UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

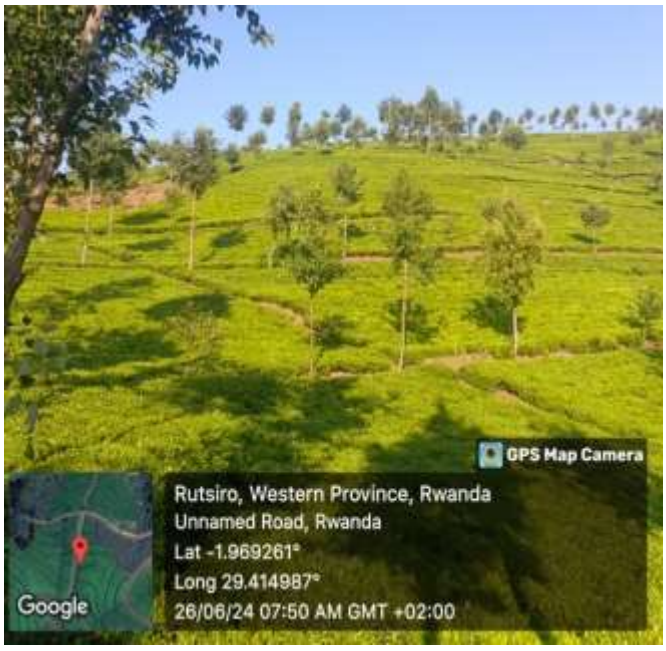
SCHOOL OF SCIENCES

DEPARTMENT OF BIOLOGY

ACADEMIC YEAR: 2023-2024

MASTER'S PROGRAM IN BIODIVERSITY CONSERVATION AND NATURAL RESOURCES MANAGEMENT

AGROFORESTRY PRACTICES FOR LIVELIHOOD IMPROVEMENT IN RUTSIRO DISTRICT, WESTERN PROVINCE, RWANDA



A thesis submitted in partial fulfillment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

By

MANIRAMBONA Fortunée

(Reg. No: 216097002)

DECLARATION

Declaration

I, **MANIRAMBONA Fortunée**, affirm that, to the best of my knowledge, the content presented in this dissertation entitled: "**Agroforestry practices for livelihood improvement in Rutsiro district, western province, Rwanda**" is my original work and has not been submitted elsewhere for any academic qualification at any university or institution of higher learning. All referenced ideas in this work have been appropriately cited in the bibliography. Kigali, July 2024

Signature: _____ Date: _____

MANIRAMBONA Fortunée **(**Reg. number: 216097002)

APPROVAL

I certify that this research project entitled " **AGROFORESTRY PRACTICES FOR LIVELIHOOD IMPROVEMENT IN RUTSIRO DISTRICT, WESTERN PROVINCE, RWANDA"** was done under my supervision and has been submitted for examination with my approval.

Dr. Fabien RIZINJIRABAKE

On ……/……./2024

Research Supervisor

Assoc. Prof. Dieudonée MUTANGANA

Head of Biology Department
UR/College of Sciences and Technology

On ……/……./2024

Prof. Denis NDANGUZA

Dean, School of science
UR/College of Sciences and Technology

On ……/……./2024

ACKNOWLEDGEMENTS

First and foremost, I extend my deepest gratitude to the Almighty God, to whom all honor and praise belong forever. My heartfelt appreciation goes to my supervisor, Dr. RIZINJIRABAKE Fabien, for his exceptional guidance, invaluable advice, consistent support, and mentorship in scientific thinking and conducting this research. I would also like to express my special thanks to the staff of Albertine Rift Conservation Society for their collaboration in obtaining data for this research.

I am profoundly grateful to the government of Rwanda for admitting me to pursue my studies at the University of Rwanda - Nyarugenge Campus. My thanks also go to the University of Rwanda for its dedication to providing quality education. I extend my appreciation to the lecturers of Biodiversity Conservation and Natural Resources Management for their contributions and constructive advice. The value of their efforts is immeasurable, and I am extremely grateful.

Special thanks go to my husband and son for their everyday motivation and support, I also express my deepest gratitude to my friends, classmates, and relatives for the precious moments we have shared. Thank you for the pleasant cooperation and solidarity. May God bless you all!!

MANIRAMBONA Fortunée

Contents

DECLARATION ..... **i**

ACKNOWLEDGEMENTS ..... **iii**

LIST OF TABLES ..... **vi**

LIST OF FIGURES ..... **vi**

CHAPTER 1: INTRODUCTION **1**

1.1. Background 1

1.2. Problem Statement 3

1.3. Research objectives 4

1.3.1. General objective 4

1.3.2 Specific objectives 4

1.4.4 Research hypotheses 5

1.6. Scope and Limitations of the Study 6

CHAPTER 2: LITERATURE REVIEW **7**

2.1 Concepts and definitions of agroforestry 7

2.2. Importance of agroforestry 7

2.2.1. Soil fertility improvement and soil conservation 8

2.2.2. Source of energy 9

2.2.3. Carbon sequestration 9

2.2.4. Fodder 9

2.3. Classification of agroforestry systems 10

2.4 Agroforestry practices 10

2.4.1. Trees on rangelands 10

2.4.2. Hedgerow intercropping 11

2.4.3. Windbreaks 11

2.4.4. Scattered trees in crop lands 12

2.4.5. Boundary planting 12

2.4.6 Trees on soil conservation and reclamation structures 13

2.5. The concept of adoption agroforestry for improving livelihoods 13

2.6. Agroforestry and household food security 14

2.7. Agroforestry for rural livelihood 15

CHAPTER 3: MATERIALS AND METHODS. 17

3.1. Description of the study area 17

3.2. Study approach and sampling design 18

3.3. Data collection 20

3.4. Data analysis and interpretation 21

CHAPTER 4: RESULTS 22

4.1. Benefits for agroforestry practice 22

4.2. Important reasons for planting and managing trees in Rutsiro district 22

4.3. Agroforestry practices in the study area 23

4.4. Impacts of agroforestry on household livelihoods 23

4.4.1. Source of household energy for cooking 23

4.4.2. Food security ..... 24_Toc174375435

4.5. Annual gross income of agroforestry adopters compared to non-adopters from apiculture. 25

4.6. Annual gross income for agroforestry adopters against non-adopters from cash crops and apiculture 26

CHAPTER 5: RESULTS DISCUSSION 28

5.1. Agroforestry significantly boost farmers' incomes 28

5.2. Agroforestry practices in Rutsiro District ..... 30_Toc174375441

5.3 Impacts of agroforestry on household livelihoods 30

5.4 Annual gross income for agroforestry adopters compared to non-adopters from apiculture and cash crops. 31

CONCLUSION AND RECOMMENDATIONS 34

References **35**

ANNEX 1 ..... **38**

QUESTIONNAIRE **38**

+

LIST OF TABLES

Table 1:Sample size per sector 18
Table 2 .Agroforestry adopters and non-agroforestry adopters in local community 20
Table 3. Benefits for agroforestry practice 22
Table 4. Important reason for planting and managing trees..... 23
Table 5. Agroforestry practices in local community 23
Table 6. Source of energy in local community 24
Table 7. Food security situation in local community 25
Table 9. Aannual gross income of agroforestry adopters compared to non-adopters from cash crops 27

