decision-making processes. These theoretical foundations collectively provide an in-depth understanding of the multifaceted benefits, adoption dynamics and resource management implications of agroforestry practices.

### 2.2.1 Theory of Agroforestry Systems

The Theory of Agroforestry Systems has been advanced by proponents such as Nair (1993) and Jose et al. (2009), who emphasize the strategic integration of trees within agricultural landscapes to enhance overall productivity and ecological resilience. This theory posits that by combining trees with crops and/or livestock, agroforestry systems can diversify agricultural production, improve soil fertility, mitigate environmental degradation and contribute to sustainable land use practices (Jose et al., 2009). Scholars have further developed this theory to incorporate a variety of agroforestry techniques such as silvopasture, alley cropping and home gardens, each tailored to specific ecological and socio-economic contexts (Nair, 1993).

The theory of agroforestry systems explores several key arguments and concepts essential to its application. Central to this theory is the notion that trees in agroecosystems serve multiple functions beyond mere timber production, including providing shade, improving microclimatic conditions and contributing to biodiversity conservation (Jose et al., 2009). Moreover, agroforestry systems are viewed as sustainable alternatives to conventional agriculture by promoting resource-use efficiency, reducing greenhouse gas emissions and enhancing socio-economic resilience among smallholder farmers (Nair, 1993).

In the context of this study on agroforestry practices, the theory aligns closely with the identified objectives and variables. The theory's emphasis on different types of agroforestry systems (such as silvopasture and alley cropping), scales of implementation and the integration of extension services resonates with the study's focus on understanding how these factors influence productivity and biodiversity conservation in Mount Elgon, Kenya.

In the Kenyan context, particularly in Mount Elgon, smallholder farmers often operate on fragmented and degraded lands, making the adoption of agroforestry critical for enhancing productivity. The theory's focus on tailored systems resonates with the region's specific ecological and socio-economic challenges, such as deforestation and declining soil fertility. By incorporating extension services, the theory emphasizes the importance of technical support to optimize agroforestry outcomes, which is vital for smallholders lacking resources and expertise. Furthermore, the theory's advocacy for biodiversity conservation aligns with Mount Elgon's urgent need to address habitat loss and ecosystem degradation, reinforcing agroforestry as a sustainable solution for balancing productivity and environmental stewardship. While the theory of agroforestry systems effectively addresses ecological integration and productivity, it does not fully account for the institutional and behavioural drivers influencing farmer decisions. Resource dependence theory and the theory of planned behaviour complement this gap by offering insights into how access to resources and individual intentions shape agroforestry adoption and outcomes.

### 2.2.2 Resource Dependence Theory

Pfeffer and Salancik (1978) developed the Resource Dependence Theory (RDT), which posits that organizations strategically manage their external dependencies on resources to ensure sustainability and effectiveness. Applied to smallholder agroforestry in Mount Elgon, Kenya, RDT emphasizes how farmers rely on natural resources and external support systems to enhance agricultural practices and livelihoods. In this context, farmers integrate trees with crops and livestock to diversify their resource base, mitigating risks associated with climate variability, enhancing soil fertility and supporting biodiversity conservation efforts (Pfeffer & Salancik, 1978).

RDT argues that farmers engage in agroforestry practices to reduce dependency on external inputs and optimize resource use efficiency (Kalamkar & Acharya, 2024). The theory suggests that farmers strategically choose agroforestry systems based on their resource dependencies, such as soil nutrient levels and water availability (Sheppard et al., 2020). This choice influences indicators such as tree species diversity, crop diversity and the integration of livestock, reflecting how farmers manage their resource dependencies to improve productivity and sustainability. Moreover, RDT highlights the role of external dependencies in shaping farmers' decisions regarding the scale of agroforestry implementation, including landholding size and allocation for agroforestry practices.

The RDT is highly applicable to the study's variables in Mount Elgon. Firstly, regarding type of agroforestry, the theory predicts that farmers will select systems that minimize external dependencies while maximizing resource efficiency, influencing tree-crop-livestock integration. Secondly, for Scale of Implementation, RDT suggests that farmers adjust agroforestry practices based on their landholding size and resource availability, influencing the extent and allocation of agroforestry land. Thirdly, concerning extension services, RDT posits that farmers utilize services to mitigate external dependencies, affecting accessibility, training opportunities and market access. Finally, for Productivity and Biodiversity Conservation, the theory underscores how agroforestry practices optimize resource use and reduce external dependencies, enhancing soil conservation, crop yields, income and biodiversity.

In the context of Mount Elgon, where smallholder farmers face challenges like declining soil fertility and climate variability, RDT explains the adoption of specific agroforestry systems, such as integrating trees with crops and livestock, to diversify resource use and mitigate risks. The theory aligns with study variables by suggesting that the type of agroforestry is determined by farmers' efforts to minimize reliance on external inputs and maximize efficiency, while the scale of implementation reflects resource availability, such as land size. Furthermore, RDT highlights the critical role of extension services in reducing farmers' external dependencies, influencing training, access to markets and agroforestry adoption. Ultimately, the theory underscores how optimizing resource use through agroforestry practices directly enhances productivity and promotes biodiversity conservation, crucial for sustainable livelihoods in Mount Elgon. While resource dependence theory effectively explains how farmers adapt agroforestry practices to manage limited resources, it overlooks individual behavioural intentions and attitudes that drive adoption. The theory of planned behaviour complements this gap by focusing on farmers' motivations, perceived control and social norms influencing agroforestry decisions.

### 2.2.3 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB), proposed by Ajzen (1991), is a widely recognized psychological theory that explains human behaviour through the lens of attitudes, individual beliefs, perceived behavioural control and subjective norms. Applied to the context of smallholder agroforestry in Mount Elgon, Kenya, TPB suggests that farmers' intentions to adopt agroforestry practices are influenced by their attitudes towards agroforestry, subjective norms within their social networks and perceived control over implementing these practices effectively (Ajzen, 1991).

TPB argues that individuals' behavioural intentions are shaped by their attitudes towards the behavior (whether positive or negative), subjective norms (whether they feel social pressure to engage or not) and perceived behavioural control (whether they believe they can carry out the behavior) (Ajzen, 2020). In the case of smallholder farmers in Mount Elgon, TPB posits that favourable attitudes towards agroforestry (e.g., perceived benefits such as increased crop yield and income), supportive subjective norms (e.g., encouragement from family, neighbours and community leaders) and perceived behavioural control (e.g., access to extension services and technical knowledge) are critical determinants of their intention to adopt agroforestry practices.

TPB provides a robust framework for understanding the study's variables in Mount Elgon. Firstly, for Type of Agroforestry, TPB predicts that farmers' attitudes towards specific agroforestry systems (e.g., tree-crop integration, agroforestry with livestock) influence their adoption decisions, shaping indicators such as tree species diversity and crop variety. Secondly, concerning Scale of Implementation, TPB suggests that farmers' intentions are influenced by subjective norms and perceived control over landholding extent and agroforestry plot size, impacting the scale and allocation of agroforestry practices. Thirdly, regarding Extension Services, TPB underscores the role of perceived behavioural control in accessing services, training opportunities and market accessibility, influencing farmers' adoption and implementation of agroforestry. Finally, for productivity and biodiversity conservation, TPB suggests that farmers' intentions to engage in agroforestry are driven by perceived benefits, social pressures and confidence in achieving environmental and economic outcomes.

The type of agroforestry adopted, such as integrating trees with crops or livestock, is influenced by farmers' positive attitudes toward specific systems and the encouragement of social networks. The scale of implementation is determined by perceived behavioural control, including access to resources and landholding size, which affects the extent of agroforestry adoption. TPB also highlights the importance of extension services, as access to training and support enhances farmers' confidence in implementing agroforestry practices effectively. Lastly, the theory links behavioural intentions to outcomes, suggesting that favourable attitudes and strong social support drive higher productivity and biodiversity conservation in agroforestry systems, addressing both ecological and economic challenges in Mount Elgon. While the theory of planned behaviour effectively captures the psychological and social factors influencing agroforestry adoption, it does not fully account for the structural and resource-based constraints faced by farmers. Resource dependence theory complements this by emphasizing the external resource limitations and strategic decisions that shape agroforestry implementation.



## 2.3 Empirical Literature Review

### 2.3.1 Type of Agroforestry and Productivity

Telwala (2023) and Araya et al. (2023) offer compelling evidence from India and Malawi respectively, emphasizing agroforestry as a nature-based solution to enhance resilience in drought-prone and climate-stressed areas. Both studies highlight specific systems such as alley cropping, silvopasture and macadamia-based agroforestry, demonstrating how these enhance soil fertility, biodiversity and income stability. While Telwala provides a diversified system-level analysis incorporating home gardens and livestock integration, Araya et al. take a more crop-specific approach, focused on macadamia. Their emphasis on local knowledge and community involvement is echoed in Yasin et al. (2023), who explore traditional agroforestry in Pakistan.

However, while Araya et al. centre on modern climate-smart practices, Yasin et al. stress the significance of indigenous knowledge in sustaining semi-arid systems. This comparison highlights a key tension in agroforestry discourse: the need to balance modern innovations with traditional ecological practices to ensure long-term sustainability.

Studies such as De Giusti et al. (2019) and Miller et al. (2020) bring in empirical and systematic review approaches respectively, linking agroforestry directly to measurable climate benefits such as greenhouse gas reduction and increased carbon sequestration. De Giusti et al., working with smallholder farmers in Kenya, underscore the synergistic effects of tree-crop-livestock integration on productivity and resilience. However, the systemic review by Miller et al. identifies a lack of region-specific outcomes and long-term assessments, highlighting a broader issue in agroforestry research: generalizability across socio-ecological contexts remains weak due to a reliance on cross-sectional or generalized findings.

Furthering this critique, Lehmann et al. (2020) and Alifa et al. (2024) both emphasize the economic and ecological sustainability of agroforestry, but from different angles. Lehmann focuses on the profitability and scaling challenges of diversified agroforestry systems, revealing structural barriers such as lack of initial investment and policy support. Alifa et al., using sustainability theory, similarly highlight agroforestry's promise in mitigating ecological trade-offs but warn against overreliance on secondary data. Both studies call for empirical, locally grounded research to validate theoretical claims, an appeal particularly relevant to under-studied areas like Mount Elgon.

Willmott et al. (2023) add another dimension by applying ecological theory to analyze the socio-ecological benefits of agroforestry, particularly in terms of ecosystem services and biodiversity. However, their findings, like those of Miller et al., suffer from a lack of contextualization, limiting their practical applicability. Kassa (2022) identifies agroforestry as a climate-smart agribusiness model but does not account for underlying variables influencing its adoption, such as socio-economic or institutional dynamics.

In the Kenyan context, while Korir et al. (2022) and Kinyili et al. (2020) affirm the role of agroforestry in addressing food insecurity and land degradation, these studies are geographically concentrated in central and eastern regions. This creates a significant knowledge gap for areas such as Mount Elgon, which, despite its ecological richness and socio-economic vulnerability, remains underexplored. The region's specific agroecological dynamics including steep terrain, shifting rainfall patterns and high biodiversity, require tailored agroforestry strategies that may differ significantly from those in other Kenyan regions. Moreover, the existing studies have not sufficiently disaggregated the types and scales of agroforestry systems or linked them to measurable productivity outcomes for smallholder farmers in this region.

### 2.3.2 Scale of Implementation and Productivity

Nyberg et al. (2020), within the Kenya Agricultural Carbon Project, provided context-specific evidence from sub-Saharan Africa, showing that larger agroforestry plots and broader land allocation enhanced soil fertility and overall productivity. This study offers a detailed empirical basis for linking scale to both ecological restoration and farm-level gains, particularly in smallholder settings. In contrast, Castle et al. (2022) conducted a systematic review primarily focused on high-income countries, yet arrived at similar conclusions. Their synthesis found that well-allocated agroforestry plots improve ecosystem services, including soil health and food security. The consistency of these findings across distinct socio-economic and ecological contexts suggests that the relationship between scale and productivity is generalizable, although its expression may vary depending on the enabling environment and institutional support.

Both studies operationalized scale using comparable indicators such as landholding size, proportion of land under agroforestry and relative plot size, allowing for meaningful comparison. However, while Nyberg et al. grounded their work in field data, Castle et al. synthesized existing studies, thus potentially inheriting methodological inconsistencies from the underlying literature. This contrast highlights a methodological gap: the need for more cross-contextual, field-based studies that validate systematic review findings under diverse agroecological conditions.

Duffy et al. (2021) extended the conversation by linking scale of implementation to food security outcomes among smallholders in Indonesia. Like Nyberg et al., they confirmed that larger, more diversified agroforestry systems support household resilience and income stability. However, Duffy et al. placed stronger emphasis on diversification within agroforestry systems as a buffer against climate and market risks, suggesting that scale alone is not sufficient, system complexity also matters. This adds a layer of nuance to prior findings, revealing that the quality and diversity of agroforestry interventions must accompany scale for optimal productivity outcomes.

Economic dimensions were explored by Cialdella et al. (2023), who analyzed how the extent of land under agroforestry affects profitability and sustainability. Their study aligns with earlier findings by confirming that larger plots can deliver both ecological and economic returns. However, their focus on cost-effectiveness and financial incentives introduces a critical dimension often underexplored in biophysical studies: the role of market integration and economic viability in scaling agroforestry. By doing so, they identify a gap in earlier work (e.g., Nyberg et al., Duffy et al.), which often emphasizes environmental or food security benefits without fully addressing financial sustainability.

Notably, Gosling et al. (2021) took a different approach by using modelling to assess the viability of silvopasture systems in less productive regions. While their findings confirmed the productivity potential of agroforestry, they did not directly investigate the scale of implementation. This omission limits the applicability of their results to real-world planning and underscores a recurring gap in theoretical modelling studies, the lack of empirical validation concerning how plot size and land allocation impact productivity in practice. Their identification of labour intensity as a barrier, however, introduces a socio-economic variable absent in most of the other studies, suggesting that implementation scale must be evaluated not only in spatial but also in labour and institutional terms.

### 2.3.3 Extension Services and Productivity

Castle et al. (2021) conducted a systematic review that broadly concluded that extension services, particularly those providing training and technical support play a pivotal role in enhancing agroforestry adoption and productivity through improved soil health, crop yields and income diversification. Their meta-analysis presents extension services as a vital knowledge transfer tool. However, the review's breadth limits its ability to examine how variations in local governance structures, resource allocation and community engagement mediate this effectiveness. The lack of localized empirical insights points to a methodological gap in understanding how and under what conditions extension services drive productivity gains.

Complementing Castle et al., Mukhlis et al. (2022) take a more community-focused lens, emphasizing the socio-economic and environmental impacts of agroforestry and the facilitative role of extension services. While they reinforce the centrality of knowledge dissemination, their findings go further by highlighting the need for institutional backing and targeted policies. This underscores a key contrast: whereas Castle et al. focus on extension as a technical tool, Mukhlis et al. present it as an institutional mechanism embedded within broader development strategies. Yet, both studies leave unexplored the role of farmer feedback in tailoring extension content to local needs, signalling a practical gap in adaptive service design.

Ahmad et al. (2023) shift attention to individual-level adoption, revealing how farmers' perceptions and socio-economic factors such as land tenure, access to credit and institutional trust, interact with extension services to influence agroforestry uptake. Unlike the previous two studies that emphasize the provision of services, Ahmad et al. question their accessibility and relevance. This contrast exposes a recurring oversight in the literature: few studies interrogate the equity and inclusivity of extension models, particularly in marginalized or resource-poor farming contexts.

A more systems-oriented perspective is offered by Pédelahore et al. (2023), who frame extension services not just as conveyors of information, but as dynamic facilitators of market linkages, policy feedback and adaptive socio-economic transformation. Their methodological approach integrates agroforestry within a complex system of stakeholders and institutional interactions. This broader framing challenges the relatively static conception of extension found in earlier studies and calls for a shift toward participatory, co-designed service models. However, empirical testing of this adaptive framework in rural African contexts remains limited, highlighting a theoretical and application gap.

In contrast to the conceptual richness of Pédelahore et al., Sheppard et al. (2020) return to a practical orientation, examining case studies in Southern Africa. They reinforce the critical role of extension services in climate adaptation through agroforestry but recommend stronger stakeholder coordination and policy integration. Unlike Castle et al., they identify extension not merely as a farm-level input but as a critical link between local resilience and national climate strategies. This reframing brings attention to a gap in scale integration how national policy goals translate into actionable, context-specific extension programs remains underexplored.

Kenyan studies by Kinyili et al. (2020) and Korir et al. (2022) add regional specificity, showing that despite relatively high adoption rates of agroforestry practices in ASALs and parts of Kericho County, extension services remain under-resourced and inconsistently linked to productivity outcomes. Kinyili et al. highlight the absence of triangulated data on adoption drivers, while Korir et al. note a lack of direct connection between extension efforts and productivity metrics. Together, they point to an empirical gap in measurement: many studies assume rather than demonstrate causality between extension services and productivity.

### 2.3.4 Moderating Effect of Biodiversity Conservation on Relationship between Agroforestry Practices and Productivity

The literature widely recognizes biodiversity conservation as a key moderating factor that strengthens the positive relationship between agroforestry practices and agricultural productivity. However, across the reviewed studies, there is notable variation in how this moderating effect is conceptualized, measured and integrated into agroforestry models, indicating both theoretical and empirical gaps. Swallow et al. (2020) offer a foundational synthesis by positioning biodiversity as a central component of productive and resilient agroforestry systems. They emphasize the role of agrobiodiversity in supporting critical ecosystem services such as pest regulation, pollination and nutrient cycling that directly contribute to higher and more stable yields. Their review highlights that agroforestry systems outperform monoculture in generating biodiversity co-benefits, especially when implemented within integrated landscape management frameworks. However, while they propose that biodiversity enhances productivity through ecosystem functioning, their evidence remains primarily conceptual and synthesized from diverse contexts. This broad approach, while informative, lacks region-specific empirical validation, particularly in African highland ecosystems like Mount Elgon, leaving a gap in practical applicability.

Klie (2018) narrows the focus by examining biodiversity's moderating role through a case study in Brazil's Atlantic Forest, linking agroforestry adoption to habitat provision for endemic species and improved ecosystem services. Unlike Swallow et al., Klie's study incorporates farmer perspectives, revealing that income diversification and increased productivity are perceived benefits of biodiversity-enhancing agroforestry systems. However, the findings also expose barriers such as lack of knowledge and technical support that hinder full realization of biodiversity's productivity benefits. This contrast highlights an implementation gap: while biodiversity is acknowledged as beneficial, systemic obstacles limit its integration into smallholder practices. Moreover, the species-specific conservation lens, while important ecologically, offers limited insight into broader agro-ecological productivity metrics.

Mulatu and Hunde (2019) extend the discourse by framing biodiversity conservation within the context of climate change mitigation and adaptation. Their review connects biodiversity-enhancing agroforestry systems with resilience to climate variability and improved carbon sequestration, further strengthening the case for biodiversity as a productivity moderator. Unlike Klie and Swallow et al., their focus is on ecosystem-wide resilience rather than species conservation or income effects. This systemic framing adds conceptual depth but lacks a direct quantification of productivity improvements, revealing a measurement gap in linking biodiversity with tangible yield or income outcomes in agroforestry contexts.