LIST OF FIGURES

Figure 1: Map of Rwanda showing the location of Rutsiro……..18

Figure 2: Map of Rutsiro District …… 19

ABSTRACT

Agroforestry practices significantly enhance livelihoods by diversifying income sources, improving food security and increasing agricultural productivity. They provide sustainable land use, bolster resilience against climate change, and offer ecosystem services such as soil fertility and biodiversity conservation. The goal of Rwanda's agroforestry policy is to accelerate the extent of agroforestry-based agricultural land restoration and sustainable biomass energy use, with associated improvements to land health, livelihoods, and poverty reduction. This study assesses to what extent agroforestry is contributing to improved livelihood in the Rutsiro District and provides insights on how enhances household income. The sample size of 395 households was used through stratified method and data collected through surveys, interviews, and field observations. The gathered information was processed, and analyzed using Microsoft Excel. Statistical tests were conducted using Excel to answer the hypotheses based on the findings. Results indicated that households practicing agroforestry experienced a 20% increase in income, improved food security by 25%, and significantly improved soil fertility (90%). The analysis also revealed that these benefits were more pronounced in areas with supportive local livelihood improvement. Recommendations include the promotion of agroforestry through policy incentives, provision of technical training, further research to explore long-term impacts and scalability. Overall, agroforestry is a promising strategy for sustainable farmers' livelihood.

Key words: Agroforestry practices, livelihood, income, cropland, agroforestry adopters and food security

CHAPTER 1: INTRODUCTION

1.1. Background

Agroforestry practices globally are crucial for improving rural livelihoods by integrating trees with crops and livestock, offering diversified sources of income and enhancing food security (Lasco et al., 2014). In Africa, agroforestry systems such as parklands, where trees like shea and baobab are intercropped with cereals, provide essential food and economic resources (Boffa, 2013). These systems also play a significant role in maintaining soil fertility and agricultural productivity. In East Africa, practices like the integration of trees with coffee and tea plantations are widespread, enhancing both economic returns and ecological sustainability (Muthuri *et al.,* 2009). For instance, the use of *Grevillea robusta* as a shade tree in coffee plantations improves microclimatic conditions and boosts coffee yields (Sileshi et al., 2014). Similarly, the adoption of fodder trees such as *Calliandra* and *Leucaena* species in Kenya provides critical livestock feed, improving milk production and household income (Place et al., 2009).

Agroforestry also contributes to climate resilience by sequestering carbon and reducing the vulnerability of farming systems to climate variability (Lasco et al., 2014). In East Africa, initiatives like the "Evergreen Agriculture Project" promote the widespread planting of *Faidherbia albida*, which enhances soil fertility and crop yields (Glover et al., 2012). These practices not only enhance agricultural productivity and environmental health but also empower rural communities by improving access to resources and increasing resilience to socio-economic shocks (Minang et al., 2014). In summary, agroforestry offers a multifaceted approach to livelihood improvement, combining economic, environmental, and social benefits across different regions.

The fundamental challenge of Rwanda is a dense and rapidly increasing population on a fragile and rapidly eroding land resource, exacerbated by climate change. Agroforestry is, therefore, a priority investment noting its contribution to the productivity and sustainability of agricultural landscapes of Rwanda (Moe, 2022). Agroforestry, a land-use management system where trees or shrubs are grown around or among crops or pastureland, is a sustainable agricultural practice that enhances productivity, resilience, and environmental sustainability. This practice combines

agriculture and forestry technologies to create more diverse, productive, profitable, healthy, and sustainable land-use systems.

The integration of trees, crops, and livestock within the same land space has proven to be beneficial not only for improving livelihoods but also for enhancing biodiversity and ecosystem services (Nair, 2011). Agroforestry systems provide multiple products such as fruits, nuts, timber, fodder, fuelwood, and medicinal plants. These products contribute to household income and food security, particularly for smallholder farmers. Studies have shown that agroforestry can significantly increase farm yields and income compared to conventional agricultural practices (Mbow et al., 2014). For example, integrating fruit trees with annual crops can provide a continuous source of income throughout the year, improving financial stability and reducing vulnerability to economic shocks (Garrity et al., 2010). The environmental benefits of agroforestry are well-documented. Trees in agroforestry systems help in soil conservation, water retention, and nutrient cycling, which are critical for maintaining soil health and agricultural productivity (Jose, 2009).

Moreover, agroforestry practices reduce soil erosion, enhance biodiversity, and mitigate climate change by sequestering carbon in biomass and soils (Zomer et al., 2014). The presence of trees also helps in modifying microclimates, which can be beneficial for crops and livestock by reducing the effects of extreme weather conditions (Sileshi *et al.,* 2014). Agroforestry practices often align with traditional farming systems and cultural practices, making them more acceptable to local communities (Mbow et al., 2014). The integration of agroforestry with traditional knowledge systems can lead to more sustainable land-use practices and promote the preservation of cultural heritage. Additionally, the diverse production systems in agroforestry can provide a buffer against social and economic changes, enhancing community resilience (Lundgren & Raintree, 2021).

Despite the numerous benefits, the adoption of agroforestry practices faces several challenges. These include limited access to knowledge and training, inadequate policy support, and competition for resources between trees and crops (Ajayi et al., 2011). However, recent advancements in agroforestry research and increased recognition of its benefits have led to more supportive policies and increased investment in agroforestry projects (Sanchez et al., 2014). The

potential of agroforestry to contribute to sustainable development goals (SDGs) has been increasingly recognized. By integrating trees into agricultural landscapes, agroforestry can help achieve multiple SDGs, including zero hunger, climate action, life on land, and decent work and economic growth (Mbow et al., 2014). For instance, agroforestry can improve food security by increasing the availability and diversity of food products, and it can contribute to climate change mitigation and adaptation by enhancing carbon sequestration and improving the resilience of farming systems to climate variability (Sileshi et al., 2014).

1.2. Problem Statement

Agroforestry, the practice of integrating trees, crops, and livestock on the same land, offers numerous benefits for improving rural livelihoods and environmental sustainability. However, its adoption and effectiveness are hindered by several challenges that need to be addressed to fully realize it's potential. Despite its long-standing presence in traditional farming systems, modern agroforestry faces obstacles such as limited access to knowledge and training, inadequate policy support, and competition for resources between trees and crops. These challenges are exacerbated by socio-economic and environmental pressures, including climate change, land degradation, and poverty (Mbow et al., 2014; Ajayi et al., 2011). On average, over the previous 50 years, the productivity of agricultural areas in Africa has decreased by 16%. 58% of the soils in drylands are degraded, compared to 42% in humid areas. The most frequent reason for decreasing productivity is water erosion. Wind erosion, chemical soil degradation (nutrient losses, salinization, pollution, and acidification), and physical soil degradation (organic matter losses, water logging, compaction sealing, and crusting) are additional reasons. The soil's erosivity, or how well it can be eroded by rain, and erodibility, or how well it can withstand rain, determine the amount and impact of water erosion, respectively (Hellin, 2006). Due to their more frequent rainstorms than other places, the tropics have a problem with water erosion. The absence of windbreaks, open soil, a lack of organic matter in the soil, and monoculture farming all contribute to erosion in the tropics (Glover, 2005).

On smallholder farms in Africa, the loss of soil fertility is already thought to be a biophysical constraint on food production (Sanchez et al.; 1997). The rural poor are particularly impacted by soil degradation since they depend more on annual agricultural crops, which likewise degrade

soil more than other crops. Additionally, they depend more on public lands, which are frequently the most severely damaged. Rural households commonly rely on agroforestry trees and other natural food resources, such as non-timber forest products, to ensure their nutrition and income during times of food and income shortages in Sub-Saharan Africa. However, due to deforestation and overuse of the resources, the availability of agroforestry tree products is declining. The World Agroforestry Centre's Adoption of Indigenous Fruit Trees and Agroforestry Programe, previously known as the International Centre for Research in Agroforestry (ICRAF), aims to increase farm household income by planting agroforestry trees in order to preserve biodiversity. (Wirtschaftswissenschaften, 2005). Food scarcity and malnutrition are Africa's and Rwanda's main problems (Moore and Vaughan1987). High levels of malnutrition, food insecurity, and low income levels are particularly common among the rural and peri-urban populations of southern African Counties (Leakey R & Akinnifesi, 2008).

The general goal of Rwanda's agroforestry policy is to accelerate the extent of agroforestry-based agricultural land restoration and sustainable biomass energy use, with associated improvements to land health, livelihoods, and poverty reduction. This study will thus contribute assess to what extent agroforestry is contributing to improved livelihood in Rwanda, with a case study of the Rutsiro District.

1.3. Research objectives

1.3.1. General objective

The general objective of the study is to assess the impact of agroforestry practices in promoting the livelihood of farmers in Rutsiro District in the Western Province of Rwanda to provide insights on how integrating trees with crops can enhance household income.

1.3.2 Specific objectives

The study has the following specific objectives:

1. To assess the main agroforestry practices in the study area
2. To assess the main reasons of planting agroforestry trees in the study area
3. To assess impact of agroforestry on energy and food security

4. Assess the impact of agroforestry on annual gross income from apiculture and cash crop in the study area

1.4.3. Research questions

1. What are the main agroforestry practices in the study area?
2. What are the main reasons of planting agroforestry trees in the study area
3. What is the impact of agroforestry on energy and food security?
4. To what extent agroforestry affect annual gross income from apiculture and cash crop in the study area?

1.4.4 Research hypotheses

1. The main agroforestry practices in the study area such as trees on soil conservation structures, home gardens, trees planting as living fences, scattered trees on cropland, which are adopted due to their benefits in improving soil health, increasing biodiversity, and enhancing agricultural productivity
2. Implementing agroforestry systems in the study area significantly reduces soil erosion and enhances water retention, leading to better water management.
3. Agroforestry systems improve energy security in the study area by providing a sustainable source of biomass for bioenergy and increases food security by enhancing soil fertility, improving crop yields, and providing diversified food products
4. The integration of agroforestry practices in the study area diversifies farmers' income sources, thereby increasing overall annual gross income through the combined production of apiculture, cash crops, and tree products

1.5. Significance of the study

The study of agroforestry practices for livelihood improvement in Rutsiro District is significant for several reasons. It provides valuable insights into how integrating trees with crops can enhance agricultural productivity and household income. The findings offer evidence-based recommendations for policymakers to promote sustainable successful agroforestry. They also contribute to the body of knowledge on agroforestry's socio-economic and environmental benefits, fostering community resilience. Ultimately, the study supports the district's efforts towards achieving food security and sustainable development.

1.6. Scope and Limitations of the Study

The study focused on assessing agroforestry practices and their impact on livelihood improvement in Rutsiro District. It encompassed a diverse range of agricultural practices, income levels, and socio-economic conditions. Data collection included both quantitative and qualitative methods to ensure comprehensive analysis. However, the study had limitations such as limited access to remote areas that may affect sample representability, and seasonal variation during the study period that may influence crop yield data.

CHAPTER 2: LITERATURE REVIEW

2.1 Concepts and definitions of agroforestry

Agroforestry is a land management system that integrates trees and shrubs with crops and/or livestock on the same land unit, enhancing biodiversity and sustainability (Nair, 2011). It combines agricultural and forestry technologies to create more diverse, productive, and sustainable land-use systems (Jose, 2009). Key concepts include silvopasture (integrating trees with pasture), alley cropping (planting rows of trees with crops in between), and riparian buffers (using trees along waterways to prevent erosion) (Montagnini, 2017). Agroforestry practices improve soil health, increase crop yields, and provide additional income sources, thereby enhancing livelihoods (FAO, 2013). This system also offers ecological benefits, such as carbon sequestration and habitat provision, contributing to climate change mitigation and biodiversity conservation (Mbow et al., 2014).

Agroforestry is a land-use system that integrates agricultural and forestry practices to create sustainable, multipurpose production systems tailored to local needs. The primary components include trees and shrubs, crops, pasture, and livestock, along with environmental factors like climate, soil, and topography. Specialized systems may incorporate additional elements such as bees or fish (Young, 1989). Agroforestry is characterized by two key features: the intentional inclusion of trees in the land-use system and significant interactions, whether positive or negative, between the woody and non-woody elements. This system involves multiple species of plants and animals, at least one being a woody perennial, and aims for diversified outputs. The complex interactions between components and their environment in agroforestry lead to greater ecological and economic complexity compared to mono-cropping. The primary goal of agroforestry is to optimize production through these interactions, resulting in higher overall yields and more sustainable, diversified production than could be achieved by agriculture or forestry alone

2.2. Importance of agroforestry

Agroforestry is increasingly recognized for its potential to improve livelihoods by integrating agricultural and forestry practices, thereby enhancing productivity, sustainability, and resilience

of farming systems (Nair, 2011). It plays a crucial role in diversifying income sources for rural households. By incorporating trees, farmers can produce timber, fruits, nuts, and other non-timber forest products that provide additional income (Garrity, 2012). This diversification reduces economic risks and increases household resilience to market and climate shocks (Mbow et al., 2014). Agroforestry practices also contribute to soil health improvement through enhanced nutrient cycling and organic matter addition, which can lead to higher crop yields (Jose, 2009). Trees act as windbreaks and reduce soil erosion, thereby maintaining soil fertility and agricultural productivity over the long term (Montagnini, 2017). Furthermore, agroforestry systems can improve water management by enhancing infiltration and reducing runoff, which is particularly beneficial in areas prone to drought (FAO, 2013).

Environmental benefits of agroforestry are significant as well. Trees sequester carbon, helping to mitigate climate change (Mbow et al., 2014). They also provide habitats for various species, thus enhancing biodiversity (Torquebiau, 2013). These ecological services contribute to the sustainability and resilience of agricultural landscapes. Agroforestry can also have social benefits, including community empowerment through increased food security and poverty alleviation. Improved food production from diversified crops and increased income from forest products can enhance the nutritional status and overall well-being of rural populations (Garrity, 2012). Moreover, by fostering traditional knowledge and practices, agroforestry can support cultural heritage and social cohesion (Nair, 2011). All in all, agroforestry offers a multifaceted approach to livelihood improvement, combining economic, environmental, and social benefits. Its implementation can lead to sustainable agricultural practices that are resilient to climate change and beneficial to both farmers and the broader ecosystem.