Liliane (2021) provides empirical clarity by analyzing the influence of biodiversity-conserving agroforestry technologies on farmer livelihoods in Rwanda. Her study is distinct in employing both qualitative and quantitative analyses, demonstrating that biodiversity benefits such as reduced soil erosion and improved fertility directly contribute to enhanced productivity and income. Liliane's work offers one of the few studies that explicitly ties biodiversity's moderating role to measurable economic outcomes, thereby partially addressing the empirical and attribution gaps identified in earlier literature. However, the study also notes that household and farm-level variables mediate these outcomes, suggesting that biodiversity's effect is not uniform but contingent on socio-economic and agro-ecological factors. This reveals a contextual gap: biodiversity's moderating effect must be understood not as a constant, but as one shaped by local conditions and resource endowments.

## 2.4 Summary of Literature and Gap

**Table 2.1 Summary of Literature Review**

| Author and year of study | Study focus | Sector of study | Theories applied | Methodology applied | Summary of findings | Research Gap(s) |
|---|---|---|---|---|---|---|
| Alifa et al. (2024) | Socioeconomic and ecological sustainability of agroforestry | Agriculture, Environmental Science | Sustainability theory | Literature review | The study emphasizes the need to understand the extent to which agroforestry can minimize economic and ecological trade-offs, optimizing benefits for both people and the environment. | The study does not use primary data to arrive at findings, a weakness in its methodology |
| Gosling et al. (2021) | Socio-economic conditions driving the selection of agroforestry at the forest frontier | Agriculture, Environmental Management | Modern Portfolio Theory | Modelling approach, Robust optimization | Silvopasture emerges as a promising land use, especially for farms with less productive soils. Although the higher labour demands compared to conventional pasture may hinder adoption for farms with labour shortages. | The study fails to look at the scale of implementation of agroforestry and its linkage to productivity |
| Kassa (2022) | Agroforestry as a pathway to climate-smart agribusiness: challenges and opportunities to smallholder farmers | Agriculture | No theory used | Literature review | Agroforestry systems offer new commercial opportunities to smallholder farmers and are gaining popularity as eco-friendly and climate-smart practices. | No theory or moderating variables used, a weakness in its approach |

| | | | | | | |
|---|---|---|---|---|---|---|
| Willmott et al. (2023) | Harnessing the socio-ecological benefits of agroforestry diversification | Agriculture, Forestry, Environmental Management | Ecological theory | Literature review, Questionnaire | Agroforestry is recognized for providing multiple ecosystem services, biodiversity habitat and socio-economic development opportunities. | The study findings were general and not contextualized to a specific region or area |
| Kinyili et al. (2020) | Socio-economic and institutional factors influencing adoption of agroforestry in ASALs | Agriculture, Rural Development in Sub Saharan Africa | None used | Survey research | The study revealed that 82% of respondents had adopted agroforestry, with boundary planting, hedgerow, woodlots, scattered planting and alley cropping being the main practices. | No triangulation of data was done |
| Mukhlis et al. (2022) | Understanding socio-economic and environmental impacts of agroforestry on rural communities | Agriculture, Rural Development | Socioeconomic theory | Literature review | Agroforestry is recognized for its potential to increase food security, improve smallholders' income, promote gender equality and stimulate cultural activities in rural areas. Additionally, it enhances ecosystem services through improved soil structure, increased carbon sequestration and higher water retention. | Secondary data was used and the farmers responses were not included |
| Korir et al. (2022) | Classification and socio-economic | Agriculture, Rural Development | Agroforestry classification theory | Qualitative research | Four classes of agroforestry systems were identified: | The study did not link agroforestry |

| | | | | | | |
|---|---|---|---|---|---|---|
| | benefits of agroforestry systems | in Soin Ward, Kericho County, Kenya | | | agrosilvopastoral, agrosilvicultural, silvopastoral and integrated farm-based agroforestry. Respondents predominantly preferred Grevillea tree species for blending with sugarcane in agroforestry systems. | practices to productivity |
| Telwala (2023) | Unlocking the potential of agroforestry as a nature-based solution for SDGs. | Agriculture, Environmental Science | Sustainability theory | Case study, field observations | Agroforestry's role in achieving SDGs, emphasizing its potential in sustainable development in drought-prone regions. | Limited data on long-term impacts of agroforestry. |
| De Giusti et al. (2019) | Agroforestry as a climate change mitigation practice in smallholder farming. | Agriculture, Climate Science | None | Quantitative analysis, field data collection | Agroforestry systems effectively sequester carbon, providing mitigation benefits in smallholder farming systems. | Lack of comparative studies with other mitigation practices. |
| Yasin et al. (2023) | Traditional agroforestry systems in climate change mitigation. | Agriculture, Climate Science | None | Quantitative survey, carbon measurement | Traditional agroforestry practices in semi-arid regions contribute significantly to carbon sequestration. | Need for broader regional studies to validate findings. |
| Nyberg et al. (2020) | Effects of agroforestry in the Kenya Agricultural | Agriculture, Environmental Science | None | Quantitative analysis, site comparison | Agroforestry enhances soil fertility, biodiversity and resilience to climate change in Kenya. | Need for long-term impact studies on different land types. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Carbon Project (KACP). | | | | | |
| Ahmad et al. (2023) | Socioeconomic determinants and perceptions of agroforestry adoption. | Agriculture | None | Survey research | Key socio-economic factors influence agroforestry adoption in northern Pakistan, with variations in perceptions. | No triangulation of data in the study. |
| Pédelahore et al. (2023) | Identifying socio-economic determinants in agroforestry transformations. | Agriculture, Rural Development | None | Qualitative research | Four agroforestry system classes identified, focusing on tree species preferences in Kenya. | Lack of link between practices and productivity. |

## 2.5 Conceptual Framework

Independent variables encompass various dimensions of agroforestry practices, including the type of agroforestry, scale of implementation and extension service variables, such as availability, accessibility and training opportunities. The dependent variable encompasses productivity benefits, including improved soil conservation, enhanced crop yields and increased household income. Biodiversity conservation forms the moderating variable.

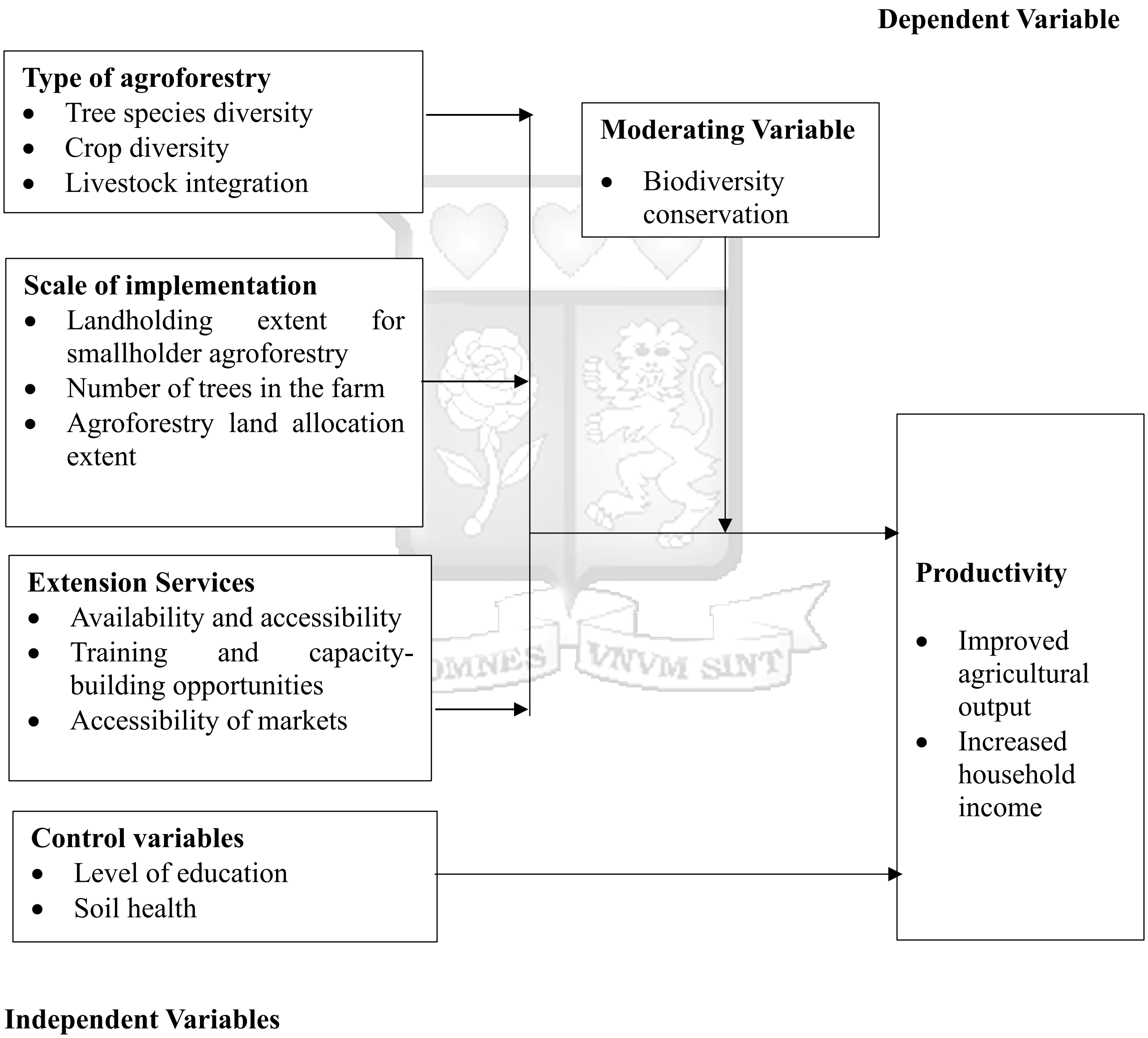


**Figure 2.1 Conceptual Framework**

The conceptual framework is grounded in the theory of agroforestry systems, which links agroforestry practices (independent variable) to improved productivity (dependent variable) through ecological benefits. The resource dependence theory supports the role of extension services by highlighting the importance of access to resources for effective implementation. The theory of planned behaviour explains how farmers' attitudes, norms and perceived control influence adoption. Biodiversity conservation moderates the agroforestry–productivity relationship by enhancing ecosystem services, reinforcing the interconnectedness of the framework.

### 2.6 Operationalization of Variables

**Table 2.2 Operationalization of Variables**

| Variable | Definition | Indicators | Measurement Method |
|---|---|---|---|
| Type of Agroforestry | Different agroforestry systems used | • Tree species diversity<br>• Crop diversity<br>• Livestock integration | Continuous or/and ordinal |
| Scale of Implementation | Extent of agroforestry practice adoption | • Landholding extent for smallholder agroforestry<br>• Number of trees in the farm<br>• Agroforestry land allocation extent | Continuous or/and ordinal |
| Extension Services | Support and training provided to farmers | • Availability and accessibility<br>• Training and capacity-building opportunities<br>• Accessibility of markets | Continuous or/and ordinal |
| Productivity | Agricultural outputs and benefits | • Improved agricultural output<br>• Increased household income | Continuous or/and ordinal |
| Biodiversity Conservation | Conservation efforts within agroforestry practices | • Species diversity<br>• Habitat quality | Continuous or/and ordinal |

## 2.7 Chapter Summary

This chapter reviewed the theoretical and empirical literature relevant to agroforestry practices, biodiversity conservation and productivity. It highlighted the gaps in existing research, particularly in the context of Mount Elgon, Kenya. The chapter concluded with a conceptual framework outlining the relationships between the study variables and the operationalization of these variables, setting the stage for the subsequent chapters.

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter outlines the methodology employed in the study, detailing the philosophical underpinnings, research design, population selection, sampling methods, procedures for data collection, reliability and validity of instruments, data analysis techniques, ethical considerations and a summary of the chapter. Each section is meticulously crafted to ensure the robustness and rigor of the research, aiming to provide comprehensive insights into the relationships between agroforestry practices, biodiversity conservation and productivity among smallholder farmers in Mount Elgon, Kenya.

## 3.2 Research Philosophy

The research philosophy serves as the foundation that underpins the researcher's assumptions about the nature of knowledge and reality, guiding decisions on how data was collected, interpreted and applied (Cuthbertson et al., 2020). Several philosophies were considered for this research, including positivism, interpretivism, critical realism and pragmatism. Positivism assumed that reality is objective and can be observed and measured through empirical evidence. This philosophy emphasizes quantitative methods and is suitable for studies seeking to establish causal relationships or test hypotheses, such as examining the impact of agroforestry practices on productivity. However, its rigid focus on observable phenomena may limit exploration of subjective experiences and contextual factors.

Interpretivism, on the other hand, is rooted in the belief that reality is socially constructed and subjective. It focuses on understanding meanings and perspectives, making it ideal for qualitative research exploring farmers' experiences, attitudes and social norms related to agroforestry practices. However, interpretivism may lack the structured framework required for measuring outcomes like productivity and biodiversity conservation (Nair, 1993). Critical Realism bridges the gap between positivism and interpretivism by recognizing the existence of an objective reality while acknowledging that our understanding is influenced by social, cultural and historical contexts. It is well-suited for studies investigating underlying mechanisms driving observed phenomena, such as socioeconomic or institutional factors affecting agroforestry adoption. However, it may require more nuanced data collection and analysis, which can be resource-intensive. Pragmatism, the chosen philosophy for this study, integrates the strengths of both positivism and interpretivism, emphasizing practical solutions and the relevance of findings in real-world contexts. Pragmatism is particularly appropriate for mixed-methods research, as it accommodates quantitative analysis to measure productivity and biodiversity outcomes while allowing qualitative insights into farmers' perceptions, attitudes and challenges (Cuthbertson et al., 2020).

This study sought to address the multifaceted interactions between agroforestry practices, biodiversity conservation and productivity among smallholder farmers in Mount Elgon. Pragmatism aligns with the research objectives by enabling the use of both quantitative methods for example statistical analysis of productivity data and qualitative approaches for example interviews to capture farmers' experiences (Telwala, 2023). This philosophy ensures a holistic understanding of the research problem while maintaining practical applicability for designing targeted interventions to improve livelihoods and promote sustainable practices in the Kenyan context.

### 3.3 Research Design

The research design acts as the structural framework guiding a study, detailing the methodological strategies and approaches used to address research questions and objectives (Bell et al., 2018). Research designs encompass various types, such as experimental, correlational, descriptive and exploratory, each serving distinct purposes and methodological methodologies. The study employed a concurrent triangulation research design to simultaneously integrate qualitative and quantitative data collection and analysis methods. This approach aimed to provide a comprehensive exploration and validation of the research findings by triangulating different data sources and methods. Qualitative methods including interviews were used to investigate the experiences, perceptions and attitudes of farmers and stakeholders regarding agroforestry practices and biodiversity conservation. These qualitative insights helped to contextualize the quantitative data and provide deeper insights into the underlying mechanisms and dynamics at play (Kalamkar & Acharya, 2024).

Quantitative methods, involving use of questionnaires, were employed to measure and quantify variables such as the type of agroforestry, scale of implementation, productivity outcomes and biodiversity indicators. These quantitative measures allowed for the assessment of correlations, trends and statistical significance among the variables studied. The concurrent triangulation design is particularly suited to this study as it facilitates the integration of diverse data sources and methods, thereby enhancing the reliability and validity of the findings. This design ensures that both qualitative richness and quantitative rigor are maintained throughout the research process, enabling a comprehensive examination of the complex relationships within the context of smallholder agroforestry in Mt. Elgon, Kenya.

The choice of a concurrent triangulation research design was justified as it allows for a comprehensive and multi-faceted exploration of the complex dynamics surrounding agroforestry practices and biodiversity conservation in Mount Elgon, Kenya. Through a combination of both qualitative and quantitative methods, this design enhances the richness and depth of the study. Qualitative methods such as interviews enable an in-depth understanding of the farmers' experiences, perceptions and attitudes, which is essential for contextualizing the quantitative data. Meanwhile, quantitative methods including use of questionnaires provide empirical measurements of key variables such as agroforestry type, scale of implementation, productivity outcomes and biodiversity indicators. The simultaneous integration of these methods allows for cross-validation, ensuring more robust, reliable and valid findings and offering a comprehensive view of how agroforestry practices can enhance productivity and biodiversity conservation in smallholder farming systems (Nair, 1993). This mixed-method approach was therefore best suited for addressing the research objectives and answering the study's research questions effectively.

### 3.4 Target Population

The target population for this study was smallholder farmers practicing agroforestry in Mt. Elgon Sub-County, Bungoma County, Kenya. Smallholder farmers in this region were defined as individuals or households engaged in agricultural activities on small plots of land, typically less than five acres. They integrate trees with crops and/or livestock as part of their farming practices to enhance productivity and sustainability (Kalamkar & Acharya, 2024). The population included both women and men farmers who actively took part in agroforestry activities, ranging from tree planting and management to crop cultivation and livestock rearing within agroforestry systems.

Bungoma County has a population of approximately 1.67 million and Mount Elgon Sub-County represents about 167,000 of the population. Typically, 70-80% of the rural population in the region is engaged in agriculture. It's estimated that around 70% of these farming households practice agroforestry. Thus, the estimated number of smallholder farmers practicing agroforestry in Mount Elgon Sub-County is approximately 16,283. All these have been sourced from the Bungoma county website (Welcome to Bungoma - COUNTY GOVERNMENT OF BUNGOMA).

### 3.5 Sampling and Sample Size

To ensure the sample represents the target population adequately and to enhance the reliability of the study, a combination of purposive and stratified random sampling methods was employed. Purposive sampling was initially used to select key informants who had significant experience and knowledge in agroforestry practices. Key informants included local agricultural officers, leaders of farmer cooperatives and other stakeholders involved in agroforestry and biodiversity conservation in Mount Elgon. Purposive sampling ensures that insights from experienced individuals are captured, enriching the qualitative aspects of the study.

For stratified random sampling; to obtain a representative sample of smallholder farmers practicing agroforestry, the population was split into strata according to geographical location (e.g., highland and lowland areas). This approach ensured that various sub-groups within the population were proportionately represented in the sample. Random sampling was then conducted within each stratum to select participants, ensuring that the sample reflected the diversity of agroforestry practices and experiences in Mount Elgon Sub-County. Fisher's formula was used to calculate the sample size, as shown;



$$n = \frac{Z^2pq}{e^2}$$

Where;

n= refer to the desired sample size when the entire survey population is greater than 10,000

Z= the standard normal deviate usually set at 1.96 which corresponds to the 95% confidence level

P= population of the target population estimated to have a particular characteristic, 50% is normally used because it is the recommended measure if there is lack of reasonable estimate.

q= 1.0-p

e= degree of accuracy desired in this context set at 0.05

Computations are as follows

$$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2}$$

n = 384

### 3.6 Data Collection

To effectively gather primary data aligned with the study's purpose and objectives, semi-structured questionnaires were employed as the principal data collection tool. The questionnaire incorporated both open-ended and closed-ended questions (qualitative and quantitative data respectively). Closed-ended questions were predominant, enabling respondents to select the response that best fits the scenario from a set of predefined options. This format is advantageous as it simplifies the data analysis process, providing immediate, quantifiable results that can be easily compared and statistically analyzed (Bell et al., 2018).