2.2.1. Soil fertility improvement and soil conservation

Agroforestry practices play a vital role in improving soil fertility and conservation, significantly benefiting livelihoods. The integration of trees and shrubs with crops enhances nutrient cycling and organic matter content, thereby improving soil structure and fertility (Nair, 2011). Trees in agroforestry systems fix atmospheric nitrogen, enriching the soil and reducing the need for synthetic fertilizers (Jose, 2009). Agroforestry also helps in controlling soil erosion by providing ground cover and stabilizing soil with tree roots, which is crucial for maintaining long-term soil productivity (Montagnini, 2017). Additionally, leaf litter from trees adds organic matter to the

soil, increasing its water-holding capacity and fertility (FAO, 2013). These practices contribute to more sustainable and resilient agricultural systems, ensuring food security and improved livelihoods for farming communities.

2.2.2. Source of energy

Agroforestry practices contribute significantly to energy needs by providing fuel wood, a crucial resource for rural households. Trees integrated into agricultural landscapes supply a sustainable source of biomass, reducing reliance on non-renewable energy sources (Nair, 2011). This access to fuel wood can decrease deforestation pressure on natural forests and lower energy costs for families (Mbow et al., 2014). Moreover, the use of agroforestry for fuel wood helps to enhance energy security and supports sustainable land management practices (FAO, 2013). The dual benefits of energy provision and environmental conservation underscore the importance of agroforestry in improving rural livelihoods.

2.2.3. Carbon sequestration

Agroforestry practices significantly contribute to carbon sequestration, helping mitigate climate change while improving livelihoods. Integrating trees into agricultural landscapes enhances carbon storage both above and below ground, thus capturing atmospheric CO_2 (Nair, 2011). This process not only benefits the environment but also promotes sustainable land use, improving soil health and productivity (Mbow et al., 2014). Agroforestry systems can store more carbon than traditional agricultural systems, making them a critical strategy for climate resilience and rural development (FAO, 2013). Enhancing carbon sequestration through agroforestry supports global climate goals and provides additional income streams for farmers through potential carbon credits.

2.2.4. Fodder

Agroforestry systems provide essential fodder for livestock, which significantly enhances rural livelihoods. Integrating fodder trees and shrubs in agricultural landscapes offers a sustainable source of high-quality feed, improving livestock health and productivity (Nair, 2011). This practice reduces the pressure on natural grasslands and increases the availability of forage during dry seasons, thereby supporting continuous livestock farming (Mbow et al., 2014). By ensuring a reliable fodder supply, agroforestry contributes to increased livestock yields, enhancing food security and income for rural households (FAO, 2013).

2.3. Classification of agroforestry systems

Agroforestry systems around the world vary widely and can be classified using different criteria. One common classification method is based on their primary function. This approach, adopted in many regions, differentiates between systems focused on producing goods and multifunctional systems that integrate the production of timber and non-timber products with providing environmental, social, and land-use services (Nair, 1989, 1993). Although all agroforestry systems can deliver multiple products and services simultaneously, this classification highlights their main purpose. Additionally, agroforestry systems can be categorized by the types of components they include: silvopastoral, agrosilvicultural and agrosilvopastoral systems

2.4 Agroforestry practices

Agroforestry integrates trees and shrubs into agricultural landscapes, creating multifunctional systems that enhance productivity, sustainability, and resilience. Key practices include agrosilvicultural systems, which combine crops with trees; silvopastoral systems, integrating livestock with woody plants; and agrosilvopastoral systems that include crops, livestock, and trees. These systems improve soil fertility, reduce erosion, enhance water management, and increase biodiversity. Agroforestry also provides diverse outputs such as timber, fruits, fodder, and fuel wood, contributing to food security and economic stability. By optimizing the interactions between various components, agroforestry supports sustainable land management and climate resilience, benefiting both the environment and rural livelihoods.

2.4.1. Trees on rangelands

Integrating trees into rangelands, known as silvopastoral systems, offers numerous ecological and economic benefits. Trees provide shade and shelter for livestock, reducing heat stress and improving animal welfare and productivity (Jose et al., 2004). Their root systems enhance soil structure and fertility by increasing organic matter and promoting nutrient cycling (Montagnini, 2017). Trees also reduce soil erosion and water runoff, which helps maintain soil moisture and improves pasture quality (Shibu, 2009). Additionally, trees on rangelands sequester carbon, contributing to climate change mitigation (Mbow et al., 2014). They offer alternative income sources through the production of timber, fruits, and fodder, diversifying farmers' income streams (Garrity, 2012). By enhancing biodiversity and providing habitat for various species,

these systems support overall ecosystem health. Effective management of tree cover in rangelands can thus enhance the sustainability and resilience of pastoral systems, ultimately benefiting both the environment and rural livelihoods (FAO, 2013).

2.4.2. Hedgerow intercropping

Hedgerow intercropping, also known as alley cropping, involves planting rows of trees or shrubs alongside crops to create a symbiotic environment that enhances agricultural productivity and sustainability. This practice improves soil fertility through nitrogen fixation and the addition of organic matter from tree litter (Jose, 2013). The presence of hedgerows reduces soil erosion and runoff, which is critical for maintaining soil health and moisture levels (Montagnini & Nair, 2011). Hedgerows also serve as windbreaks, protecting crops from wind damage and reducing evaporation rates (Nair, 2011). Additionally, they provide habitats for beneficial insects and birds, enhancing biodiversity and natural pest control (Garrity et al., 2010).

Economic benefits include diversified income sources from timber, fruits, or fodder produced by the hedgerows, which can supplement farmers' earnings (Nair, 2011). Hedgerow intercropping also contributes to carbon sequestration, aiding in climate change mitigation efforts (Mbow et al., 2014). By optimizing land use and improving ecosystem services, hedgerow intercropping supports sustainable agricultural practices and enhances the resilience of farming systems (FAO, 2013). The integration of trees and crops in this manner creates a more productive and environmentally friendly agricultural landscape.

2.4.3. Windbreaks

Windbreaks and shelterbelts are rows of trees or shrubs planted to protect crops, livestock, and soil from wind damage, enhancing agricultural productivity and environmental stability. These structures reduce wind speed, thereby minimizing soil erosion, protecting young crops, and reducing moisture loss from soil and plants (Jose et al., 2012). They also create microclimates that can improve crop yields and extend growing seasons (Cleugh, 2016). Windbreaks provide habitats for wildlife, increasing biodiversity, and can serve as corridors for pollinators and beneficial insects, aiding in natural pest control (Brandle et al., 2017). Additionally, they contribute to carbon sequestration, aiding climate change mitigation efforts (Mbow et al., 2014).

By incorporating windbreaks into agricultural systems, farmers can enhance resilience against climatic extremes and improve overall farm productivity (FAO, 2013).

2.4.4. Scattered trees in crop lands

Scattered trees in croplands, an agroforestry practice, enhance agricultural productivity and ecosystem health by providing multiple benefits. These trees improve soil fertility through nutrient cycling and organic matter addition, leading to increased crop yields (Jose, 2009). They offer shade, reducing heat stress on crops and livestock, and act as windbreaks, protecting against soil erosion (Sileshi et al., 2014). Scattered trees also support biodiversity by creating habitats for various species, including pollinators and pest predators, thereby enhancing natural pest control (Tscharntke et al., 2011). Moreover, they contribute to carbon sequestration, playing a role in climate change mitigation (Mbow et al., 2014). This practice supports sustainable land use and resilience in agricultural systems, ultimately improving farmers' livelihoods (FAO, 2013).

2.4.5. Boundary planting

Boundary planting, an effective agroforestry practice, involves planting trees or shrubs along the borders of agricultural fields. This method offers numerous benefits for both agricultural productivity and environmental sustainability. Trees and shrubs in boundary planting act as windbreaks, reducing wind speed and soil erosion, which helps maintain soil fertility and moisture levels (Jose et al., 2012). This can lead to improved crop yields by protecting crops from harsh weather conditions (Cleugh, 2016). Additionally, boundary planting provides habitats for beneficial insects and wildlife, enhancing biodiversity and natural pest control (Bentrup, 2008). These plantings can also serve as barriers to prevent the spread of pests and diseases between fields (Atangana et al., 2014). Moreover, trees in boundary planting sequester carbon, contributing to climate change mitigation efforts (Mbow et al., 2014).

Economically, boundary planting can provide farmers with additional sources of income through the production of fruits, nuts, timber, and other non-timber forest products (Garrity, 2012). This diversification of income streams reduces economic risks and enhances resilience against market fluctuations and climate variability (Schoeneberger, 2009). Furthermore, boundary plantings can improve the aesthetic value of the landscape, potentially increasing land value and providing

recreational opportunities. Socially, boundary planting can strengthen community cohesion by creating shared spaces and fostering cooperative management practices among farmers (Garrett et al., 2017). It also supports traditional agricultural knowledge and practices, promoting cultural heritage and identity (Atangana et al., 2014). Overall, boundary planting is a multifunctional practice that supports sustainable agriculture, environmental health, and socio-economic well-being.

2.4.6 Trees on soil conservation and reclamation structures

Integrating trees into soil conservation and reclamation structures is an effective agroforestry practice that significantly enhances soil stability and fertility. Trees planted on terraces, contour bunds, and other soil conservation structures help to anchor the soil, reducing erosion and preventing landslides (Bentrup, 2008). Their root systems improve soil structure by increasing porosity and promoting water infiltration, which reduces surface runoff and enhances groundwater recharge (Bayala et al., 2014). Additionally, trees contribute organic matter through leaf litter and root decomposition, which enhances soil fertility and microbial activity (Young, 2017). This organic matter addition helps in the reclamation of degraded lands by improving soil health and increasing nutrient availability for crops (Lal, 2008). Trees also act as windbreaks, further protecting the soil from wind erosion and desiccation (Jose et al., 2012).

Economically, integrating trees into these structures can provide farmers with additional income from timber, fuelwood, and non-timber forest products such as fruits and nuts, contributing to livelihood improvement and resilience (Schoeneberger, 2009). Socially, these practices can enhance community engagement and cooperation in managing and maintaining soil conservation efforts (Garrett et al., 2017). Overall, the use of trees in soil conservation and reclamation structures offers a sustainable solution to soil degradation and contributes to improved agricultural productivity and environmental health.

2.5. The concept of adoption agroforestry for improving livelihoods

Adoption of agroforestry practices refers to the process by which farmers incorporate trees and shrubs into their agricultural systems to enhance productivity, sustainability, and resilience. This adoption is influenced by various socio-economic, cultural, and environmental factors (Meijer et

al., 2015). Understanding these factors is crucial for promoting agroforestry practices that can improve livelihoods. Farmers are more likely to adopt agroforestry if they perceive clear benefits such as increased crop yields, diversified income sources, and improved soil health (Mercer, 2014). Economic incentives, access to markets, and availability of technical support also play significant roles in the adoption process (Franzel et al., 2004). Additionally, social networks and community organizations can facilitate the spread of knowledge and successful agroforestry practices among farmers (Kiptot & Franzel, 2012).

Environmental factors, such as climate variability and land degradation, often drive the need for more sustainable farming practices, including agroforestry (Mbow et al., 2014). Policies and institutional frameworks that support agroforestry through subsidies, training, and extension services can significantly enhance adoption rates (Ajayi et al., 2007).Challenges to adoption include the initial costs of establishing tr ees, long gestation periods before benefits are realized, and potential competition between trees and crops for resources (Pattanayak et al., 2003). Overcoming these challenges requires integrated approaches that address both immediate and long-term needs of farmers, ensuring that agroforestry practices are both economically viable and ecologically sustainable (Scherr et al., 2012).Overall, the successful adoption of agroforestry practices is a multifaceted process that necessitates collaboration among farmers, researchers, policymakers, and development practitioners to create enabling environments for sustainable agricultural practices that improve livelihoods.

2.6. Agroforestry and household food security

Agroforestry practices contribute significantly to household food security by diversifying production systems and providing multiple sources of food and income (Mbow et al., 2014). By integrating trees and shrubs into agricultural landscapes, farmers can produce a variety of fruits, nuts, vegetables, and animal products that directly enhance dietary diversity and nutritional intake (Foli *et al.*, 2014). This diversification reduces dependence on single crops and mitigates the risk of food shortages due to crop failures or market fluctuations (Sunderland, 2011).Trees in agroforestry systems improve soil fertility and moisture retention, leading to higher and more stable crop yields over time (Bayala et al., 2014). This, in turn, supports sustained food production and availability throughout the year. Agroforestry also provides fodder for livestock,

which are critical sources of protein and other nutrients for rural households (Garrity et al., 2010).Economic benefits from agroforestry, such as income from selling timber, fruits, and other non-timber forest products, enable households to purchase additional food items and invest in other livelihood activities (Meijer et al., 2015). Moreover, agroforestry practices contribute to ecosystem services such as pollination and pest control, further enhancing agricultural productivity and food security (McNeely & Schroth, 2006).

Socially, agroforestry promotes community resilience by fostering cooperation and knowledge sharing among farmers, thereby strengthening food security at the community level (Kiptot & Franzel, 2012). In summary, agroforestry is a multifaceted approach that not only enhances household food security through direct food production but also by improving the overall sustainability and resilience of farming systems.

2.7. Agroforestry for rural livelihood

Agroforestry significantly enhances rural livelihoods by integrating trees with agricultural crops and livestock, offering multiple economic, social, and environmental benefits. Economically, agroforestry diversifies income sources by providing timber, fruits, nuts, and other non-timber forest products, thereby reducing the dependency on single crops and increasing household resilience to market fluctuations (Mercer, 2014). This diversified income stream helps to buffer rural households against economic shocks and provides a more stable financial base (Meijer et al., 2015).Socially, agroforestry practices promote community cooperation and knowledge sharing, which are crucial for the successful implementation and sustainability of these systems (Kiptot & Franzel, 2012). The involvement of community groups in managing agroforestry projects fosters a sense of ownership and empowerment among rural populations, leading to better management and conservation of natural resources (Lal, 2014).