The inclusion of closed-ended questions is particularly beneficial for achieving the study's objectives. However, to capture the contextual insights that closed-ended questions may overlook, open-ended questions were also included. These questions allowed respondents to provide detailed explanations and elaborate on specific issues. This mixed-methods approach ensured a comprehensive understanding of the subject matter, aligning with the study's goal. The questionnaire was divided into sections to systematically address the study objectives. Section A gathered the respondent's basic demographic information, such as age and gender to contextualize the responses and ensure a representative sample. Section B and subsequent sections focused on the variables derived from the objectives of the study. The questionnaire was administered using two research assistants, who were trained by the researcher and helped with data input and other logistical tasks. The research assistants were locals with at least Diploma level qualification in the related studies. The enumerators received training to improve their proficiency and reduce data collection and data entry errors as much as possible.

Interviews were also conducted to supplement data collected through questionnaires. Semi-structured interviews targeted key informants, such as agricultural officers, leaders of farmer cooperatives and county government stakeholders involved in agroforestry. A total of 12 interviews were done, 4 from each group. This method allowed for deeper insights into the issues under study, providing qualitative data that enriches the analysis. The semi-structured format ensured consistency while also allowing flexibility to explore emergent themes during the interviews.

Observations were used as an additional data collection method to gain first-hand insights into agroforestry practices in Mount Elgon Sub-County. The researcher observed activities such as tree planting, crop cultivation and livestock rearing within agroforestry systems. This method helped to validate the data collected through questionnaires and interviews, offering a practical understanding of the integration of trees, crops and livestock in farming systems. Observational data was recorded systematically and analyzed to identify patterns and correlations with the study's objectives.

### 3.6.1 Instrument Validity

### 3.6.1 Validity

The ability of the study tool to measure what it is intended to measure is known as validity (Bell et al., 2018). Validity test is important indicator to ascertain consistence of data obtained from the questionnaires and whether we may rely on such data for this particular study. The study used face validity to ascertain the validity of the questionnaires. Before using it for the final data collection activity, the instrument was suitably modified depending on the evaluation. The feedback from supervisors was examined and used to improve the validity of the content.

### 3.6.2 Reliability of the Instruments

The questionnaire's design was enhanced by the researcher using feedback from the pilot study. In a similar vein, the reliability of the questionnaire was examined to make sure it did not repeatedly measure the same variable. The internal consistency (reliability) of the survey was verified using the Cronbach Alpha test. A maximum value of 0.9 was suggested, with a score of more than 0.6 being deemed critical because it showed that the instrument was dependable (Saunders et al., 2018). Table 3.1 shows the reliability findings.

**Table 3.1: Reliability Results**

| Variable | Cronbach's Alpha |
|---|---|
| Type of Agroforestry | 0.85 |
| Scale of Implementation | 0.87 |
| Extension Services | 0.89 |
| Biodiversity Conservation | 0.90 |
| Productivity | 0.91 |
| Overall Reliability | 0.88 |

### 3.6.3 Pilot Testing

Before using the tool to collect data for the actual study, a pilot test was conducted to fine-tune the questions. Asenahabi (2019) state that a pilot study may be conducted using a 10% sampling frame, which include 38 respondents (10% of 384) who were selected from the study's overall sample size. The test was carried out to identify design and instrumentation flaws and to supply proxies for data needed to choose a probability sample. Analyses were performed following the pilot research to determine the tool's acceptability. The reliability and validity of the data collection instruments significantly impacted on the precision of the data obtained. The pilot research report's findings were helpful in identifying faults and making tool modifications for the actual data collection process. The pilot respondents were excluded from the main data collection and analysis.



## 3.7 Data Analysis

The information gathered was evaluated for accuracy and comprehension. The information was then tallied, coded and summarized. Quantitative data was analyzed using descriptive statistics including frequency distribution, means and standard deviation using the Statistical Package for Social Sciences (SPSS). The presentation of quantitative data made use of frequency tables, bar charts, percentages and pie charts. Through describing what the respondents stated in their responses, this guaranteed that the information acquired was understood clearly (Singh, 2015). Content analysis was used to assess qualitative data, which was then presented in prose form. The model specification was as follows:

The model was as expressed below:

$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \varepsilon$……………………………………(i)

Where: Y  Represents the dependent variable.

X1 - X4 Represents independent variables and the moderating variable

ε Error term

β0 Represents Constant

β1, β2, β3 and β4 represent the regression coefficient of the independent variables and the moderating variable.

To indicate the moderation effect;

$Y = \beta0 + \beta1(X1 * X4) + \beta2(X2 * X4) + \beta3(X3 * X4) + \varepsilon$……………………………………(ii)

Where:

- Y is the dependent variable.
- X1, X2, X3 are the independent variables.
- X4 is the moderating variable.
- X1 * X4, X2 * X4, X3 * X4 are the interaction terms between the moderating variable and each independent variable.
- ε is the error term.
- β0 is the constant (intercept).
- β1, β2, β3, β4 are the regression coefficients of the independent variables.
- β5, β6, β7 are the regression coefficients of the interaction terms.

The interaction terms (X1 * X4, X2 * X4, X3 * X4) capture the moderation effect, indicating how the relationship between each independent variable and the dependent variable changes with the level of the moderating variable.

### 3.8 Ethical Considerations

Ethical considerations are paramount in ensuring the validity and integrity of the research (Bell et al., 2018). This study adhered to the highest ethical standards to protect the welfare and rights of all participants. Firstly, informed consent was obtained from all respondents. Participants were provided with comprehensive information about the study's purpose, procedures, potential risks and benefits, ensuring they fully understand what their participation entails. They were assured that their involvement was voluntary and that they could withdraw at any point without any repercussions. Anonymity and confidentiality were strictly upheld during the entire research process. Respondents' personal information and responses were coded to protect their identities and data was stored securely with access limited to the research team. The findings were reported in aggregate form, ensuring that no individual could be identified from the published results.

The study ensured that no harm comes to the participants as a result of their involvement. This includes avoiding any psychological, social, or economic harm. The research was conducted in a manner that respects the autonomy and dignity of all participants. Finally, ethical approval was sought from the Strathmore Institutional Review Board (IRB) and research permit from National Commission for Science, Technology and Innovation (NACOSTI) before commencing the study. This included a thorough review of the research proposal to ensure that all ethical considerations were adequately addressed.

### 3.9 Chapter Summary

This chapter has outlined the methodology that was employed in the study, detailing the philosophical underpinnings, research design, population selection, sampling methods, data collection procedures, reliability and validity of instruments, data analysis techniques, ethical considerations and a summary of the chapter.

## CHAPTER FOUR

## RESULTS

### 4.1 Introduction

This chapter presents the results obtained in the study. The section presents the findings in regard to the research objectives. The results were analysed by the use of SPSS version 27 and presented in form of tables, charts, graphs discussing the frequencies, percentages, means and standard deviation of the research findings.

### 4.2 Response Rate

The study used questionnaires to gather data from the respondents who were smallholder farmers practicing agroforestry in Mt. Elgon Sub-County, Bungoma County, Kenya. The research achieved a response rate of 84% (n=322) and a non-response rate of 16% (n=62). This indicates that a small number of respondents did not return the questionnaires. According to Saunders et al. (2018), a response rate of 60% is deemed fairly representative and sufficient for drawing valid conclusions. Therefore, the response rate obtained in the study enhances the credibility of the respondents and supports the reliability of the study results (Figure 4.1).

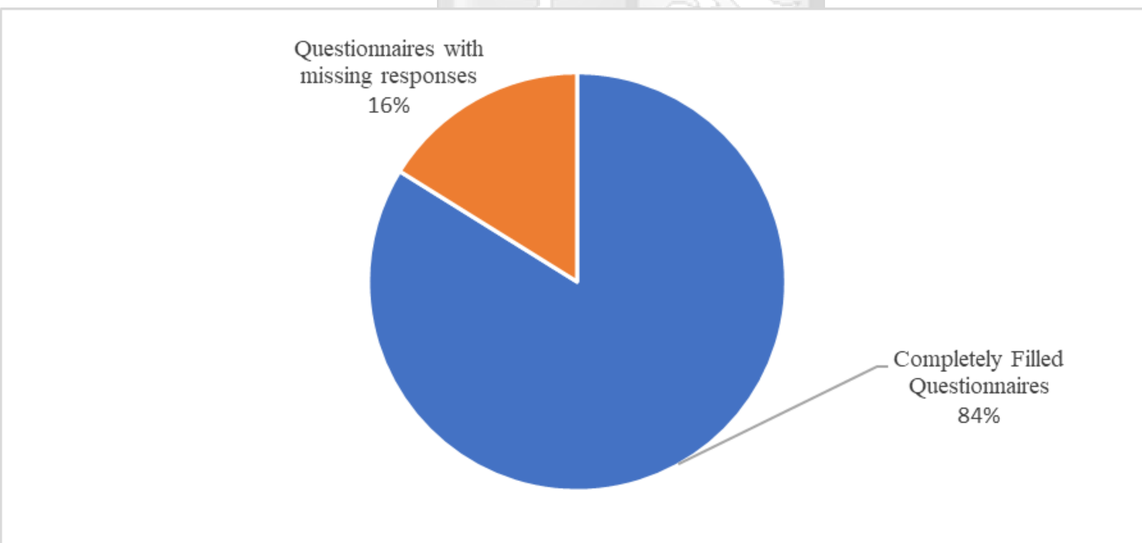


**Figure 4.1 Response Rate**

### 4.3 Demographic Information of Respondents

This section contains results on demographic analysis which include; gender, age, years of schooling, farming experience in years and landholding size in acres. Figure 4.2 shows the gender distribution of the respondents. The majority of the respondents were male (n=183), accounting for 56.8% of the sample. Female respondents comprised the remaining 43.2% (n=139). This gender distribution suggests a higher participation of males in practicing agroforestry in Mt. Elgon Sub-County.

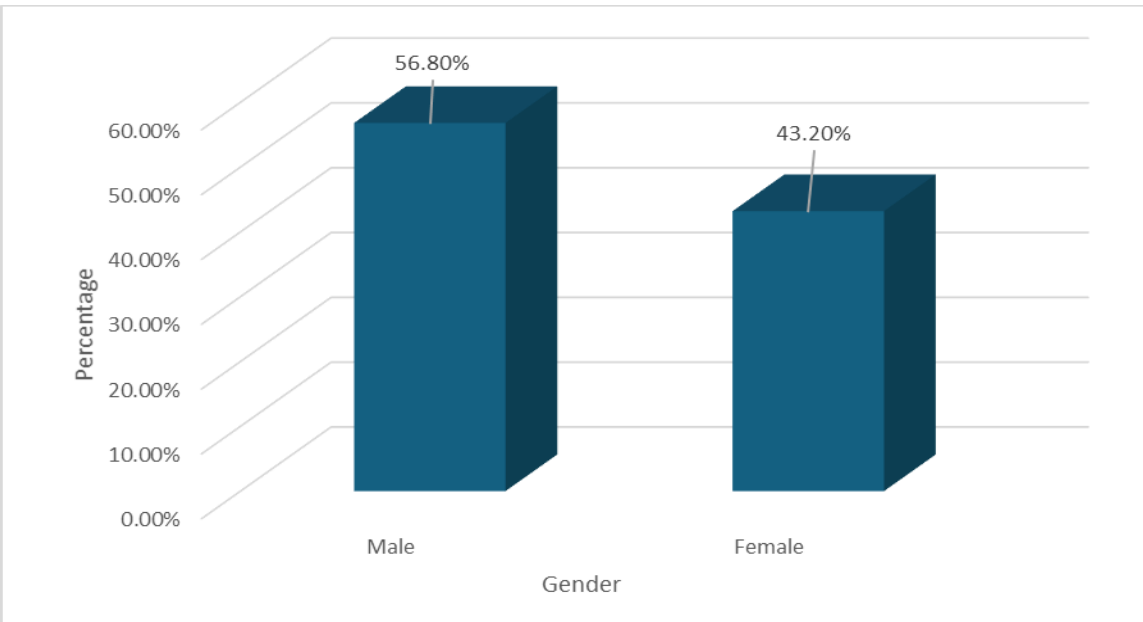


**Figure 4.2 Gender of the Respondents**

The descriptive statistics in Table 4.1 provide insights into the demographic characteristics of the respondents. On average, participants were 48.11 years old (SD = 22.845), with notable variation in age and had 11.81 years of schooling (SD = 6.541), indicating a moderately educated group. They reported an average of 19.76 years of farming experience (SD = 12.624), suggesting substantial expertise in agriculture. The mean landholding size was 3.95 acres (SD = 1.004), reflecting small to medium-scale farming operations with some variability in land ownership. The findings are shown in the Table 4.1.

**Table 4.1 Descriptive Statistics on Demographic Data**

| Demographic | Mean | Std. Deviation |
|---|---|---|
| Age in years | 48.11 | 22.845 |
| Years of schooling | 11.81 | 6.541 |
| Farming Experience in years | 19.76 | 12.624 |
| Landholding size in acres | 3.95 | 1.004 |

### 4.4 Descriptive Analysis of the Independent Variables

The study sought to assess the impact of agroforestry practices on farm sustainability. The findings indicate that agroforestry practices play a crucial role in influencing farm productivity, biodiversity and income diversification.

#### 4.4.1 Descriptive Findings on Type of Agroforestry

The research sought to determine the type(s) of agroforestry respondents implemented in their farm. The survey revealed a strong preference for integrating trees with grazing livestock, with 83.9% (n=270) adopting this agroforestry practice, followed by riparian buffer strips (41%, n=132), windbreaks (30.4%, n=98) and alley cropping (22.4%, n=72). This distribution suggests that farmers prioritize practices offering direct benefits to livestock management, such as shade and forage from tree-livestock integration, which also enhances soil health and carbon sequestration. Riparian buffer strips, likely chosen for water quality protection and erosion control, indicate environmental stewardship, though their adoption is less widespread. Windbreaks, aiding in microclimate regulation and alley cropping, which diversifies income through intercropping, are less common, possibly due to higher labour or knowledge demands. The findings are shown in the Figure 4.3.

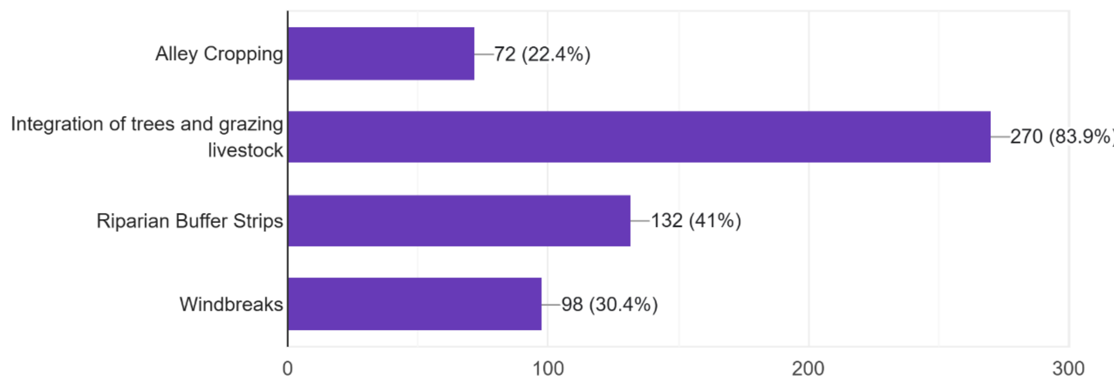


**Figure 4.3 Agroforestry Practices Implemented on Farm**

The research sought to assess the respondent's main reasons for practicing agroforestry. The research highlighted diverse motivations for practicing agroforestry, with reducing erosion emerging as the top reason, cited by 76.7% (n=247), reflecting a strong focus on soil conservation. Improving soil fertility follows closely, with 62.4% (n=201), underscoring the importance of long-term land productivity. Improved agricultural output, endorsed by 49.1% (n=158) and economic benefits like timber and fodder, noted by 48.1% (n=155), indicate a balance between ecological and economic goals. Enhancing biodiversity, supported by 41.6% (n=134), suggests growing environmental awareness, while increasing crop yield, with 32.3% (n=104), is less prioritized, possibly due to perceived complexity or slower returns. The results are shown in the Figure 4.4.

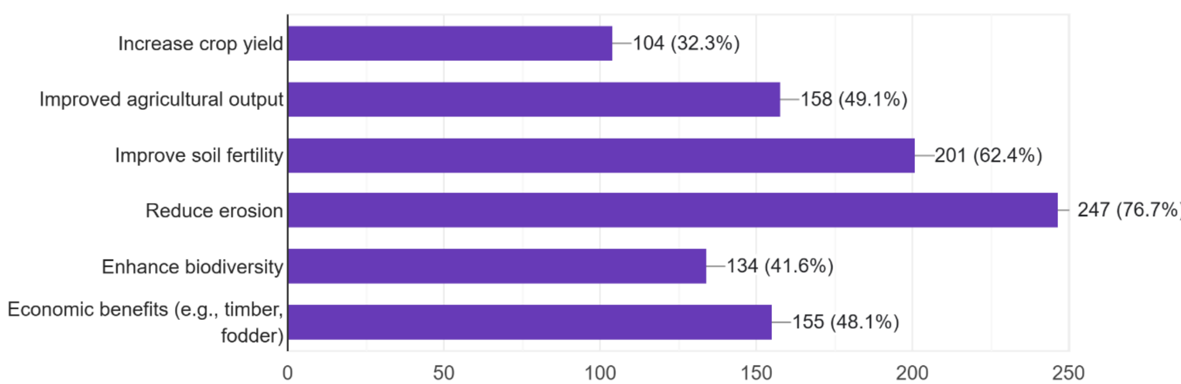


**Figure 4.4 Main Reasons for Practicing Agroforestry**

The descriptive statistics revealed varied perceptions regarding agroforestry practices among respondents. Tree diversity within agroforestry systems was perceived as moderate, with a mean of 2.79 (SD = 1.262), indicating that while agroforestry is practiced, tree diversity is not fully optimized. Similarly, crop integration in agroforestry systems was seen to a moderate extent, with a mean of 2.75 (SD = 1.133), highlighting a gap in diversification strategies that could improve resilience. Livestock integration was practiced moderately, with a mean of 2.89 (SD = 1.263), suggesting the potential benefits of nutrient recycling and sustainability, though further education may be needed. Agroforestry's contribution to sustainability was perceived positively, with a mean of 2.86 (SD = 1.202), but more efforts are required to demonstrate its long-term impacts. Soil health improvement through agroforestry had a mean of 2.85 (SD = 1.241), indicating moderate agreement that agroforestry benefits soil health. The integration of trees and crops to boost farm productivity was also moderately perceived, with a mean of 2.80 (SD = 1.247), highlighting the need for further training on how these elements can work synergistically. Income diversification through agroforestry was moderately viewed as beneficial, with a mean of 2.79 (SD = 1.202), suggesting room for expansion of agroforestry enterprises. Finally, respondents had a moderate understanding of agroforestry principles, with a mean of 2.77 (SD = 1.222), pointing to the importance of targeted training programs. The results are shown in the Table 4.2.