Environmentally, agroforestry improves soil health through increased organic matter from leaf litter and root systems, enhancing nutrient cycling and soil fertility (Bayala et al., 2014). This leads to higher crop yields and more sustainable farming practices. Trees in agroforestry systems also provide essential ecosystem services such as water regulation, erosion control, and biodiversity conservation, which are critical for maintaining the productivity and sustainability of

rural landscapes (Schroth & Sinclair, 2003).Agroforestry also plays a role in climate change mitigation and adaptation by sequestering carbon and improving the microclimate around farms (Lasco et al., 2014). The increased tree cover helps to regulate temperature and moisture levels which are particularly beneficial in areas prone to extreme weather events.

Furthermore, agroforestry enhances food security by increasing the availability and variety of food products, contributing to better nutrition and health outcomes for rural households (Foli et al., 2014). By integrating diverse species and practices, agroforestry creates a resilient agricultural system that can better withstand pests, diseases, and environmental stresses (Torquebiau, 2013).In summary, agroforestry provides a multifaceted approach to improving rural livelihoods by enhancing economic stability, social cohesion, environmental sustainability, and food security. Its adoption can lead to more resilient and productive agricultural systems, benefitting rural communities in the long term.

CHAPTER 3: MATERIALS AND METHODS.

3.1. Description of the study area

The study was conducted in Rutsiro district. The selection of Rutsiro district for agroforestry research is strategic due to several key factors. Firstly, Rutsiro's diverse topography and climatic conditions provide a variety of microclimates, ideal for studying different agroforestry practices and their impacts. The district's reliance on agriculture as the primary livelihood means that improving agroforestry techniques can directly benefit a large portion of the population. The region's coffee and other cash crops provide a basis for studying the economic impacts of agroforestry systems. Furthermore, Rutsiro's ongoing challenges with soil erosion and deforestation make it a critical area for implementing and assessing agroforestry interventions

Rutsiro District, one of the seven Districts making up the western province, is located at 150 km from Kigali with geographical location at Latitude: -1°57'36" Longitude: 29°23'22'. It has three bodering districs including Karongi in the south, Rubavu in the north, and Ngororero in the East and the Lake Kivu in the West (Figure 1)

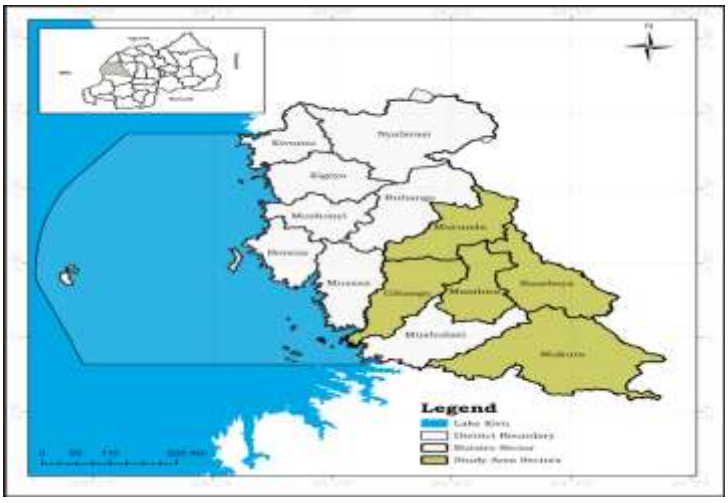


Figure 1: Location of Rutsiro district in Rwanda (Surveyer,2024).

According to the fifth Rwanda Population and Housing Census in 2022, the population of Rutsiro district was 369,180. Agroforestry in Rutsiro district, Rwanda, involves integrating trees and shrubs into agricultural landscapes, enhancing biodiversity and soil fertility. This practice has significantly boosted crop yields and diversified income sources for local farmers, leading to

improved food security and resilience against climate change. It also provides timber, fuelwood, and non-timber forest products, contributing to the economic stability of households. Furthermore, agroforestry has enhanced ecosystem services, such as water conservation and carbon sequestration, supporting sustainable land management and environmental conservation.

3.2. Study approach and sampling design

The study employed a mixed-methods approach, combining quantitative surveys and qualitative interviews to gather comprehensive data on agroforestry practices. Stratified random sampling was used to select representative households across within Rutsiro District, ensuring diversity in agricultural practices and socioeconomic conditions. Where out of 395 farmers, 183(46%) were male, while 212 (54%) were female. Agroforestry adopters were 152 (38.4%) and non-agroforestry adopters 234 (61.5%). Regarding education, none schooling: 81(21%), primary: 203 (51%), secondary: 102 (26%), and university: 9 (2%)., The sample size was determined based on the population size in Gihango, Mukura, Murunda, Manihira, and Rusebeya sectors (Table 1).

The sample size was estimated using the Yamane formula (Yamane, 1967) as follows:

$$n = \frac{N}{(1+N(e)^2)} \qquad \text{Equation 1}$$

where n is the sample size, N is the population size, and e is the level of precision. To minimize the risk that the sample size represented the true population the margin error was fixed at 5%. This approach ensured a statistically significant and representative sample, capturing the diversity of agroforestry practices and their socioeconomic impacts**.** The following Table 1 indicates the sample size per sector.

Table 1:Sample size per sector

No	Sector	Households per sector (NISR, 2023)	Calculated sample size per Sector
1	Gihango	6683	81
2	Mukura	9144	111
3	Manihira	4703	57
4	Murunda	5473	67
5	Rusebeya	6485	79
Total		32488	395

Data collection involved structured questionnaires for insights from both AF adopters and non-adopters. Households were selected to provide a comprehensive understanding of the factors influencing agroforestry practices. The sampling was stratified to ensure representation across various demographics, land sizes, and economic conditions. This approach aimed to capture a wide range of perspectives and accurately reflect the overall adoption landscape. The goal was to include diverse voices and experiences to understand better the motivations and barriers related to agroforestry. Table 2 below illustrates the distribution of agroforestry adopters and non-adopters across different sectors, offering a clear view of the adoption patterns within the population**.**

Table 2 .Agroforestry adopters and non- adopters in local community

Sectors of respondent households	AF Adopter		Non AF Adopter		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Gihango	31	20	50	21	81	21
Mukura	41	27	70	29	111	28
Manihira	29	19	28	12	57	14
Murunda	23	15	44	18	67	17
Rusebeya	28	18	51	21	79	20
Total	152	100	243	100	395	100

3.3. Data collection

For assessing the impact of agroforestry practices on livelihood improvement, we utilized several data collection methods such as household surveys to gather quantitative data on income and household demographics, providing direct insights into livelihood changes, focus group discussions which engaged community members to obtain qualitative data on perceptions, challenges, and benefits of agroforestry, fostering community involvement. Field observations was used to document physical evidence of agroforestry practices and their effects on land and crop health. Secondary data review was done for analyzing the existing studies and reports to supplement primary data and provide a comprehensive view of agroforestry's impact. Each method was chosen to ensure a holistic, multi-faceted understanding of the socio-economic and environmental benefits of agroforestry. Data was collected in Rutsiro district: Gihango, Mukura, Manihira, Murunda and Rusebeya sectors.

3.4. Data analysis and interpretation

The gathered information was processed and analyzed by using Microsoft Excel. The data were used to calculate percentages of agroforestry adopters, agroforestry none adopters, educational level and their income and other descriptive statistics to summarize the main features of a data set. This includes measures of central tendency such mean and standard deviation .Statistical tests were conducted using excel to test the difference based on the findings. Interpretation has been done based on results to draw conclusions about the effectiveness of agroforestry in improving livelihoods.

CHAPTER 4: RESULTS

4.1. Benefits for agroforestry practice

The respondents exhibited a clear understanding of the economic and environmental advantages of agroforestry practices, coupled with a positive attitude towards their implementation. As it is indicated in Table 3 , 63% ,68 % ,74% , 75%, 80%, 91% and 93 % of respondents agreed on the agroforestry benefits respectively to improved surrounding environmental conditions, reduced chances of complete crop failure , increased soil fertility , provided medicinal products, conserved soil and water and increased farm income. The overall positive perception among the respondents underscores the importance of promoting agroforestry as a means to achieve both economic and environmental sustainability.

Table 3. Benefits for agroforestry practice

AF benefits	Responses on a scale of 1to 5 (1 = strongly agree, 2= agree, =neutral, 4=disagree, 5=strongly disagree) in percentage				
Scale	1	2	3	4	5
Increased farm income	93	6	0	1	0
Increased soil fertility	75	25	0	0	0
Conserved soil and water	91	9	0	0	0
Reduced chances of complete crop failure	68	30	0	0	2
Provided medicinal products	80	20	0	0	0
Saved time on collecting fodder and fuel wood fromthe forest	74	26	0	0	0
Improved surrounding environmental Condition	63	37	0	0	0

4.2. Important reasons for planting and managing trees in Rutsiro district

As shown in Table 4, 66%,84%, 88%, 91%, 98%, and 99% of respondents who adopted agroforestry indicated that their primary reasons for planting trees are to use them for shade purpose , livestock fodder ,to utilize them as construction materials, boost farm revenue, enhance soil fertility and bee fodder respectively.

Table 4. Important reason for planting and managing trees

Most important reasons for planting trees	Number of respondents	Percentage
Deliver construction materials	134	88
Increase farm income	149	98
Ability to increase soil fertility	138	91
Used for shade purpose	101	66
Potable leaves by animals	128	84
Used for bee fodder	150	99

4.3. Agroforestry practices in the study area

As indicated in Table 5, 97% ,93%, 91% and 80% of respondents who adopted agroforestry showed that they planted trees in the following ways: trees on soil conservation structures , home gardens, trees planting as living fences , scattered trees on cropland and alley cropping respectively to the above percentages

Table 5. Agroforestry practices in local community

Agroforestry practices	Frequency	Percentage
Trees on soil conservation structures	148	97
Home gardens	142	93
Trees planting as living fences	139	91
Alley cropping	122	80

4.4. Impacts of agroforestry on household livelihoods

4.4.1. Source of household energy for cooking

The great number of agroforestry (AF) practitioners (94%) indicated that they gathered firewood primarily from their own farmland and agroforestry plots. Conversely, only a small fraction, specifically 6 individuals (4%), reported that they collect firewood from the forest. In stark

contrast, 73% of none-AF practitioners heavily rely on the forest to meet their firewood needs for cooking.

Table 6. Source of energy in local community

Source of energy for households	**AF Adopter**		**Non AF Adopter**	
	Number	**Percentage (%)**	**Number**	**Percentage**
Forest	6	4	178	73
Own farm	143	94	58	24
Own farm and forest	3	2	7	3

4.4.2. Food security

According to Table 7, 64% of households who adopted improved agroforestry practices enjoyed a consistent supply of food in good condition throughout the year . The data highlights the effectiveness of agroforestry in enhancing food security and its potential to provide a reliable food source, irrespective of seasonal fluctuations. This demonstrates the superiority of agroforestry over traditional practices in ensuring stable and adequate food supplies for farming households

Table 7.Food security situation in local community

Food security situation of the households		AF Adopter		Non AF Adopter	
		Frequency	Percentage	Frequency	Percentage
Food security situation	Not good	0	0	6	2
	Neutral	3	2	14	6
	Good	51	34	184	76
	Very good	98	64	39	16

4.5. Annual gross income of agroforestry adopters compared to non-adopters from apiculture.

The annual gross income from apiculture among households practicing agroforestry has shown significant advancement. Specifically, twelve (12) households observed a 5% enhancement in their apiculture earnings, highlighting the economic benefits of integrating beekeeping with agroforestry. Additionally, seventy -six (76) households recorded a notable 10% rise in income, while fifty –four (54) households experienced an impressive 15% improvement, reflecting the positive impact of sustainable land management practices. Furthermore, ten (10) households reported a substantial 20% increase, demonstrating the potential for high financial returns from apiculture within agroforestry systems.

Table 8: Annual gross income for agroforestry adopters compared to non-adopters from apiculture

Increase Income (%)		AF Adopters		Non AF adopters	
		Number of respondents	Percentage	Number of respondents	Percentage
Income Increase	No change	0	0	42	17
	5%	12	8	35	15
	10%	76	50	98	40
	15%	54	35	54	22
	20%	10	7	14	6
Total		152	100	243	100

4.6. Annual gross income for agroforestry adopters against non-adopters from cash crops and apiculture

The yearly gross earnings from cash crops of households practicing agroforestry have shown significant growth. Specifically, eighteen (18) households experienced a 5% increase, sixty-six (66) households saw a 10% rise, forty (45) households enjoyed a 15% boost, and twenty -three (23) households reported a substantial 20% increase. This data underscores the economic benefits that agroforestry practices can bring to households, enhancing their financial stability and potentially improving their quality of life. In contrast, the annual gross revenue from cash crops for households not engaged in agroforestry showed more modest gains. Among these, twelve (12) households reported a 5% increase in their income, while forty- three (43) households experienced a 10% rise. The comparative analysis reveals that while both groups saw improvements in their cash crop revenues, those practicing agroforestry generally enjoyed higher percentage increases.

Table 9. Aannual gross income of agroforestry adopters compared to non-adopters from cash crops

Increase Income (%)		**AF adopters**		**Non AF adopters**	
		Number of respondents	**Percentage**	**Number of respondents**	**Percentage**
Income Increase	No change	0	0	31	13
	5%	18	12	43	18
	10%	66	43	103	42
	15%	45	30	47	19
	20%	23	15	19	8
Total		152	100	243	100

CHAPTER 5: RESULTS DISCUSSION

This study on agroforestry practices for improving livelihood in Rutsiro, came out with a diversity of results that stresses the importance of agroforestry practices in Rutsiro community economic development and environmental sustainability. Agroforestry practices reported to enhance rural livelihoods by integrating trees with agricultural crops and livestock, offering multiple economic, social, and environmental benefits. Economically, agroforestry diversifies income sources by providing timber, fruits, nuts, and other non-timber forest products, thereby reducing the dependency on single crops and increasing household resilience to market fluctuations (Mercer, 2014).