**Table 4.2 Descriptive Findings on Agroforestry Practices**

| | Mean | SD |
|---|---|---|
| The diversity of tree species on my farm is high. | 2.79 | 1.262 |
| I integrate a variety of crops within my agroforestry system. | 2.75 | 1.133 |
| Livestock is an essential part of my agroforestry practice. | 2.89 | 1.263 |
| I believe agroforestry enhances the sustainability of my farm. | 2.86 | 1.202 |
| Agroforestry practices on my farm improve soil health. | 2.85 | 1.241 |
| The integration of trees and crops benefits my farm's productivity. | 2.80 | 1.247 |
| Agroforestry helps in diversifying my farm income. | 2.79 | 1.202 |
| I have a good understanding of different agroforestry systems. | 2.77 | 1.222 |
| My agroforestry practice includes various types of trees and plants. | 2.79 | 1.223 |

From the open-ended questions, the respondents stated that agroforestry practices in their region provided several advantages. They mentioned that it served as a source of income for those practicing it, with some even mixing it with cow dung to produce manure from decomposed leaves. They also highlighted that agroforestry contributed to both income generation and soil conservation. Additionally, they emphasized its role in reducing soil erosion. Overall, the responses consistently pointed to agroforestry's economic benefits, its contribution to soil conservation and its effectiveness in minimizing soil erosion.

The respondents also identified several agroforestry practices they believed to be most effective for improving productivity. They highlighted riparian buffer strips as particularly beneficial, especially in muddy areas where they help reduce soil erosion. Some mentioned that practicing agroforestry in swampy areas had led to increased yields due to improved soil conditions. Additionally, they emphasized the importance of agro-silviculture, noting its positive impact on farms, particularly in potato-growing regions. Others pointed to the effectiveness of planting trees alongside livestock, which they stated had significantly reduced soil erosion in swampy areas. Agrosilvopastoral systems were also favoured, with respondents explaining that many farmers preferred this approach due to its soil conservation benefits and the fact that it was well understood within their communities.

**4.4.2 Descriptive Findings on Scale of Implementation**

The study sought to determine the scale of implementation and productivity. The research first sought to discuss the number of trees of the respondent's farm. From the findings, the majority of the respondents reported having less than 50 trees, accounting for 56.8% (n=183) of the sample. Respondents with 50 to 100 trees made up the remaining 43.2% (n=139). This tree number distribution indicates a higher prevalence of farms with fewer than 50 trees in the study, which reflect a greater tendency or necessity among farmers to maintain limited tree integration, possibly due to constraints such as land size or resource availability in the context of agroforestry practices. The findings are shown in the Table 4.3.

**Table 4.3 Number of Trees in the Respondent's Farm**

| | Frequency | Percent |
|---|---|---|
| Less than 50 trees | 183 | 56.8 |
| 50 to 100 trees | 139 | 43.2 |
| Total | 322 | 100.0 |

The research sought to determine the scale of agroforestry implementation among the respondents. The majority of respondents, 90.7% (n=292), practiced medium-scale agroforestry (1-5 acres), indicating that a significant portion of farmers engage in agroforestry at a moderate level, possibly integrating it with other farming activities. A smaller percentage of respondents (9.3%, n=30) practiced small-scale agroforestry on less than 1 acre. This indicates that smallholder farmers or households interested in agroforestry remain a minority. Their limited land sizes may affect their ability to maximize the benefits of agroforestry, such as income diversification, soil conservation and environmental sustainability. The findings are shown in the Table 4.4.

**Table 4.4 Scale of Respondent's Agroforestry Implementation**

| | Frequency | Percent |
|---|---|---|
| Small-scale (Less than 1 acre) | 30 | 9.3 |
| Medium-scale (1-5 acres) | 292 | 90.7 |
| Total | 322 | 100.0 |

The research identified key challenges in implementing agroforestry, with lack of knowledge or training as the most significant barrier, reported by 39.1% (n=126) of respondents, highlighting a critical need for educational outreach and capacity building. Limited financial resources, cited by 37% (n=119), indicate that economic constraints are a close second, suggesting that many farmers struggle to afford initial investments like seedlings or labour. Land tenure issues, affecting 13.7% (n=44), point to systemic challenges such as insecure land ownership, which may deter long-term agroforestry adoption. Lastly, lack of seedlings or planting material, noted by 10.2% (n=33), reflects supply chain gaps that hinder practical implementation. These findings imply that agroforestry programs must prioritize accessible training and financial support, such as subsidies or microloans, to overcome knowledge and cost barriers. The results are shown in the Figure 4.5.

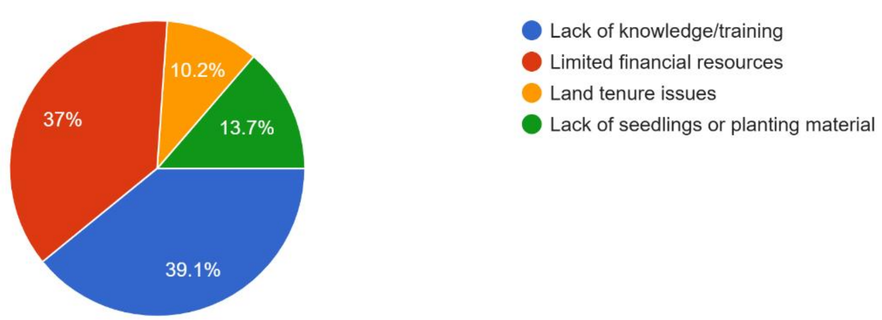


**Figure 4.5: Challenges in Implementing Agroforestry Practices**

The results highlight various aspects of agroforestry practices. The mean score for landholding size allowing for extensive agroforestry practices was 2.86 (SD = 1.249), indicating a moderate feasibility. Respondents reported allocating a significant portion of their land to agroforestry with a mean of 2.58 (SD = 1.161), suggesting limited land dedication to agroforestry. The adequacy of agroforestry plots was assessed with a mean of 2.70 (SD = 1.247), pointing to a moderate sense of adequacy. Regarding the expansion of agroforestry practices over the years, the mean score was 2.73 (SD = 1.232), indicating modest growth. The impact of agroforestry on agricultural yield was reported with a mean of 2.79 (SD = 1.261), suggesting a positive but limited effect. On the optimal allocation of land for agroforestry, the mean was 2.76 (SD = 1.251), showing that the current land allocation is somewhat suboptimal for productivity. When assessing whether agroforestry implementation met expectations, the mean was 2.70 (SD = 1.243), indicating that agroforestry on many farms did not fully meet expectations. For future plans, the mean score for increasing agroforestry practices was 2.79 (SD = 1.201), suggesting a positive outlook for future expansion. Finally, the contribution of agroforestry to biodiversity was reported with a mean of 2.70 (SD = 1.227), suggesting a moderate contribution to biodiversity conservation. The findings are shown in the Table 4.8.

**Table 4.5 Descriptive Statistics on Agroforestry Practices**

| | Mean | SD |
|---|---|---|
| My landholding size allows for extensive agroforestry practices. | 2.86 | 1.249 |
| I allocate a significant portion of my land to agroforestry. | 2.58 | 1.161 |
| The relative size of my agroforestry plots is adequate for my needs. | 2.70 | 1.247 |
| I have expanded my agroforestry practices over the years. | 2.73 | 1.232 |
| The extent of agroforestry on my farm has positively impacted my agricultural yield. | 2.79 | 1.261 |
| My farm's agroforestry land allocation is optimal for productivity. | 2.76 | 1.251 |
| The implementation scale of agroforestry on my farm meets my expectations. | 2.70 | 1.243 |
| I plan to increase the extent of agroforestry practices on my farm. | 2.79 | 1.201 |
| The current scale of agroforestry on my farm supports biodiversity. | 2.70 | 1.227 |

From the key informant interview guide; the respondents responded differently on the factors influencing the scale of agroforestry adoption among farmers. The respondents identified several factors influencing the scale of agroforestry adoption among farmers. They emphasized the importance of training, stating that farmers should be educated on the positive impacts of agroforestry and the differences in tree maturation rates. Financial resources were also highlighted as a key determinant, with some noting that limited finances could hinder adoption. Additionally, a lack of knowledge about agroforestry was mentioned as a barrier, suggesting that greater awareness could encourage more farmers to adopt the practice. Some respondents pointed to labour demands and the challenges posed by pests and diseases as additional factors affecting agroforestry adoption.

The respondents highlighted that labour demands and financial constraints were the challenges farmers faced in scaling up agroforestry practices on their farms. The respondents provided mixed opinions on the presence and effectiveness of programs supporting the expansion of agroforestry practices. Some acknowledged the existence of a few programs but noted that low farmer participation had discouraged their continuation. Others mentioned that most initiatives had been disrupted due to environmental challenges. Some respondents stated that no such programs were in place, while others felt that existing initiatives were not effective. A few pointed out that, on occasion, the community receives agroforestry education through Barazas, but the overall impact remains limited.

### 4.4.3 Descriptive Findings on Extension Services

The research sought to determine the respondent's extension services and productivity. The research assessed whether the respondents had access to extension services related to agroforestry. The majority of the respondents reported having access to such services, accounting for 56.8% of the sample (n=183). Respondents with no access made up the remaining 43.2% (n=139). This access distribution indicates a higher prevalence of farmers with connections to agroforestry extension services in the study, which may reflect a greater availability or awareness of these resources among this group, potentially influencing their adoption and understanding of agroforestry practices. The research findings are shown in the Table 4.6.

**Table 4.6 Accesses to Extension Services Related to Agroforestry**

| | Frequency | Percent |
|---|---|---|
| Yes | 183 | 56.8 |
| No | 139 | 43.2 |
| Total | 322 | 100.0 |

The study sought to determine the frequency at which respondents received services. The majority of respondents (61.5%) received services annually, indicating that most participants engaged with the service on a long-term or infrequent basis. This suggests that the nature of the service provided may not require frequent access, or there may be constraints such as cost, availability, or policy limitations affecting more regular utilization. Quarterly service recipients make up 28.6% of respondents, highlighting a significant portion of individuals who engage with the service on a more regular basis. This suggested a structured service delivery system where periodic access is necessary for continued benefits, such as seasonal agricultural support, healthcare check-ups, or financial assistance programs. A smaller percentage of respondents (9.9%) received services on a monthly basis. This relatively low proportion indicated that only a limited number of participants had access to frequent services, possibly due to the specialized nature of the support provided or the intensive needs of certain groups. The findings are shown in the Figure 4.6.

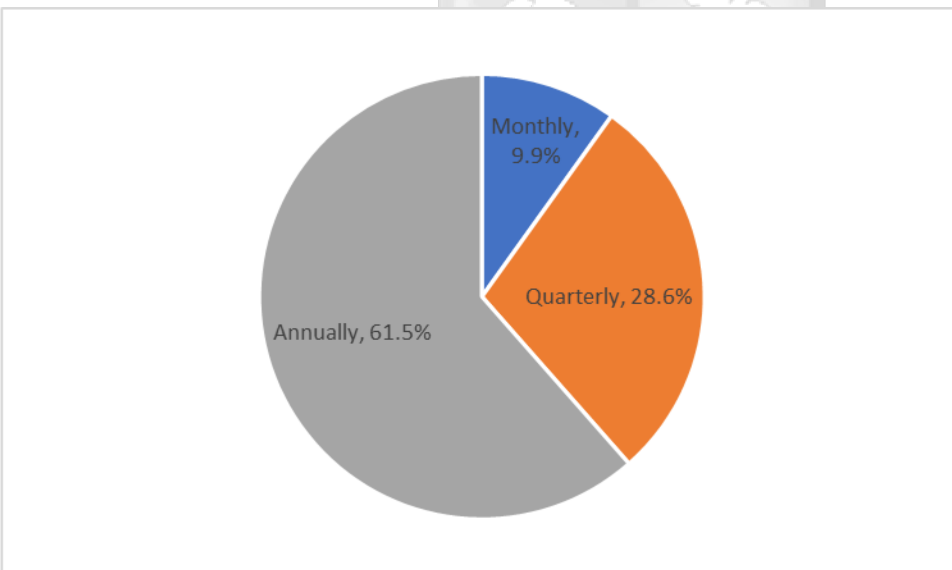


**Figure 4.6 Frequency of Receiving Calls if Yes**

From the study findings, services provided varied support for agroforestry, with technical support for planting and management being the most utilized, cited by 59.5% (n=147), indicating a strong reliance on practical guidance. Training on agroforestry techniques, endorsed by 51.4% (n=127) and access to seedlings or planting materials, noted by 47.8% (n=118), further highlight the importance of hands-on resources and education. Financial assistance or credit, supported by

21.5% (n=53) and marketing assistance for agroforestry products, used by 19.8% (n=49), are less common, suggesting gaps in economic and market-related support. These findings imply that extension services are effective in delivering technical and training support but could expand financial and marketing aid to enhance agroforestry adoption and sustainability, addressing economic barriers faced by farmers (Figure 4.7).

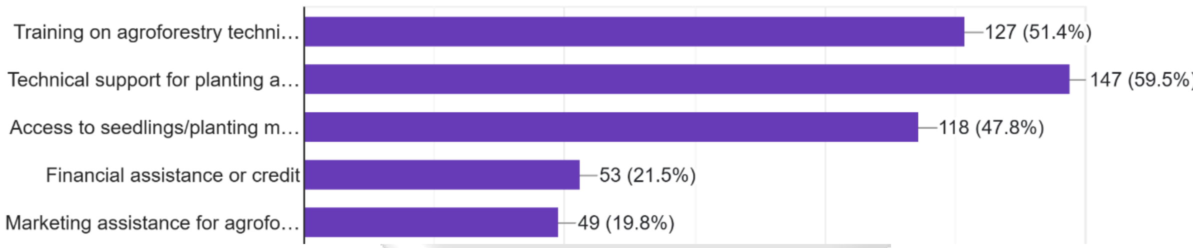


**Figure 4.7 Type of Support the Respondents Receive from Extension Services**

The descriptive statistics revealed varied perceptions regarding the availability and effectiveness of extension services in agroforestry. The mean score for the availability of extension services was 2.36 (SD = 1.395), suggesting moderate accessibility. In terms of receiving adequate training in agroforestry practices, the mean was 2.29 (SD = 1.261), indicating that training may not be sufficient. Extension services' contribution to improving agroforestry practices also had a mean of 2.36 (SD = 1.367), reflecting a moderate level of impact. Market accessibility for agroforestry products due to extension services had a mean of 2.29 (SD = 1.288), indicating limited improvement in market access. Regarding participation in capacity-building opportunities, the mean was 2.39 (SD = 1.312), showing a slight level of engagement. Technical assistance from extension services was rated with a mean of 2.31 (SD = 1.293), suggesting some benefit to farmers' practices. Awareness of government policies supporting agroforestry had a mean score of 2.37 (SD = 1.272), showing moderate awareness. Extension services' impact on increasing knowledge about agroforestry benefits was rated with a mean of 2.33 (SD = 1.287), indicating moderate effectiveness. Lastly, the accessibility and helpfulness of extension services were rated with a mean of 2.35 (SD = 1.348), reflecting moderate satisfaction with their availability and utility. The findings are shown in the Table 4.7.

**Table 4.7 Descriptive Findings on Extension Services**

| | Mean | SD |
|---|---|---|
| Extension services are readily available to me. | 2.36 | 1.395 |
| I have received adequate training in agroforestry practices. | 2.29 | 1.261 |
| Extension services have helped me improve my agroforestry practices. | 2.36 | 1.367 |
| Market accessibility for my agroforestry products has improved due to extension services. | 2.29 | 1.288 |
| I participate in capacity-building opportunities provided by extension services. | 2.39 | 1.312 |
| Technical assistance from extension services has been beneficial to my farm. | 2.31 | 1.293 |
| I am aware of various government policies supporting agroforestry. | 2.37 | 1.272 |
| Extension services have increased my knowledge about agroforestry benefits. | 2.33 | 1.287 |
| I find extension services to be easily accessible and helpful. | 2.35 | 1.348 |

From the key informant interview guides, the respondents had varied perspectives on the role of extension services in promoting agroforestry practices in the region. Some indicated that most extension officers primarily focus on cash crops and livestock, making it difficult to assess their impact on agroforestry. Others noted that extension services play a role in creating awareness about the advantages and disadvantages of agroforestry. However, some respondents stated that there were no agroforestry-specific extension officers in their community. A few acknowledged that extension officers engage with farmers and educate them on the importance of agroforestry, but their overall presence and impact appeared to be limited.

The respondents expressed mixed views on the support provided by extension officers to farmers regarding agroforestry. Some stated that the support was not applicable or non-existent, while others noted that the assistance was minimal, as most farmers prioritized cash crop farming over agroforestry due to financial constraints. A few respondents indicated that extension services were not effective in promoting agroforestry. However, one respondent recalled that, in the past, an extension officer had visited and provided advice on agroforestry practices.

The respondents indicated that extension services were inadequate in supporting farmers to adopt and sustain agroforestry practices. Some noted that there were no extension officers in their community, while others stated that they had not received any extension services and, therefore, could not assess their effectiveness.

The respondents recommended several improvements to extension services to better support agroforestry practices. They suggested that more extension officers should be deployed in communities to assist farmers in improving their skills and expressing their views on agroforestry. Additionally, they emphasized the need for extension officers to create awareness about agroforestry and ensure their presence in all areas. Frequent visits by extension officers were also highlighted as essential for sustained support and guidance.

#### 4.4.4 Descriptive Statistics on Biodiversity Conservation

The study sought to determine the rate of biodiversity conservation and productivity among the respondents. The research first sought to access the distribution of perceived changes in biodiversity on the farms of the respondents over the last 5 years. The majority of the respondents reported noticing changes in biodiversity, accounting for 94.7%(n=305). Respondents who did not notice any changes made up the remaining 5.3% (n=17). This biodiversity change distribution indicates a higher prevalence of farmers observing shifts in biodiversity on their farms, which reflect a greater impact of agroforestry practices, environmental conditions, or land management strategies over the five-year period. The findings are shown in the Table 4.8.

**Table 4.8 Changes in Biodiversity on the Farm for the Last 5 Years**

| | Frequency | Percent |
|---|---|---|
| Yes | 305 | 94.7 |
| No | 17 | 5.3 |
| Total | 322 | 100.0 |

The survey of respondents who observed biodiversity changes through agroforestry indicated that an increase in wildlife presence, such as birds and insects, is the most common outcome, reported by 69.8% (n=217), indicating that agroforestry significantly enhances habitat diversity. Improved soil and water quality, noted by 48.6% (n=151), underscores the practice’s role in ecosystem health, likely due to reduced erosion and enhanced soil structure. An increase in tree species diversity, observed by 44.7% (n=139), reflects successful integration of varied tree species, contributing to ecological resilience. These findings suggest that agroforestry delivers substantial environmental benefits, particularly in supporting wildlife and improving land quality, which aligns with farmers’ motivations like erosion control and soil fertility from prior surveys. The findings are shown in the Figure 4.8.

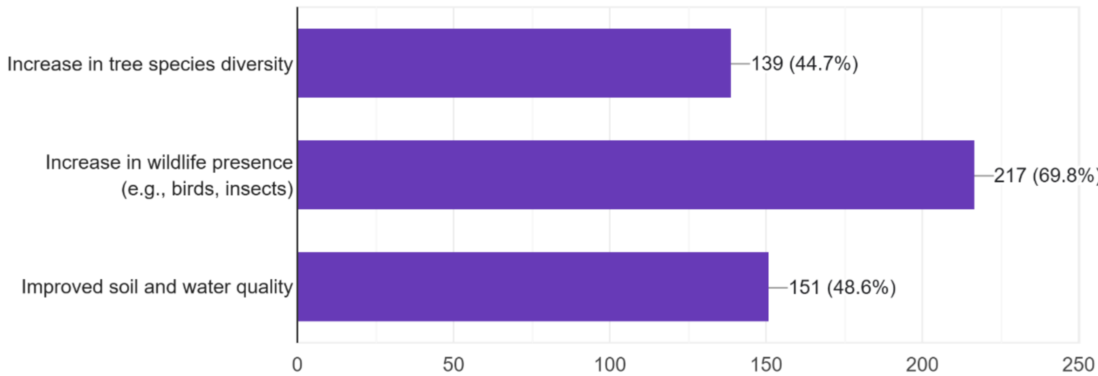


**Figure 4.8 Types of Biodiversity Changes Respondents Observed**

The research sought to determine whether farmers took specific actions to conserve biodiversity on their farms. The majority of respondents (82.6%, n=266) reported engaging in biodiversity conservation efforts, indicating a strong awareness and commitment to sustainable farming practices. This high level of participation suggests that conservation measures, such as agroforestry, crop diversification, soil conservation and wildlife-friendly farming, are widely adopted. The overwhelmingly high percentage of farmers practicing biodiversity conservation implies that agricultural sustainability is a key concern for most respondents, as shown in the Table 4.9.

**Table 4.9 Presence of Specific Actions to Conserve Biodiversity on their Farm**

| | Frequency | Percent |
|---|---|---|
| Yes | 266 | 82.6 |
| No | 56 | 17.4 |
| Total | 322 | 100.0 |

The research revealed that protecting natural habitats, such as wetlands and forest patches, is the most adopted action, reported by 65.8% (n=177), reflecting a strong commitment to preserving existing ecosystems alongside agroforestry. Planting diverse tree species, endorsed by 51.7% (n=139), indicated a focus on enhancing biodiversity, aligning with observed increases in tree species diversity from prior data. Using organic farming methods, cited by 38.3% (n=103), suggested a growing interest in sustainable practices that complement agroforestry goals like soil health and reduced chemical use. These findings imply that farmers are actively engaging in habitat conservation and species diversification, likely driven by observed biodiversity benefits, while organic methods lag, possibly due to knowledge or resource limitations. The findings are presented in the Figure 4.9.

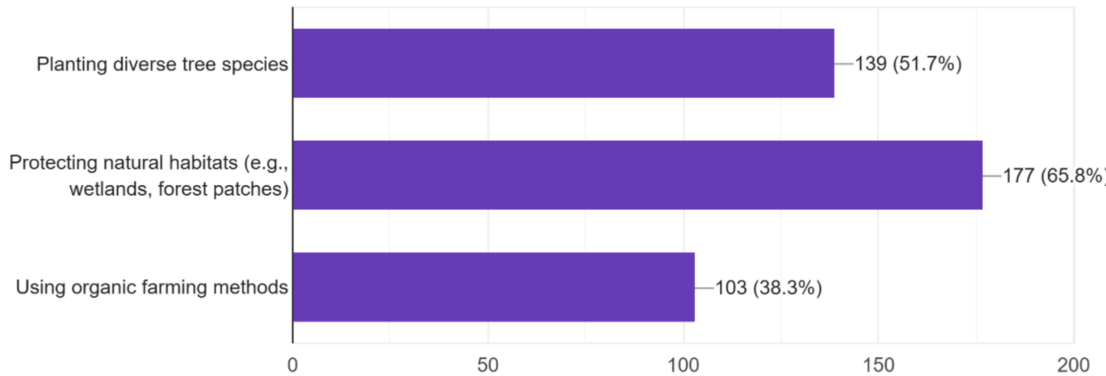


**Figure 4.9 Actions Taken by Respondents**

The descriptive statistics suggest that while some respondents recognize agroforestry as beneficial for biodiversity conservation, there is no overwhelming consensus. The mean score for agroforestry enhancing species diversity was 2.91 (SD = 1.202), suggesting a moderate recognition of its role in species diversity. Regarding agroforestry's contribution to habitat quality, the mean was 2.88 (SD = 1.145), indicating a moderate level of perceived benefit to habitat quality. The importance of biodiversity conservation in agroforestry activities was rated with a mean of 2.93 (SD = 1.195), showing that it is somewhat of a priority. The recognition of increased biodiversity since adopting agroforestry had a mean of 2.87 (SD = 1.149), indicating moderate observation of biodiversity improvements. Agroforestry's role in maintaining ecological balance on the farm was rated with a mean of 2.85 (SD = 1.158), suggesting that it is somewhat effective in this regard. The belief in agroforestry's importance for environmental conservation had a mean of 2.91 (SD = 1.170), showing moderate agreement with its environmental significance. The integration of biodiversity conservation practices into farming methods was rated with a mean of 2.87 (SD = 1.156), reflecting a moderate level of integration. The understanding of agroforestry's biodiversity benefits within the community had a mean score of 2.91 (SD = 1.178), indicating some awareness of its ecological advantages. Finally, the positive impact of agroforestry on wildlife on the farm was rated with a mean of 2.82 (SD = 1.118), reflecting moderate recognition of its benefits for wildlife. The findings are shown in the Table 4.10.

**Table 4.10 Descriptive Findings on Biodiversity Conservation**

| | Mean | SD |
|---|---|---|
| Agroforestry on my farm enhances species diversity. | 2.91 | 1.202 |
| My agroforestry practices contribute to habitat quality. | 2.88 | 1.145 |
| Biodiversity conservation is a priority in my agroforestry activities. | 2.93 | 1.195 |
| I have noticed increased biodiversity since adopting agroforestry. | 2.87 | 1.149 |
| Agroforestry helps in maintaining ecological balance on my farm. | 2.85 | 1.158 |
| I believe agroforestry is crucial for environmental conservation. | 2.91 | 1.170 |
| Biodiversity conservation practices are well integrated into my farming methods. | 2.87 | 1.156 |
| The biodiversity benefits of agroforestry are well understood in my community. | 2.91 | 1.178 |
| Agroforestry has positively impacted wildlife on my farm. | 2.82 | 1.118 |

### 4.4.5 Descriptive Statistics on Productivity

The research sought to determine the types of crops the respondents grew. The survey indicated that beans were the most commonly grown crop, with 75.5% (n=243) cultivating them, closely followed by potatoes at 71.1% (n=229) and maize at 72.4% (n=233), reflecting a strong reliance on staple crops likely suited to agroforestry systems. Horticultural crops, such as tomatoes and carrots, were grown by 55.3% (n=178), suggesting moderate diversification into vegetables. Fruits, however, were cultivated by only 2.2% (n=7), indicating limited adoption of fruit trees, possibly due to longer maturation periods or market challenges. These findings imply that farmers prioritize crops with shorter cycles and immediate food security benefits, aligning with agroforestry practices like integration with livestock or alley cropping. The findings are shown in the Figure 4.10.


**Figure 4.10 Types of Crops Grown by the Respondents**

The research sought to determine the total annual income from agricultural sales among respondents. The largest proportion of farmers (40.4%, n=130) reported earning between Kshs 50,000 and Kshs 100,000 per year, indicating that most respondents generate modest agricultural income, possibly from small to medium-scale farming activities. A significant portion (18%, n=58) reported earning more than Kshs 200,000, suggesting that a subset of farmers engages in high-value or commercial-scale agriculture, benefiting from economies of scale, value addition, or access to better markets. Meanwhile, 16.8% (n=54) earned between Kshs 100,000 and Kshs 150,000 and 13.0% reported annual earnings of Kshs 150,000 to Kshs 200,000, reflecting varying levels of agricultural success. Notably, 11.8% (n=38) of respondents earned less than Kshs 50,000 annually, indicating potential financial vulnerability among smallholder farmers. The findings are shown in the Table 4.11.

**Table 4.11 Respondent's Total Annual Income from Agricultural Sales**

| | Frequency | Percent |
|---|---|---|
| Less than Kshs 50,000 | 38 | 11.8 |
| Kshs 50,000 - Kshs 100,000 | 130 | 40.4 |
| Kshs 100,000 - Kshs 150,000 | 54 | 16.8 |
| Kshs 150,000 - Kshs 200,000 | 42 | 13.0 |
| More than Kshs 200,000 | 58 | 18.0 |
| Total | 322 | 100.0 |

The research sought to determine the proportion of farm area allocated to agroforestry among respondents. The largest share of farmers (40.7%, n=131) allocated between 25% and 50% of their farm area to agroforestry, indicating a balanced integration of tree-based farming with other agricultural activities. This suggests that many farmers recognized the benefits of agroforestry but still dedicate a significant portion of their land to other crops or livestock. A substantial number of respondents (30.1%, n=97) allocated less than 25% of their farm area to agroforestry, which indicated a preference for conventional farming practices or limited awareness of the potential benefits of agroforestry systems. Conversely, 15.2% (n=49) of farmers allocated more than 75% of their land to agroforestry, demonstrating a strong commitment to tree-based agriculture, which may be driven by environmental sustainability efforts, market incentives, or land suitability. Meanwhile, 14% (n=45) of respondents allocated between 51% and 75% of their farm area to agroforestry, reflecting a significant but not dominant emphasis on tree-based farming. The findings are shown in the Table 4.12.

**Table 4.12 Percentage of Respondent's Farm Area Allocated to Agroforestry**

| | Frequency | Percent |
|---|---|---|
| Less than 25% | 97 | 30.1 |
| 25% - 50% | 131 | 40.7 |
| 51% - 75% | 45 | 14.0 |
| More than 75% | 49 | 15.2 |
| Total | 322 | 100.0 |

The descriptive statistics revealed diverse perceptions regarding the effects of agroforestry on farm productivity and economic factors. The change in crop yield since adopting agroforestry practices had a mean of 2.17 (SD = 0.738), suggesting only a slight improvement in output. Labour requirements showed a mean of 2.30 (SD = 0.777), indicating a modest increase in the effort needed. Changes in farm input costs had a mean of 2.43 (SD = 0.884), reflecting a slight decrease or stabilization in expenses such as fertilizers and pesticides. The effect of agroforestry on overall farm income was rated with a mean of 2.33 (SD = 0.792), pointing to a small but positive economic impact. The findings are shown in the Table 4.13.

**Table 4.13 Descriptive Statistics on Productivity**

| | Mean | SD |
|---|---|---|
| How has crop yield (kilograms per acre) changed since adopting agroforestry practices? | 2.17 | .738 |
| Has the labour required on your farm changed due to agroforestry practices? | 2.30 | .777 |
| How have your farm input costs (e.g., fertilizer, pesticides) changed since adopting agroforestry? | 2.43 | .884 |
| How has agroforestry affected your overall farm income? | 2.33 | .792 |

The research sought to determine the level of productivity of the respondents. The research first sought to discuss the proportion of total income derived from agroforestry products among respondents. The largest share of respondents (48.4%, n=156) indicated that between 25% and 50% of their total income comes from agroforestry, suggesting that agroforestry plays a supplementary but significant role in household income generation. This indicates that for many farmers, agroforestry is an important but not dominant source of earnings.

A notable proportion (23.3%, n=75) reported that less than 25% of their income comes from agroforestry products, implying that the majority of their revenue is derived from other agricultural activities or non-farm sources. Meanwhile, 20.5% (n=66) of respondents indicated that between 51% and 75% of their income is generated from agroforestry, highlighting a more substantial reliance on tree-based farming for financial sustainability. Only 7.8% (n=25) of respondents reported that more than 75% of their income comes from agroforestry, indicating that few farmers depend almost entirely on this sector. The results are shown in the Table 4.14.

**Table 4.14 Proportion of Respondent's Total Income Coming from Agroforestry Products**

| | Frequency | Percent |
|---|---|---|
| Less than 25% | 75 | 23.3 |
| 25% - 50% | 156 | 48.4 |
| 51% - 75% | 66 | 20.5 |
| More than 75% | 25 | 7.8 |
| Total | 322 | 100.0 |

The research sought to determine the types of products the respondents harvested from agroforestry practices. The survey revealed that firewood was the most harvested product from agroforestry practices, with 80.1% (n=258) utilizing it, reflecting its widespread demand for energy needs. Fruits followed closely, cited by 72.7% (n=234), suggesting significant integration of fruit trees despite their lower cultivation rates in crop surveys, possibly due to agroforestry's long-term benefits. Timber, harvested by 53.4% (n=172), indicated a moderate focus on wood products, likely for construction or sale. Fodder, however, is the least harvested, with only 18.3% (n=59), which contrasts with the popularity of livestock integration, hinting at potential underutilization of forage resources. These findings imply that agroforestry is highly valued for fuel and fruit production, aligning with economic and subsistence needs, while fodder harvesting could be enhanced through targeted support like training or improved fodder tree species. The results are shown in the Figure 4.11.

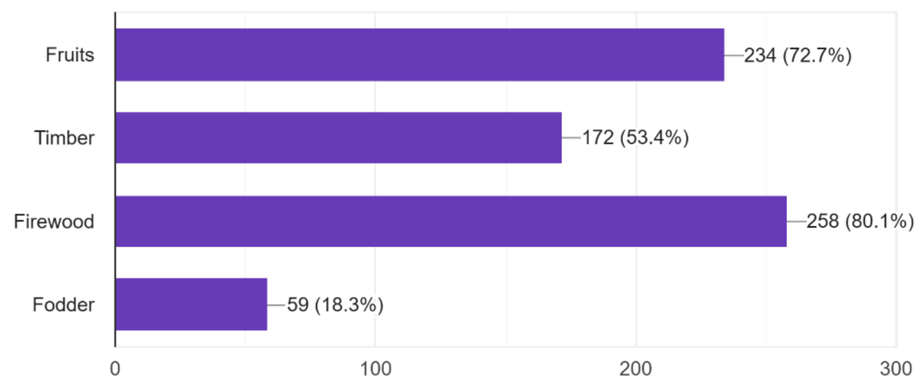


**Figure 4.11 Types of Products the Respondents Harvest from Agroforestry Practices**

The research sought to access the average annual income generated from agroforestry products among respondents. The largest proportion of respondents (44.1%, n=142) reported earning between Kshs 10,000 and Kshs 25,000 annually from agroforestry, suggesting that for many, agroforestry contributes a modest but significant portion of their farm-based income. Similarly, 43.8% (n=141) of respondents earned between Kshs 25,000 and Kshs 50,000, indicating that nearly half of the farmers derive moderate revenue from agroforestry activities. A smaller percentage (7.1%, n=23) of respondents reported earning less than Kshs 10,000, suggesting that some farmers may engage in agroforestry at a minimal level or face challenges in profitability.

Notably, only 5.0% (n=16) of respondents reported earning more than Kshs 100,000 annually from agroforestry, indicating that high-income generation from this sector remains relatively uncommon. These findings highlight the potential of agroforestry as a supplemental income source for many farmers. The findings are shown in the Table 4.15.

**Table 4.15 Respondent's Average Annual Income Generated from Agroforestry Products**

| | Frequency | Percent |
|---|---|---|
| Less than Kshs 10,000 | 23 | 7.1 |
| Kshs 10,000 - Kshs 25,000 | 142 | 44.1 |
| Kshs 25,000 - Kshs 50,000 | 141 | 43.8 |
| More than Kshs 100,000 | 16 | 5.0 |
| Total | 322 | 100.0 |

The study sought to determine the respondents' perceptions of how agroforestry had impacted their access to on-farm resources such as firewood, fodder and fruits. The majority of respondents (67.1%, n=216) indicated that their access to these resources had increased slightly, suggesting that agroforestry provides a steady but moderate improvement in resource availability. Additionally, 13.0% (n=42) of respondents reported that their access had increased significantly, highlighting that for some farmers, agroforestry played a crucial role in resource sustainability. Conversely, 16.1% (n=52) of respondents stated that their access had seen no change, indicating that agroforestry may not always lead to immediate or noticeable resource improvements, possibly due to factors such as tree maturity periods or land constraints. A small proportion (3.7%, n=12) reported a decrease in resource availability, which may be attributed to competition for land use, improper species selection, or management challenges. These findings emphasize the positive role of agroforestry in enhancing resource accessibility for most farmers. The findings are shown in the Table 4.16.

**Table 4.16 Impact of Agroforestry on Respondent's Access to On-farm Resources**

| | Frequency | Percent |
|---|---|---|
| Increased significantly | 42 | 13.0 |
| Increased slightly | 216 | 67.1 |
| No change | 52 | 16.1 |
| Decreased | 12 | 3.7 |

| | | |
|---|---|---|
| Total | 322 | 100.0 |

The study sought to determine the respondents' perceptions of how agroforestry had affected their overall farm productivity. The majority of respondents (61.5%, n=198) reported that agroforestry had increased their farm productivity slightly, suggesting that while agroforestry practices contribute positively to yields and land efficiency, the improvements might be gradual or moderate. Additionally, 12.1% (n=39) of respondents indicated that agroforestry had significantly increased their farm productivity, demonstrating that for some farmers, agroforestry plays a crucial role in enhancing agricultural output. However, 20.2% (n=65) of respondents observed no change in their farm productivity, indicating that agroforestry's benefits may not always be immediately visible, possibly due to factors such as long tree growth cycles, poor integration of tree and crop systems, or suboptimal species selection. Meanwhile, 6.2% (n=20) of respondents reported a decrease in farm productivity, which may be attributed to competition for land, water and nutrients between trees and crops or mismanagement of agroforestry practices. The findings are presented in the Table 4.17.

**Table 4.17 How Agroforestry Affected Overall Farm Productivity**

| | Frequency | Percent |
|---|---|---|
| Increased significantly | 39 | 12.1 |
| Increased slightly | 198 | 61.5 |
| No change | 65 | 20.2 |
| Decreased | 20 | 6.2 |
| Total | 322 | 100.0 |

The study sought to assess the main challenges the respondents face in improving productivity through Agroforestry. The survey identified lack of knowledge or technical skills as the primary challenge in improving productivity through agroforestry, cited by 53.7% (n=173), highlighting a critical need for enhanced training programs. Limited access to markets, reported by 44.7% (n=144), suggesting that farmers struggle to sell agroforestry products like fruits and timber, potentially discouraging adoption. High input costs, noted by 29.2% (n=94), indicate financial barriers in acquiring resources like seedlings or tools, while pests and diseases, affecting 23.9%

(n=77), point to ecological challenges that may reduce yields. The findings are shown in the Figure 4.12.

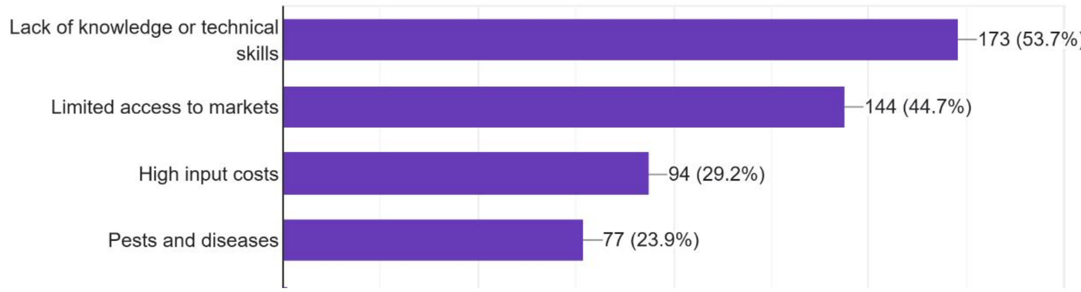


**Figure 4.12 Main Challenges in Improving Productivity through Agroforestry**

The descriptive statistics reveal that ecosystem services such as water retention, soil erosion reduction, pest control and carbon sequestration are perceived differently in terms of their impact. Water retention had the highest mean rating of 2.80 (SD = 1.115), indicating a relatively strong perceived benefit. Soil erosion reduction followed with a mean of 2.66 (SD = 1.018), while pest control was rated slightly lower at 2.61 (SD = 1.103). Carbon sequestration, such as through shade and tree cover, had the lowest mean of 2.39 (SD = 1.131), suggesting it was the least acknowledged benefit among the listed environmental outcomes. The findings are shown in the Table 4.18.

**Table 4.18 Descriptive Findings on Environmental Productivity**

| | Mean | SD |
|---|---|---|
| Water retention | 2.80 | 1.115 |
| Soil erosion reduction | 2.66 | 1.018 |
| Pest control | 2.61 | 1.103 |
| Carbon sequestration (e.g., shade and trees) | 2.39 | 1.131 |

From the key informant interview guide, the respondents indicated that agroforestry contributes to biodiversity conservation in Mt. Elgon Sub-County by providing natural habitats for wildlife, insects, birds and pollinators. They also noted that agroforestry supports livestock by serving as a source of income, as some farmers sell firewood to purchase fodder such as Napier grass. Additionally, agroforestry was recognized for its role in soil conservation, further enhancing environmental sustainability.

The respondents indicated that agroforestry practices have led to improvements in biodiversity indicators such as pollinators, wildlife and soil conservation. They highlighted that soil health has improved due to reduced soil erosion, which in turn has contributed to increased agricultural productivity. Additionally, they acknowledged that agroforestry enhances overall environmental sustainability by supporting ecosystem balance.

The respondents stated that most farmers do not understand the importance of biodiversity conservation. They emphasized the need for extension officers to educate farmers and provide collective solutions to enhance awareness. According to them, the presence of agroforestry extension officers would help bridge this knowledge gap by creating awareness and promoting sustainable farming practices.

The respondents identified several challenges in balancing biodiversity conservation with farm productivity. They highlighted inadequate habitats and the lack of wildlife protection as key concerns. Additionally, they pointed out that costly labour, financial constraints and a lack of knowledge about agroforestry hinder efforts to integrate biodiversity conservation with farming. Pests and diseases were also mentioned as significant obstacles affecting both conservation and productivity.

The study sought to determine the respondents' observations on seasonal differences in productivity due to agroforestry practices. The vast majority (82.3%, n=265) indicated that they observed seasonal variations in productivity, suggesting that agroforestry is highly sensitive to climatic conditions such as rainfall patterns, temperature fluctuations and seasonal growth cycles of trees and crops. Conversely, 17.7% (n=57) of the respondents reported no seasonal differences in productivity, implying that some agroforestry systems may provide year-round benefits or that farmers have implemented effective strategies to stabilize output. The results are shown in the Table 4.19.

**Table 4.19 Seasonal Differences in Productivity Due to Agroforestry Practices**

| | Frequency | Percent |
|---|---|---|
| Yes | 265 | 82.3 |
| No | 57 | 17.7 |
| Total | 322 | 100.0 |

From the key informant interview guides, the respondents stated that while there are government policies and programs aimed at supporting agroforestry and biodiversity conservation in Mt. Elgon, they are largely ineffective. They emphasized that although such initiatives exist, they have not yielded meaningful results in promoting agroforestry or biodiversity conservation in the region.

The respondents stated that local organizations, cooperatives and community groups primarily play a role in creating awareness about agroforestry and its impacts. However, they also noted that many of these organizations tend to focus more on cash crop production rather than promoting agroforestry and biodiversity conservation. The respondents suggested that deforestation in the region should be prohibited as a necessary policy intervention to enhance agroforestry adoption and biodiversity conservation. More trees should be planted to enhance the productivity of smallholder farmers through agroforestry in Mt. Elgon Sub-County. They also emphasized the need for more extension officers, suggesting that they should be available at least once a month and easily accessible so that farmers can express their views and receive necessary support.

### 4.5 Regression Analysis Findings

#### 4.5.1 Regression Analysis Model without Moderator

The regression analysis aimed to examine the relationship between agroforestry practices and the productivity of smallholder farmers in Mt. Elgon, Kenya. The model was specified as follows: $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \varepsilon$, where Y represents productivity, $X_1$ is the type of agroforestry, $X_2$ is the scale of implementation, $X_3$ is extension services, $X_4$ is biodiversity conservation, $\beta_0$ is the constant and $\varepsilon$ is the error term. The model summary revealed a strong positive correlation (R = 0.898), with approximately 80.6% of the variation in productivity explained by the independent variables ($R^2 = 0.806$). The adjusted $R^2$ of 0.803 confirmed the model's robustness and the standard error of 0.30308 indicated a relatively small prediction error (Table 4.20).

**Table 4.20 Regression Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .898[a] | .806 | .803 | .30308 |

a. Predictors: (Constant), Biodiversity Conservation, Type of Agroforestry, Extension Services, Scale of Implementation

The ANOVA results show that the model is statistically significant, $F(4, 317) = 328.853$, $p < 0.001$, indicating that at least one of the independent variables significantly influences productivity. This justifies the inclusion of the selected predictors in explaining variations in productivity (Table 4.21).

**Table 4.21 Regression ANOVA**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 120.828 | 4 | 30.207 | 328.853 | .000[b] |
| | Residual | 29.118 | 317 | .092 | | |
| | Total | 149.946 | 321 | | | |

a. Dependent Variable: Productivity

b. Predictors: (Constant), Biodiversity Conservation, Type of Agroforestry, Extension Services, Scale of Implementation

The regression analysis was conducted to determine the relationship between agroforestry practices, implementation scale, extension services and biodiversity conservation on productivity. The initial model, presented in Table 4.22, indicates that all four independent variables - Type of Agroforestry, Scale of Implementation, Extension Services and Biodiversity Conservation - significantly influence productivity ($p < 0.05$). Scale of Implementation ($B = 0.325$, $p < 0.001$) had the strongest positive impact on productivity, suggesting that larger-scale agroforestry practices lead to higher productivity levels. Type of Agroforestry ($B = 0.292$, $p < 0.001$) also had a substantial influence, indicating that the choice of agroforestry techniques significantly affects productivity outcomes. Extension Services ($B = 0.140$, $p = 0.024$) and Biodiversity Conservation ($B = 0.059$, $p = 0.015$) were statistically significant but had smaller effects compared to the other variables, implying that while they contribute to productivity, their impact is relatively lower.

**Table 4.22 Regression Coefficients**

| Model | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Error | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 1.163 | .067 | | 17.493 | .000 |
| | Type of Agroforestry | .292 | .038 | .405 | 7.574 | .000 |
| | Scale of Implementation | .325 | .041 | .496 | 7.955 | .000 |
| | Extension Services | .140 | .034 | .161 | 2.177 | .024 |
| | Biodiversity Conservation | .059 | .048 | .089 | 2.241 | .015 |

a. Dependent Variable: Productivity

### 4.5.2 Regression Analysis with Moderation Effect

The model summary indicates that incorporating the moderation effect improved the model's explanatory power. The R Square value increased to 0.821, meaning that 82.1% of the variation in productivity is now explained by the independent variables and their interactions with the moderating variable. The adjusted R Square value of 0.817 confirms the model's robustness even after adding interaction terms. The standard error of the estimate remains low at 0.295, indicating that the model predictions are close to the actual values (Table 4.23).

**Table 4.23 Moderated Regression Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.906 | 0.821 | 0.817 | 0.295 |

a. Predictors: (Constant), Biodiversity Conservation, Type of Agroforestry, Extension Services, Scale of Implementation, $X_1 * X_4$, $X_2 * X_4$, $X_3 * X_4$

The ANOVA results confirm that the model remains statistically significant, $F(7, 314) = 246.735$, $p < 0.001$, showing that the inclusion of interaction terms improves the model's predictive capability. This suggests that the moderating variable plays a meaningful role in influencing productivity.

**Table 4.24 Moderated Regression ANOVA Results**

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 123.058 | 7 | 17.580 | 246.735 | 0.000 |
| Residual | 26.888 | 314 | 0.086 | | |
| Total | 149.946 | 321 | | | |

a. Dependent Variable: Productivity

b. Predictors: (Constant), Biodiversity Conservation, Type of Agroforestry, Extension Services, Scale of Implementation, $X_1 * X_4$, $X_2 * X_4$, $X_3 * X_4$

After introducing the moderating variable and interaction terms, Table 4.25 shows an improved model fit and changes in coefficient magnitudes. The coefficients for Type of Agroforestry (B = 0.356, $p < 0.001$) and Scale of Implementation (B = 0.398, $p < 0.001$) increased, reinforcing their critical role in enhancing productivity. Extension Services (B = 0.145, p = 0.022) and Biodiversity Conservation (B = 0.572, p = 0.001) remained significant, with biodiversity conservation showing a stronger effect compared to the non-moderated model, indicating that its impact on productivity becomes more pronounced when interactions are considered.

The interaction terms further explain the moderating effect. Type of Agroforestry * Scale of Implementation (B = 0.412, $p < 0.001$) had a strong positive effect, suggesting that when agroforestry is implemented at a larger scale, its benefits to productivity are significantly amplified. Similarly, Scale of Implementation * Biodiversity Conservation (B = 0.487, p = 0.041) was positive and significant, indicating that biodiversity conservation enhances productivity when agroforestry practices are expanded. Lastly, Extension Services * Biodiversity Conservation (B = 0.164, $p < 0.001$) was significant, demonstrating that the combined effect of extension services and biodiversity conservation further strengthens productivity outcomes.

**Table 4.25 Moderated Regression Coefficients**

| Model | Unstandardized Coefficients (B) | Std. Error | Standardized Coefficients (Beta) | t | Sig. |
|---|---|---|---|---|---|
| (Constant) | 1.102 | 0.072 | | 15.306 | 0.000 |
| Type of Agroforestry | 0.356 | 0.037 | 0.354 | 6.919 | 0.000 |
| Scale of Implementation | 0.398 | 0.039 | 0.455 | 7.641 | 0.000 |
| Extension Services | 0.145 | 0.036 | 0.168 | 2.250 | 0.022 |
| Biodiversity Conservation | 0.572 | 0.049 | 0.508 | 3.357 | 0.001 |
| Type of Agroforestry * Biodiversity Conservation | 0.412 | 0.028 | 0.468 | 3.964 | 0.000 |
| Scale of Implementation * Biodiversity Conservation | 0.487 | 0.042 | 0.429 | 2.052 | 0.041 |
| Extension Services * Biodiversity Conservation | 0.164 | 0.037 | 0.195 | 4.696 | 0.000 |

a. Dependent Variable: Productivity

The findings confirm that all independent variables positively influence productivity, with scale of implementation having the most substantial direct effect. The introduction of interaction terms reveals that the moderating variable (biodiversity conservation) enhances the effects of scale of implementation and extension services on productivity, indicating that biodiversity conservation plays a critical role in maximizing agroforestry benefits. These results suggest that expanding agroforestry practices, investing in extension services and integrating biodiversity conservation strategies would significantly enhance productivity levels.

## CHAPTER FIVE

## DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Introduction

This chapter discusses the research findings, concludes on the research findings as well as the recommendations of the research. The research discussions are based on the specific objectives. Specifically, the research analyzes the effect of type of agroforestry, scale of agroforestry implementation and utilization of extension services, as well as the moderating effect of biodiversity conservation on the relationship between agroforestry practices and productivity.

### 5.2 Discussions

#### 5.2.1 Type of Agroforestry and Productivity

The findings reveal mixed perceptions about agroforestry practices among Kenyan farmers, with moderate adoption rates across various dimensions. Tree diversity was perceived as moderate, indicating small to medium extent of diversity. This aligns with De Giusti et al.'s (2019) research in Kenya, which emphasized the integration of specific tree species like Grevillea robusta with crops such as maize and beans. The moderate tree diversity observed in both studies suggests that while farmers recognize the potential benefits of agroforestry, implementation remains limited to familiar species, potentially constraining the full range of ecosystem services that could be achieved through greater biodiversity in agroforestry systems.

The data indicates moderate crop integration within agroforestry systems, with most respondents practicing it to a small or medium extent. This finding corresponds with Araya et al.'s (2023) study in Malawi, which demonstrated how integrating macadamia trees with traditional crops enhances soil health through increased organic matter and nutrient cycling. Both studies highlight the potential for improved integration, suggesting that farmers could benefit from greater knowledge transfer regarding optimal crop combinations within agroforestry systems to maximize productivity and ecosystem benefits. The moderate adoption rates point to opportunities for enhanced extension services focused on crop diversification strategies.

Livestock integration within agroforestry systems showed varied adoption rates, with most respondents integrating livestock to a great or very great extent. This practice aligns with Miller et al.'s (2020) systematic review, which identified agrosilvopastoral systems as enhancing agricultural productivity by improving soil fertility and biodiversity. The findings from both studies emphasize the potential of livestock integration in creating synergistic effects within agroforestry systems. However, the current moderate adoption rates suggest that many farmers may not fully understand or be able to implement the complex management practices required for successful livestock integration, indicating a need for targeted training and support in this area.

Farmers' perception of agroforestry as a sustainability tool was moderately positive, with a majority agreeing to a great or very great extent. This perception corresponds with Kassa's (2022) research, which identified agroforestry as an eco-friendly approach enhancing climate change resilience while increasing agricultural productivity for smallholder farmers. Both studies highlight farmers' recognition of agroforestry's sustainability benefits, yet the moderate agreement levels suggest that many farmers may not fully comprehend the long-term ecological advantages. This indicates an opportunity for educational initiatives that demonstrate the comprehensive sustainability impacts of agroforestry practices, particularly in relation to climate resilience and ecological health.

Regarding soil health improvement through agroforestry, majority of respondents agreed to a great or very great extent. This finding is consistent with Yasin et al.'s (2023) research in Pakistan, which found that traditional agroforestry systems preserve soil fertility and water resources while reducing climate change effects. Both studies highlight the soil enhancement benefits of agroforestry, yet the moderate agreement levels in the Kenyan context suggest that many farmers may not be implementing soil-focused agroforestry practices optimally. This gap represents an opportunity for knowledge dissemination about specific tree species and management practices that maximize soil health benefits, potentially leading to greater adoption of these techniques.

The integration of trees and crops benefiting farm productivity was acknowledged by most of respondents to a great or very great extent. This aligns with Lehmann et al.'s (2020) study, which found that integrating fruit trees with vegetables enhanced overall farm productivity while maintaining ecosystem health. Both studies recognize the productivity benefits of tree-crop integration, yet the moderate agreement levels in Kenya suggest that farmers may be experiencing competition effects between trees and crops, or may lack the technical knowledge to optimize these interactions. This highlights the need for context-specific research and training on compatible tree-crop combinations and management practices to maximize synergistic rather than competitive relationships.

Income diversification through agroforestry was viewed positively by most respondents to a great or very great extent. This perception corresponds with Telwala's (2023) research in rural India, which found that home gardens combining fruit trees, vegetables and medicinal plants enhance biodiversity and provide households with diverse food and income sources. Both studies emphasize agroforestry's potential for economic diversification, yet the moderate agreement level in Kenya suggests that many farmers may not be fully capitalizing on the multiple income streams possible through agroforestry products. This indicates an opportunity for market development initiatives and value chain support for agroforestry products to enhance the economic benefits perceived by farmers.

Farmers' understanding of agroforestry systems showed moderate levels, with majority indicating good understanding to a great or very great extent. This finding relates to Willmott et al.'s (2023) research, which highlighted a research gap in region-specific studies to better understand localized impacts of agroforestry practices. Both studies point to knowledge limitations as barriers to optimal agroforestry implementation. The moderate understanding levels among Kenyan farmers suggest that extension services and farmer education programs have been somewhat effective but could be significantly enhanced to improve technical knowledge transfer. Targeted training programs that incorporate local knowledge systems while introducing innovative agroforestry techniques could address this gap.

The inclusion of various tree and plant species showed moderate adoption, with most respondents practicing it to a great or very great extent. This finding connects with Alifa et al.'s (2024) research, which emphasized the integration of specific tree species like Leucaena leucocephala and Gliricidia sepium to improve soil health and biodiversity conservation. Both studies recognize the importance of species selection in agroforestry success, yet the moderate adoption rates in Kenya suggest limited species diversity in current practices. This indicates a need for initiatives promoting a wider range of suitable tree species, particularly those with multiple benefits such as nitrogen fixation, fodder production and marketable products, to encourage greater diversification within agroforestry systems.

The open-ended responses and key informant interviews revealed specific agroforestry practices considered most effective, including riparian buffer strips, agro-silviculture and agrosilvopastoral systems. These findings complement Miller et al.'s (2020) systematic review, which found that various agroforestry types contribute positively to human well-being by increasing income and food security. Both sources highlight the multifunctional benefits of agroforestry, from economic advantages to ecological services such as soil conservation and erosion control. However, the emphasis on specific practices like riparian buffer strips in swampy areas in the Kenyan context underscores the importance of site-specific agroforestry solutions tailored to local environmental conditions and farming systems, supporting Willmott et al.'s (2023) call for region-specific agroforestry research and implementation strategies.

The findings from this section are strongly underpinned by the theoretical foundations guiding the study. The theory of agroforestry systems supports the observed link between the integration of trees, crops and livestock and enhanced farm productivity and sustainability. The farmers' adoption patterns and perceptions ranging from moderate tree diversity to varied levels of livestock integration reflect the principles of this theory, which emphasize the multifunctionality of agroforestry. The theory of planned behaviour explains the moderate adoption levels by illustrating how attitudes, subjective norms and perceived behavioural control influence farmers' decisions, particularly where technical knowledge or support is limited. The role of resource dependence theory is evident in the constrained adoption of crop diversification and species selection, pointing to gaps in access to knowledge, inputs and institutional support.

### 5.2.2 Scale of Implementation and Productivity

The findings reveal that the majority of respondents have fewer than 50 trees on their farms. This distribution aligns with Gosling et al.'s (2021) research on socio-economic factors driving agroforestry adoption, which identified significant barriers due to the labour-intensive nature of agroforestry systems compared to conventional practices. The prevalence of farms with fewer trees suggests that labour constraints identified by Gosling et al. may indeed be influencing farmers' decisions regarding tree integration in Kenya. This correlation is further supported by the study's key informant interviews, which explicitly mentioned labour demands as challenges farmers face in scaling up agroforestry practices, demonstrating how resource limitations directly impact the extent of tree integration within agricultural systems.

Despite the limited number of trees per farm, the research indicates that most respondents practiced large-scale agroforestry on more than 5 acres, suggesting significant land allocation to agroforestry systems. This finding appears to contradict Nyberg et al.'s (2020) study within the Kenya Agricultural Carbon Project, which emphasized the importance of both landholding extent and relative size of agroforestry plots for improved outcomes. The apparent contradiction may be explained by understanding that while farmers have allocated large land areas to agroforestry, the tree density remains relatively low. This suggests that farmers may be practicing extensive rather than intensive agroforestry, potentially limiting the soil fertility benefits and productivity gains that Nyberg et al. identified as resulting from more robust agroforestry implementation with greater tree integration per unit area.

The study found that a majority of respondents indicated their landholding size allows for agroforestry to only a small or no extent. This finding contradicts the high percentage of respondents practicing large-scale agroforestry, suggesting a perceptual disconnect between actual land availability and perceived constraints. This complexity aligns with Castle et al.'s (2022) systematic review, which emphasized that both the relative size of agroforestry plots and landholding extent significantly impact outcomes. The contradiction between perceived land constraints and reported large-scale implementation suggests that farmers may be implementing agroforestry at suboptimal intensity levels, potentially explaining the limited biodiversity and productivity benefits reported elsewhere in the study. This highlights the need for education on intensive agroforestry practices that maximize benefits even on limited landholdings.

The research reveals that most of respondents allocate a significant portion of their land to agroforestry only to a small or no extent, reflecting land competition with other agricultural activities. This finding is consistent with Duffy et al.'s (2021) research in Indonesia, which demonstrated that larger and more diversified agroforestry systems improved household food availability and increased income sources. The limited land allocation observed in the current study may explain why many farmers fail to realize the full benefits of agroforestry that Duffy et al. documented. The perceived competition between agroforestry and other agricultural activities suggests that farmers may not fully appreciate the complementary nature of well-designed agroforestry systems, indicating a need for demonstration projects that showcase how integrated approaches can enhance overall farm productivity rather than competing with other agricultural pursuits.

The findings indicate that majority of respondents considered their agroforestry plots inadequate to meet their needs to a small or no extent. This perception aligns with Cialdella et al.'s (2023) research, which emphasized the importance of appropriate scale in achieving economic benefits from agroforestry. The inadequacy reported by farmers suggests they may not be realizing the economic returns through diversified product outputs that Cialdella et al. identified as potential benefits of well-implemented agroforestry. This perception of inadequacy, despite the reported large-scale implementation (over 5 acres), further suggests that farmers may be implementing agroforestry systems that are extensive in area but lacking in diversity or intensity, limiting their economic potential. This highlights the need for economic incentives and supportive policy frameworks, as recommended by Cialdella et al., to encourage more intensive and diverse agroforestry practices.

The study found that most respondents had expanded their agroforestry practices over the years to only a small or no extent. This limited expansion corresponds with Gosling et al.'s (2021) identification of labour constraints as a significant barrier to agroforestry adoption. The key informant interviews in the current study explicitly mention labour demands and financial constraints as challenges to scaling up agroforestry, directly validating Gosling et al.'s findings. The consistency between these findings underscores how practical resource limitations continue to constrain agroforestry expansion despite awareness of its benefits. This suggests that successful scaling of agroforestry in Kenya may require addressing these fundamental resource constraints through labour-saving technologies, financial support mechanisms, or community-based approaches that distribute labour demands across multiple households.

Regarding the impact of agroforestry on agricultural yield, majority of respondents indicated that agroforestry influenced their yield to only a small or no extent. This perceived limited impact contrasts with Nyberg et al.'s (2020) findings that agroforestry significantly enhances soil fertility and increases farm productivity. This discrepancy may be explained by inadequate implementation intensity or inappropriate agroforestry designs that fail to optimize tree-crop interactions. The gap between scientific evidence and farmer perception highlights the need for context-specific agroforestry models that demonstrate clear productivity benefits under local conditions. Nyberg et al. emphasized the importance of integrating agroforestry into broader agricultural policies, suggesting that the limited yield impacts reported in the current study may reflect a lack of supportive policy frameworks that would enable farmers to implement more effective agroforestry systems.

The findings show that most respondents believed their land allocation to agroforestry was optimal for productivity to only a small or no extent. This perception aligns with Castle et al.'s (2022) systematic review, which found that optimal land allocation significantly impacts soil health and productivity outcomes in agroforestry systems. The low perception of optimization in the current study suggests that farmers may lack the technical knowledge to design agroforestry systems that maximize complementary interactions between trees and crops. This interpretation is supported by the key informant interviews, which identified a lack of knowledge about agroforestry as a barrier to adoption, emphasizing that "farmers should be educated on the positive impacts of agroforestry." The alignment between these findings highlights the critical importance of farmer education and extension services in improving agroforestry outcomes through optimized land allocation strategies.

The study found that most of respondents indicated that agroforestry implementation on their farms met their expectations to only a small or no extent. This widespread disappointment with agroforestry outcomes contradicts the positive potentials identified across multiple studies in the literature review. Particularly, it contrasts with Duffy et al.'s (2021) findings that agroforestry systems significantly enhance food production and bolster farmers' resilience to climate variability. The gap between expected and realized benefits suggests implementation challenges that prevent farmers from achieving the theoretical advantages of agroforestry. Key informant interviews corroborate this interpretation, noting that "limited finances could hinder adoption" and identifying "challenges posed by pests and diseases" as factors affecting agroforestry implementation. This disconnects between expected and realized benefits underscores the need for holistic support systems that address the multiple constraints limiting effective agroforestry implementation.

The finding that majority of respondents believed agroforestry supported biodiversity to only a small or no extent contrasts with Castle et al.'s (2022) review, which emphasized agroforestry's crucial role in biodiversity conservation. This perception gap suggests that the agroforestry systems being implemented may lack the diversity and structural complexity needed to support significant biodiversity improvements. The contradiction between scientific evidence and farmer perception highlights the need for biodiversity-focused agroforestry designs that create visible ecological improvements. The key informant interviews revealed that programs supporting agroforestry expansion had limited effectiveness, with “low farmer participation” discouraging their continuation and most initiatives being “disrupted due to environmental challenges.” This programmatic weakness may explain why farmers are not implementing biodiversity-enhancing agroforestry designs, suggesting that more effective extension services and demonstration projects are needed to showcase biodiversity benefits in local contexts.

The observed trends in the scale of agroforestry implementation and perceived productivity align with the theory of agroforestry systems, which emphasizes that ecological and economic benefits depend on the intensity and diversity of tree-crop integration, elements notably lacking in the extensive yet low-density systems described. The widespread mention of labour, land and financial constraints among respondents also reflects the resource dependence theory, which posits that farmers’ ability to implement and expand agroforestry is influenced by their access to and control over critical resources. Furthermore, the theory of planned behavior is evident in the mismatch between reported large-scale agroforestry and perceptions of inadequate productivity, suggesting that farmers’ attitudes, subjective norms and perceived behavioural control shaped by knowledge gaps, resource limitations and unmet expectations significantly influence both the implementation intensity and expansion decisions.

### 5.2.3 Extension Services and Productivity

The research indicates that most of respondents had access to agroforestry-related extension services. This finding aligns with Castle et al. (2021), who found that effective extension services significantly enhance the uptake and implementation of agroforestry practices, thereby improving agricultural productivity in low- and middle-income countries. The higher prevalence of access in the Kenyan study could reflect greater availability or awareness, as noted in the research, which supports Castle et al.’s assertion that extension services are pivotal for agroforestry adoption. However, the significant portion without access echoes Castle et al.’s observation that effectiveness varies by regional context, hinting at potential gaps in service delivery or outreach in certain areas of Kenya.

Regarding the frequency of service receipt, the study found that most of respondents accessed services annually. This distribution suggests infrequent engagement, which may limit the impact on productivity. Mukhlis et al. (2022) emphasize that extension services are critical for disseminating knowledge and improving yields, implying that more regular interaction could amplify benefits like income diversification and soil health. The Kenyan findings, with a majority receiving annual services, contrast with Mukhlis et al.'s call for robust institutional support, indicating that constraints such as cost or availability might hinder more frequent service delivery, thus potentially undermining productivity gains.

Most respondents reported that extension services were not readily available and inadequate training. These findings resonate with Ahmad et al. (2023), who highlighted that access to technical knowledge and training via extension services is crucial for agroforestry adoption among smallholder farmers in Pakistan. The Kenyan data's low mean scores and high standard deviations suggest variability in access and quality, consistent with Ahmad et al.'s observation that adoption rates depend on institutional support. This correlation underscores the need for enhanced training programs in Kenya to bridge these gaps and boost agroforestry productivity.

The research also found that most respondents felt extension services did not improve their agroforestry practices. This contrasts with Pédelahore et al. (2023), who argue that responsive extension services should facilitate market dynamics and align socio-economic goals with sustainability. The Kenyan findings suggest a disconnect between service provision and practical outcomes, contradicting Pédelahore et al.'s emphasis on adaptive management. This discrepancy highlights a potential need for more tailored extension strategies in Kenya to enhance market linkages and practice improvement.



Participation in capacity-building was low, with most respondents reporting no participation and technical assistance was deemed inadequate. These results align with Sheppard et al. (2020), who stress the importance of extension services in knowledge transfer and technical assistance for agroforestry adoption in Southern Africa. The Kenyan data's low engagement levels support Sheppard et al.'s call for strengthened services, indicating that limited capacity-building and support may hinder sustainable development and climate resilience in the region.

Awareness of government policies was low. This finding parallels Kinyili et al. (2020), who identified a significant gap in extension services in Sub-Saharan Africa's ASALs, despite high adoption rates. The Kenyan study's low awareness and knowledge scores reinforce Kinyili et al.'s recommendation for enhanced services to provide deeper insights and support, suggesting that ineffective communication may limit policy uptake and agroforestry benefits. The key informant interviews highlighted a focus on cash crops over agroforestry and a lack of agroforestry-specific officers, aligning with Korir et al. (2022) in Kericho County, Kenya. Korir et al. noted a research gap in linking extension services to productivity outcomes, which the current findings echo through respondents' mixed views on support effectiveness and calls for more officers and frequent visits. This consistency underscores the need for policy interventions to prioritize agroforestry-specific extension services to maximize productivity and sustainability.

The challenges highlighted in the research regarding the effectiveness of extension services and their impact on agroforestry productivity can be analyzed through the lens of the theory of agroforestry systems, which stresses the importance of tailored, intensive agroforestry practices that are facilitated by effective knowledge transfer. The discrepancies between access to services, frequency of engagement and practical improvements in agroforestry systems reflect the resource dependence theory, suggesting that farmers' productivity outcomes are influenced by their access to essential resources, such as technical knowledge and consistent support. Additionally, the theory of planned behavior is evident in the reported low participation and dissatisfaction with extension services, highlighting that farmers' attitudes toward agroforestry and their perceived control over adoption are influenced by the quality and frequency of extension services, which may shape their intention to implement practices that could enhance their productivity.

### 5.2.4 Biodiversity Conservation and Productivity

The research findings indicate that most respondents noticed changes in biodiversity on their farms over the past five years, reflecting a high awareness of biodiversity shifts potentially linked to agroforestry practices. This aligns closely with Swallow et al. (2020), who argue that agroforestry enhances landscape biodiversity and agrobiodiversity, improving ecosystem services such as pollination and soil health, which in turn boost productivity. The overwhelming majority observing changes supports Swallow et al.'s proposition that agroforestry produces higher biodiversity benefits compared to monoculture systems. However, the lack of specificity in the Kenyan study about the nature of these changes (positive or negative) leaves room for further investigation, as Swallow et al. emphasize the need to understand factors enhancing or restricting biodiversity benefits to maximize productivity impacts.

The study also found that most respondents took specific actions to conserve biodiversity, indicating a strong commitment to sustainable practices. This finding resonates with Klie (2018), who noted that small-scale farmers in Brazil's Atlantic Forest biome were motivated to adopt agroforestry for biodiversity conservation due to its contributions to habitat provision and ecosystem resilience, which enhance productivity. The high participation rate in Kenya, coupled with key informant reports of agroforestry supporting wildlife and pollinators, mirrors Klie's observation of biodiversity's moderating effect on productivity through improved soil health and income diversification. However, the few who did not act due to limited knowledge or financial constraints echo Klie's identified barriers, such as lack of technical knowledge, suggesting a need for enhanced extension services to bridge this gap and fully leverage biodiversity benefits.

Descriptive findings on agroforestry's impact on biodiversity show varied perceptions for enhancing species diversity and only a few reporting a very great extent of impact. This tempered perception contrasts with Mulatu and Hunde (2019), who assert that agroforestry significantly promotes genetic diversity and habitat provision, enhancing resilience and productivity. The Kenyan data's moderate mean and high standard deviation indicate context-specific outcomes, possibly due to farm size or management practices, as the research suggests. This partial alignment with Mulatu and Hunde highlights that while agroforestry contributes to biodiversity conservation in Kenya, its effectiveness may not be as pronounced or consistent as their literature review suggests, necessitating tailored interventions to optimize ecological and productivity outcomes.

Regarding productivity, most respondents reported a slight increase in crop yield. These findings align with Liliane (2021), who found that agroforestry technologies in Rwanda increased farmers' income and consumption expenditure through biodiversity benefits like reduced soil erosion and improved fertility, which enhance productivity. The Kenyan study's majority reporting slight increases supports Liliane's conclusion that biodiversity conservation moderates' productivity positively. However, the few reporting no change and observing a decrease in yield suggest variability not as prominently addressed in Liliane's work, indicating that factors like species selection or management practices, as noted in the research, may limit consistent productivity gains.

The research also reveals economic dimensions, with a majority earning Kshs 50,000–100,000 annually, reflecting diverse income outcomes from agroforestry. This corresponds with Swallow et al. (2020), who highlight agroforestry's potential to diversify and sustain rural incomes through biodiversity-enhanced ecosystems. The significant proportion earning higher incomes aligns with their view that biodiversity acts as a moderator enhancing productivity and economic benefits. Yet, the 11.8% earning less than Kshs 50,000 underscores financial vulnerability, supporting Swallow et al.'s caveat that benefits depend on integrated land use approaches, which may not be fully realized in all Kenyan contexts.

Key informant interviews emphasized agroforestry's role in soil conservation and habitat provision, improving biodiversity indicators like pollinators and wildlife, which enhance productivity. This aligns with Mulatu and Hunde (2019), who link agroforestry's biodiversity benefits to climate resilience and productivity through carbon sequestration and ecosystem balance. The Kenyan findings of improved soil health and productivity corroborate their conclusions. However, the informants' note that most farmers lack understanding of biodiversity conservation contradicts Mulatu and Hunde's call for increased awareness, suggesting a gap in education that limits the full realization of agroforestry's potential in Kenya.

Challenges identified by informants, such as inadequate habitats, costly labour and pests, resonate with Klie (2018), who found uncertainties and lack of knowledge as barriers to agroforestry adoption in Brazil. The Kenyan study's mention of financial constraints and pest issues as obstacles to balancing biodiversity conservation with productivity mirrors Klie's emphasis on the need for technical assistance to overcome such limitations. This correlation highlights the necessity for enhanced support systems in Kenya to strengthen biodiversity's moderating effect on productivity.

The findings on biodiversity conservation and its relationship with productivity can be understood through the theory of agroforestry systems, which posits that the integration of trees into agricultural landscapes enhances ecosystem services, thereby supporting biodiversity and productivity. The variability in productivity outcomes highlighted by respondents aligns with the resource dependence theory, suggesting that farmers' access to key resources, such as knowledge, financial support and technical assistance, influences their ability to maximize the biodiversity benefits of agroforestry. Additionally, the theory of planned behavior helps explain the mixed perceptions and actions regarding biodiversity conservation, as farmers' intentions to engage in conservation practices are shaped by their attitudes toward biodiversity, perceived control over resources and the external constraints, such as financial limitations and lack of technical knowledge, which may limit their full participation in agroforestry practices that enhance both biodiversity and productivity.

### 5.3 Conclusions

### 5.3.1 Type of Agroforestry and Productivity

The research concludes that there was a moderate level of adoption and perception of agroforestry practices, with clear potential to enhance productivity through better implementation and support. The findings suggest that tree diversity and crop integration are seen as moderately present, indicating that while farmers recognize some benefits, they may not be fully utilizing a wide range of species or combinations to improve ecosystem services and yields. Livestock integration shows promise for enhancing soil fertility and biodiversity, yet its inconsistent use points to challenges in managing these complex systems. The moderate uptake and understanding of agroforestry practices suggest that while they contribute to farm productivity, there is significant room for growth. This could be achieved by overcoming barriers such as limited knowledge or resources, which currently prevent farmers from realizing the full potential of these systems.

Farmers view agroforestry as a tool for sustainability, soil health and income diversification with moderate enthusiasm, reflecting an awareness of its ecological and economic advantages. However, the lukewarm endorsement of tree-crop integration and overall understanding suggests that challenges like competition between trees and crops or a lack of technical expertise may be limiting its impact. These findings point to a disconnect between the potential benefits of agroforestry such as improved resilience and diverse income streams and its current application. The moderate grasp of agroforestry systems among farmers further indicates that while some educational efforts have taken root, deeper knowledge transfer is needed.

The identification of specific agroforestry practices like riparian buffer strips and systems combining trees, crops and livestock highlights their perceived effectiveness in enhancing productivity and ecological benefits. Yet, the moderate adoption of diverse tree and plant species suggests a reliance on familiar options rather than exploring a broader range of possibilities that could further enrich farm systems. This conservative approach may limit biodiversity and economic gains, pointing to a need for tailored solutions that suit local conditions.

### 5.3.2 Scale of Implementation and Productivity

The study concluded that the majority of farmers engage in agroforestry at a relatively low intensity, with many maintaining only a small number of trees on their farms. Despite allocating significant portions of land to agroforestry, the low tree density suggests that extensive rather than intensive agroforestry is being practiced. This approach may limit potential benefits such as soil fertility improvement and increased productivity. Furthermore, while land availability was cited as a constraint by some respondents, many still practiced large-scale agroforestry, indicating a possible disconnect between perceived and actual land constraints. This highlights the need for better education on optimizing land use for agroforestry to ensure farmers can fully benefit from its potential.

The study further concluded that competition between agroforestry and other agricultural activities affects the extent to which farmers implement tree-based systems. Many respondents reported allocating land to agroforestry only to a small extent, reflecting competing priorities for food production and income generation. This may explain why some farmers perceive agroforestry as less beneficial than expected, as limited diversification and low tree density can reduce its overall impact. The study also found that many farmers considered their agroforestry plots inadequate to meet their needs, reinforcing concerns about the effectiveness of current practices. This suggests a need for strategies that integrate agroforestry more effectively into broader farming systems to enhance productivity and economic viability.

Finally, the study concluded that financial and labour constraints remain significant barriers to the expansion of agroforestry. Many respondents indicated that they had expanded their agroforestry practices only to a small extent over the years, citing challenges such as high labour demands and limited financial resources. Additionally, the perceived benefits of agroforestry on agricultural yields were lower than expected, suggesting that current implementation practices may not be optimized for productivity. Farmers also expressed dissatisfaction with agroforestry's ability to support biodiversity, indicating that existing designs may lack the diversity needed for ecological improvements. The findings emphasize the importance of targeted interventions such as technical training, financial support and policy initiatives to encourage more effective agroforestry adoption.

### 5.3.3 Extension Services and Productivity

The study concluded that while agroforestry-related extension services were accessible to a majority of respondents, a significant proportion still lacked access, highlighting disparities in service reach. The findings indicate that although extension services play a crucial role in enhancing agroforestry adoption, their effectiveness is constrained by inconsistent availability, infrequent service delivery and inadequate technical training. The limited engagement of farmers with extension officers suggests that the impact of these services on productivity remains suboptimal. Furthermore, the observed variations in service provision across different regions point to structural inefficiencies that hinder uniform access.

Additionally, the study found that low participation in capacity-building and insufficient technical assistance limited the potential benefits of extension services. Many farmers expressed dissatisfaction with the impact of these services on their agroforestry practices, suggesting a disconnect between service provision and practical outcomes. The absence of agroforestry-specific officers and a general focus on cash crops further weakened the effectiveness of extension programs. This lack of specialization may contribute to ineffective knowledge transfer, ultimately restricting the successful implementation of agroforestry initiatives.

The research concluded that weak awareness of government policies and inadequate policy communication hampered the effectiveness of extension services in promoting agroforestry. The findings suggest that ineffective dissemination of policy information limited farmers' ability to leverage governmental support, thereby restricting the expansion of agroforestry practices. Moreover, the reliance on annual extension visits failed to provide farmers with the sustained guidance necessary for long-term improvements.

**5.3.4 Biodiversity Conservation and Productivity**

The study concluded that biodiversity conservation through agroforestry practices has significantly influenced agricultural productivity, as evidenced by the high proportion of respondents who observed changes in biodiversity over the past five years. The widespread acknowledgment of biodiversity shifts suggests a strong interaction between agroforestry and ecosystem functions such as pollination, soil health and climate resilience. However, the study also highlighted that the extent of perceived biodiversity impact varied among respondents, indicating the need for further exploration of specific ecological benefits and challenges. While a majority of farmers took deliberate actions to conserve biodiversity, a notable portion lacked the necessary knowledge or resources, which may have limited the full realization of agroforestry's benefits.

Furthermore, the study revealed that while agroforestry contributed to modest increases in crop yield for most respondents, productivity outcomes were inconsistent. Variability in reported yield improvements suggests that factors such as farm size, management practices and species selection play a crucial role in determining agroforestry's effectiveness. Economic benefits were also diverse, with a substantial portion of farmers experiencing income growth, while others continued to face financial constraints. This disparity underscores the need for a more structured approach to integrating biodiversity conservation with agricultural productivity, ensuring that farmers have access to adequate technical support, market opportunities and financial resources.

Lastly, the study identified critical challenges that hinder the full realization of biodiversity's role in enhancing productivity. Key informant interviews highlighted issues such as inadequate habitats, costly labour and pest infestations, all of which limit the potential benefits of agroforestry. These challenges, coupled with limited farmer awareness of biodiversity conservation principles, indicate that more focused policy and institutional support are needed. Strengthening extension services, increasing farmer education and providing financial incentives could help mitigate these barriers and promote more effective biodiversity-friendly practices.

### 5.4 Recommendations

From the study findings, the research recommends that;

#### 5.4.1 Type of Agroforestry and Productivity

The study recommends that targeted interventions be implemented to enhance agroforestry's productivity by improving farmer knowledge and resource access. Training programs should focus on the benefits of diverse tree-crop-livestock systems, ensuring farmers understand optimal species selection and management techniques. Strengthening extension services can bridge knowledge gaps, helping farmers integrate trees without competition concerns. Additionally, financial and technical support should be provided to encourage the adoption of underutilized agroforestry practices, such as riparian buffer strips. Policies promoting agroforestry-friendly land use and market linkages will further incentivize its expansion.

#### 5.4.2 Scale of Implementation and Productivity

The research recommends that farmers should be supported with targeted interventions to enhance the scale and effectiveness of agroforestry implementation. Training programs should focus on optimizing land use by promoting intensive rather than extensive agroforestry, ensuring higher tree density for improved productivity. Financial assistance, such as subsidies or low-interest loans, should be provided to address cost barriers and encourage expansion. Also, integrating agroforestry with existing farming activities through tailored strategies can help mitigate competition for land.

### 5.4.3 Extension Services and Productivity

The research recommends that there should be strengthening of extension services by ensuring their consistent availability, improving technical training and increasing the frequency of farmer engagement. Efforts should be made to expand access by deploying more agroforestry-specific officers and integrating agroforestry into mainstream extension programs. Additionally, capacity-building initiatives should be enhanced through hands-on training and demonstration farms to improve knowledge transfer and practical application. To address policy communication gaps, extension officers should actively disseminate relevant government policies and provide guidance on accessing available support.

### 5.4.4 Biodiversity Conservation and Productivity

The research recommends there should be enhancement of biodiversity conservation in agroforestry by improving farmer education, technical support and financial incentives. Expanding access to training on biodiversity-friendly practices will help farmers better understand the ecological benefits of agroforestry. Additionally, integrating biodiversity conservation strategies into extension services can address knowledge gaps and improve implementation. To ensure consistent productivity gains, policymakers should promote diversified agroforestry models suited to local conditions. Financial incentives, such as subsidies and grants, should be introduced to mitigate cost-related barriers, while stronger institutional support can facilitate market access for biodiversity-friendly products.

## 5.5 Limitations and Areas for Further Research

This research has established the relationship between agroforestry practices, biodiversity conservation and productivity in Mt. Elgon Sub-County, Kenya. However, several limitations must be acknowledged. First, the study was geographically limited to Mt. Elgon Sub-County, which may not fully represent the diverse agroecological zones and socio-economic conditions present in other parts of Kenya or across Africa. Second, the study relied heavily on self-reported data from farmers and key informants, which may be subject to recall bias or social desirability bias, potentially affecting the accuracy of responses. Third, the research design was primarily cross-sectional, which restricts the ability to infer causal relationships over time between agroforestry practices and productivity outcomes. Fourth, while the study considered perceptions and reported impacts of biodiversity conservation, it did not include direct field-based biodiversity assessments or long-term productivity measurements. These limitations suggest the need for caution when generalizing the findings beyond the immediate study area.

Future scholars can expand the scope of the study by focusing on other regions in Kenya and across Africa where agroforestry is practiced, to compare findings across ecological and socio-economic contexts. Longitudinal studies that track biodiversity and productivity changes over time, as well as experimental designs that incorporate field-based ecological indicators, would provide more robust insights. Further research could also examine the role of institutional support, financial incentives and policy frameworks in influencing the effectiveness of agroforestry in promoting biodiversity and improving livelihoods.

Based on the findings, this study recommends that future theoretical work should integrate ecological and socio-economic dimensions, recognizing biodiversity as a moderating factor in the agroforestry–productivity nexus. For policy, there is a need to strengthen agroforestry-specific extension services, increase funding for training programs and enhance policy communication to improve farmers' awareness and adoption of biodiversity-friendly practices. Practically, farmers should be supported through localized, frequent extension services, training on species diversification and biodiversity monitoring and linkage to markets and climate-smart practices to maximize agroforestry's productivity and sustainability potential.

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# APPENDICES

## Appendix 1: Questionnaire

### SECTION A: DEMOGRAPHIC DATA

1. Gender
    - Male
    - Female
2. Age in years ……………….
3. Years of schooling…………….
4. Farming Experience in years…………
5. Landholding size in acres……….

### SECTION B: TYPE OF AGROFORESTRY

Which type(s) of agroforestry practices do you implement on your farm? (Check all that apply)

1) Alley Cropping
2) Integration of trees and grazing livestock
3) Riparian Buffer Strips
4) Windbreaks
5) Others (Please specify): ___________________

What are the main reasons for practicing agroforestry? (Check all that apply)

1) Increase crop yield
2) Improved agricultural output
3) Improve soil fertility
4) Reduce erosion
5) Enhance biodiversity
6) Economic benefits (e.g., timber, fodder)
7) Others (Please specify): ___________________

Use the Likert Scale where 1- - Not at all, 2-Small extent, 3- Medium extent, 4-Great extent, 5-Very great extent to rate the extent that you agree with these statements.

| No. | Statement | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | The diversity of tree species on my farm is high. | | | | | |
| 2 | I integrate a variety of crops within my agroforestry system. | | | | | |
| 3 | Livestock is an essential part of my agroforestry practice. | | | | | |
| 4 | I believe agroforestry enhances the sustainability of my farm. | | | | | |
| 5 | Agroforestry practices on my farm improve soil health. | | | | | |
| 6 | The integration of trees and crops benefits my farm's productivity. | | | | | |
| 7 | Agroforestry helps in diversifying my farm income. | | | | | |
| 8 | I have a good understanding of different agroforestry systems. | | | | | |
| 9 | My agroforestry practice includes various types of trees and plants. | | | | | |

**SECTION C: SCALE OF IMPLEMENTATION**

What is the number of trees on your farm?

1) Less than 50 trees
2) 50 to 100 trees
3) 101 to 200 trees
4) More than 200 trees

What is the scale of your agroforestry implementation?

1) Small-scale (Less than 1 acre)
2) Medium-scale (1-5 acres)
3) Large-scale (More than 5 acres)

What challenges do you face in implementing agroforestry practices? (Check all that apply)

1) Lack of knowledge/training
2) Limited financial resources

3) Land tenure issues
4) Lack of seedlings or planting material
5) Others (Please specify): ____________________

Use the Likert Scale where 1- Not at all, 2-Small extent, 3- Medium extent, 4-Great extent, 5-Very great extent to rate the extent that you agree with these statements.

| No. | Statement | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | My landholding size allows for extensive agroforestry practices. | | | | | |
| 2 | I allocate a significant portion of my land to agroforestry. | | | | | |
| 3 | The relative size of my agroforestry plots is adequate for my needs. | | | | | |
| 4 | I have expanded my agroforestry practices over the years. | | | | | |
| 5 | The extent of agroforestry on my farm has positively impacted my agricultural yield. | | | | | |
| 6 | My farm's agroforestry land allocation is optimal for productivity. | | | | | |
| 7 | The implementation scale of agroforestry on my farm meets my expectations. | | | | | |
| 8 | I plan to increase the extent of agroforestry practices on my farm. | | | | | |
| 9 | The current scale of agroforestry on my farm supports biodiversity. | | | | | |

**SECTION D: EXTENSION SERVICES**

Do you have access to extension services related to agroforestry?

- Yes
- No

If yes, how frequently do you receive these services?

1) Monthly
2) Quarterly
3) Annually
4) Other (Please specify): ____________________

What type of support do you receive from extension services? (Check all that apply)

1) Training on agroforestry techniques
2) Technical support for planting and maintenance
3) Access to seedlings/planting material
4) Financial assistance or credit
5) Marketing assistance for agroforestry products
6) Others (Please specify): ___________________

Use the Likert Scale where - Not at all, 2-Small extent, 3- Medium extent, 4-Great extent, 5-Very great extent to rate the extent that you agree with these statements.

| No. | Statement | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Extension services are readily available to me. | | | | | |
| 2 | I have received adequate training in agroforestry practices. | | | | | |
| 3 | Extension services have helped me improve my agroforestry practices. | | | | | |
| 4 | Market accessibility for my agroforestry products has improved due to extension services. | | | | | |
| 5 | I participate in capacity-building opportunities provided by extension services. | | | | | |
| 6 | Technical assistance from extension services has been beneficial to my farm. | | | | | |
| 7 | I am aware of various government policies supporting agroforestry. | | | | | |
| 8 | Extension services have increased my knowledge about agroforestry benefits. | | | | | |
| 9 | I find extension services to be easily accessible and helpful. | | | | | |

## SECTION E: BIODIVERSITY CONSERVATION

Have you noticed any changes in biodiversity on your farm over the last 5 years?

1) Yes

2) No
3) Not sure

If yes, what types of biodiversity changes have you observed? (Check all that apply)

1) Increase in tree species diversity
2) Increase in wildlife presence (e.g., birds, insects)
3) Improved soil and water quality
4) Others (Please specify): ___________________

Do you take specific actions to conserve biodiversity on your farm?

- Yes
- No

If yes, what actions do you take? (Check all that apply)

1) Planting diverse tree species
2) Protecting natural habitats (e.g., wetlands, forest patches)
3) Using organic farming methods
4) Others (Please specify): ___________________

Use the Likert Scale where 1- Not at all, 2-Small extent, 3- Medium extent, 4-Great extent, 5-Very great extent to rate the extent that you agree with these statements.

| **No.** | **Statement** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| 1 | Agroforestry on my farm enhances species diversity. | | | | | |
| 2 | My agroforestry practices contribute to habitat quality. | | | | | |
| 3 | Biodiversity conservation is a priority in my agroforestry activities. | | | | | |
| 4 | I have noticed increased biodiversity since adopting agroforestry. | | | | | |
| 5 | Agroforestry helps in maintaining ecological balance on my farm. | | | | | |
| 6 | I believe agroforestry is crucial for environmental conservation. | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Biodiversity conservation practices are well integrated into my farming methods. | | | | | |
| 8 | The biodiversity benefits of agroforestry are well understood in my community. | | | | | |
| 9 | Agroforestry has positively impacted wildlife on my farm. | | | | | |

**SECTION F: PRODUCTIVITY**

Please provide the following objective information regarding your farm's productivity:

1. What types of crops do you grow on your farm? (Select all that apply)

    1) Maize

    2) Beans

    3) Potatoes

    4) Horticultural crops (e.g., tomatoes, carrots)

    5) Other (please specify): ___________

2. What is your total annual income from agricultural sales?

    1) Less than Kshs 50,000
    2) Kshs 50,000 - Kshs 100,000
    3) Kshs 100,000 - Kshs 150,000
    4) Kshs 150,000 - Kshs 200,000
    5) More than Kshs 200,000

Crop Diversity and Yields

6. What percentage of your farm area is allocated to agroforestry compared to other crops or activities?

    1. Less than 25%

    2. 25% - 50%

3. 51% - 75%

4. More than 75%

7. Use the Likert Scale where 1- Not at all, 2-Small extent, 3- Medium extent, 4-Great extent, 5-Very great extent to rate the extent that you agree with these statements.

| **Question** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| 7. How has crop yield (kilograms per acre) changed since adopting agroforestry practices? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. Has the labour required on your farm changed due to agroforestry practices? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. How have your farm input costs (e.g., fertilizer, pesticides) changed since adopting agroforestry? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. How has agroforestry affected your overall farm income? | ☐ | ☐ | ☐ | ☐ | ☐ |

11. What proportion of your total income comes from agroforestry products (e.g., fruits, timber)?

1. Less than 25%
2. 25% - 50%
3. 51% - 75%
4. More than 75%



Agroforestry-Specific Productivity

12. What types of products do you harvest from agroforestry practices? (Select all that apply)

1. Fruits
2. Timber
3. Firewood
4. Fodder

5. Other (please specify): __________

13. What is the average annual income generated specifically from agroforestry products?

1. Less than Kshs 10,000
2. Kshs 10,000 - Kshs 25,000
3. Kshs 25,000 - Kshs 50,000
4. Kshs 50,000 - Kshs 100,000
5. More than Kshs 100,000

14. How has agroforestry impacted your access to on-farm resources? (e.g., firewood, fodder, fruits)

- Increased significantly: __________
- Increased slightly: __________
- No change: __________
- Decreased: __________

Perceptions of Productivity



15. What is your perception of how agroforestry has affected your overall farm productivity?

1. Increased significantly
2. Increased slightly
3. No change
4. Decreased

16. What are the main challenges you face in improving productivity through agroforestry? (Select all that apply)

1. Lack of knowledge or technical skills

2. Limited access to markets
3. High input costs
4. Pests and diseases
5. Other (please specify): __________

Environmental Productivity

17. How has agroforestry affected the following environmental indicators on your farm? (Rate on a scale of 1 to 5, where 1 = No impact and 5 = Very significant impact)
    - o Water retention: __________
    - o Soil erosion reduction: __________
    - o Pest control: __________
    - o Carbon sequestration (e.g., shade and trees): __________
18. Do you observe any seasonal differences in productivity due to agroforestry practices?

- Yes (specify): __________
- No

SECTION G: OPEN-ENDED QUESTIONS

- In your opinion, what are the main advantages of agroforestry practices in your region?
- Could you provide specific examples of how agroforestry has impacted your crop yields, soil fertility, or income?
- How do different types of agroforestry practices (e.g., agro-silviculture, agro-horticulture) benefit your farm productivity?
- What challenges do you think need to be addressed to improve agroforestry practices in Mt. Elgon Sub-County? *(Objective ii: To investigate the effect of the scale of agroforestry implementation on productivity)*

- Are there specific limitations in scaling up agroforestry on your farm (e.g., lack of space, labour, or resources)?
- How do you perceive the community or institutional support for implementing agroforestry practices on a larger scale?
- Do you have any additional comments or suggestions related to agroforestry, biodiversity, or farm productivity?
    1. Deforestation in the region should be prohibited

***Thank you for your response***

**Appendix 2: Key Informant Interview Guide**

Background Information

- Name: __________
- Organization/Institution: __________
- Role/Position: __________
- Years of experience in agroforestry or biodiversity conservation: __________

Section 1: General Perceptions of Agroforestry Practices

1. How would you describe the current state of agroforestry practices in Mt. Elgon Sub-County?
2. What types of agroforestry systems are most common in this region?
    - Agro-silviculture (trees + crops)
    - Agro-horticulture (fruit trees + crops)
    - Agro-pastoralism (trees + livestock)
    - Others (specify)
3. What do you consider to be the main benefits of agroforestry for smallholder farmers in this region?
4. Are there specific agroforestry practices that you believe are most effective for improving productivity? Why?

Section 2: Scale of Agroforestry Implementation

5. In your opinion, what factors influence the scale of agroforestry adoption among farmers?
6. What challenges do farmers face in scaling up agroforestry practices on their farms?
    - Land availability

- Financial constraints
- Labour demands
- Others (specify)

7. Are there any programs or initiatives in place to support the expansion of agroforestry practices? If so, how effective are they?

Section 3: Extension Services and Farmer Support

8. What role do extension services play in promoting agroforestry practices in this region?
9. What type of support do farmers receive from extension officers (e.g., technical advice, training, resources)?
10. Do you think the extension services are adequate for helping farmers adopt and sustain agroforestry practices? Why or why not?
11. What improvements or changes would you recommend to extension services to better support agroforestry practices?

Section 4: Biodiversity Conservation

12. How does agroforestry contribute to biodiversity conservation in Mt. Elgon Sub-County?
13. Are there any specific biodiversity indicators (e.g., wildlife, pollinators, soil health) that have improved due to agroforestry practices?
14. Do you think farmers understand the importance of biodiversity conservation? If not, what can be done to improve awareness?
15. What are the main challenges in balancing biodiversity conservation with farm productivity?

Section 5: Policy and Institutional Support

16. Are there government policies or programs that directly support agroforestry and biodiversity conservation in Mt. Elgon? If so, are they effective?

17. What role do local organizations, cooperatives, or community groups play in promoting agroforestry and biodiversity conservation?

18. What additional policies or interventions do you think are needed to enhance agroforestry adoption and biodiversity conservation?

Section 6: Recommendations and Closing

19. What are your key recommendations for improving the productivity of smallholder farmers through agroforestry in Mt. Elgon Sub-County?

20. Is there anything else you would like to add that might be important for this study?

*Thank you for your response*

## Appendix 3: Ethical Review Clearance

Strathmore UNIVERSITY

**7th March 2025**

Ms Loyatum Antonious,
antonious.loyatum@strathmore.edu

Dear Ms Loyatum,

**RE: The Effect of Agroforestry Practices on Productivity of Smallholder Farmers in Mt. Elgon, Kenya: The Moderating Effect of Biodiversity Conservation**

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** proposal. Your application reference number is **SU-ISERC2620/25.** The approval period is from **7th March 2025 to 6th March 2026.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

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

Yours sincerely,

**Mr Ambrose Rachier,**
**Chairperson; SU-ISERC**

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu

## Appendix 4: Research Permit from NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **890227**

Date of Issue: **20/March/2025**

**RESEARCH LICENSE**

**This is to Certify that Miss.. Antonious Cherop Loyatum of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Bungoma on the topic: The Effect of Agroforestry Practices on Productivity of Smallholder Farmers in Mt. Elgon, Kenya: The Moderating Effect of Biodiversity Conservation for the period ending : 20/March/2026.**

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