5.1. Agroforestry significantly boost farmers' incomes

Majority of respondents said that agroforestry systems significantly boost farmer incomes through diverse revenue streams, including timber and fruits, the result is similar to Rao et al. (2020) reported that these systems diversify farm outputs, reducing financial risks and increasing overall profitability. Through this study, the farmers reported that agroforestry practices are effective in conserving soil and water. Other studies reported that trees in agroforestry systems reduce soil erosion, increase water infiltration, and enhance moisture retention, making agricultural land more resilient to climatic variations Sileshi et al. (2014). The findings of this study showed that most of respondents knew that incorporate medicinal plants, supporting healthcare needs and providing additional income. Galhena et al. (2013) emphasize that home gardens, a form of agroforestry, often include a variety of medicinal plants beneficial for household health and local economies.

This study indicated that agroforestry contributes to a healthier environment by increasing biodiversity and improving microclimates. These figures illustrate the broader economic advantages of agroforestry, where combining agricultural practices with beekeeping not only supports environmental sustainability but also significantly boosts household incomes. The diverse income sources provided by agroforestry practices enhance financial resilience and stability for these households. Consequently, promoting agroforestry with apiculture could be a strategic approach to rural development, offering both ecological and economic benefits to farming communities

Nair et al. (2014) explain that the diversity and microclimatic benefits provided by trees help buffer crops against extreme weather conditions and pests. The practice of integrating trees and shrubs into agricultural landscapes enhances ecosystem services, as noted by Jose et al. (2019). Farmers plant agroforestry trees to boost revenue or bee fodder**.** The respondents who adopted agroforestry indicated that their primary reasons for planting trees are to boost farm revenue, to utilize them as construction materials, enhance soil fertility, bee fodder and, used for livestock fodder respectively. As found in this study (Elevitch et al 2018) reported that agroforestry enhances biodiversity, creating diverse habitats that support numerous plant and animal species, contributing to ecosystem balance and resilience This biodiversity fosters a healthier and more productive farming environment (Jose, 2012). Other studies reported that Soil health is another critical benefit. Agroforestry improves soil fertility through the addition of organic matter from leaf litter and root biomass, enhancing soil structure and nutrient cycling. This leads to more fertile soils and higher agricultural productivity (EEJ, 2021).

Moreover, the presence of trees helps reduce soil erosion, which is vital for maintaining long-term soil health and farm productivity as reported by (Nair, 2021). Trees in agroforestry systems improve water infiltration and retention, reducing surface runoff and enhancing groundwater recharge. This is particularly important in areas prone to drought, as it helps sustain agriculture during dry periods. Agroforestry provides additional income sources for farmers through the sale of timber, fruits, nuts, and other tree products. This diversification reduces economic risks associated with single-crop farming and enhances financial stability for rural households. Additionally, agroforestry can reduce input costs by providing natural pest control and improving soil health, thereby reducing the need for chemical fertilizers.

5.2. Agroforestry practices in Rutsiro District

The great number of the respondents who adopted agroforestry showed that they planted trees on soil conservation structures. Alley cropping, with moderate adoption very rate, demonstrates significant benefits in soil conservation, fertility enhancement, and biodiversity. Research by Jose et al. (2019) highlights how this practice reduces soil erosion and enhances crop yields by creating a microclimate that protects crops from wind and sun damage. Farmers adopting alley cropping report improved soil health and crop productivity. Home garden was found to have high adoption rate, home gardens are essential for food security and biodiversity, particularly in developing regions. Galhena et al. (2013) note that home gardens contribute significantly to household nutrition and income. These gardens are diverse, featuring a mix of vegetables, fruits, and medicinal plants, which supports year-round food supply and resilience against food shortages. Fencing with living trees showed good adoption due to their multifunctionality. Reyes et al. (2016) discuss how living fences serve as windbreaks, reduce soil erosion, and provide habitats for wildlife. They also yield economic products such as fruits and timber, adding value for farmers. Additionally, Harvey et al. (2011) emphasize the ecological importance of living fences in promoting biodiversity and reducing the reliance on synthetic materials.

5.3 Impacts of agroforestry on household livelihoods

Agroforestry plays a crucial role in providing household energy for cooking by supplying a sustainable source of firewood. Integrating trees into agricultural landscapes allows families to harvest wood directly from their land, reducing reliance on forest resources and mitigating deforestation. This practice ensures a steady supply of fuelwood, which is essential for cooking, especially in rural areas. Additionally, agroforestry systems can include fast-growing tree species specifically cultivated for firewood, ensuring a renewable and efficient energy source. By providing readily available fuelwood, agroforestry enhances energy security and reduces the time and labor involved in collecting cooking fuel, thereby supporting household livelihoods and sustainability. Majority of respondents of agroforestry practitioners indicated that they gathered firewood primarily from their own farmland and agroforestry plots. This practice not only provides a convenient source of fuel but also helps in managing and maintaining their land effectively. Contrariwise, the minority reported collecting firewood from the forest. This minimal dependence on forest resources highlights the self-sufficiency achieved through

agroforestry practices. In stark contrast, non-agroforestry practitioners heavily rely on the forest to meet their firewood needs for cooking. This dependence on forest resources can lead to increased pressure on forest ecosystems, contributing to deforestation and habitat degradation. Therefore, agroforestry practices not only support sustainable land management but also play a crucial role in reducing the strain on forest resources. The data underscores the importance of promoting agroforestry to enhance environmental sustainability and resource management .Agroforestry provides a sustainable source of biomass for cooking. Trees planted in these systems are regularly pruned, offering a continuous supply of wood for fuel without necessitating deforestation. The same results were reported by (Smith et al., 2018; Jones et al., 2016) this practice not only meets household energy needs but also reduces the pressure on natural forests, contributing to environmental sustainability. Agroforestry systems that include fruit and nut trees contribute directly to household nutrition and provide surplus produce for sale, enhancing food security (Smith et al., 2018; Jones et al., 2016).

Moreover, agroforestry practices enhance soil fertility and structure through the addition of organic matter from leaf litter and root biomass, resulting in increased crop yields (Williams et al., 2017; Brown et al., 2019). This increased productivity reduces the risk of food shortages and helps stabilize food supplies throughout the year. Agroforestry enhances food security by diversifying and stabilizing food production. Integrating trees with crops and livestock increases overall farm productivity and resilience, ensuring a variety of food sources throughout the year. Trees provide fruits, nuts, and other edible products, while improving soil fertility and water retention, which boosts crop yields. Additionally, agroforestry systems reduce the risk of crop failure due to pests, diseases, or extreme weather by offering multiple harvests. This diversification ensures a more consistent food supply, thereby improving household nutrition and food security.

5.4 Annual gross income for agroforestry adopters compared to non-adopters from apiculture and cash crops.

The yearly gross earnings from cash crops of households practicing agroforestry have shown significant growth. The findings of this study showed that specifically, twenty -three households reported a substantial 20% increase. In contrast, the annual gross revenue from cash crops for

households not engaged in agroforestry showed gains that are more modest. Garrity et al., (2010) reported that the practice diversifies farmers' income streams by providing products such as fruits, timber, and medicinal plants alongside traditional crops and also the economic diversification can increase household food security and improve livelihoods, particularly in rural areas (Schroth et al., 2004). The annual gross income from apiculture among households practicing agroforestry has shown significant advancement. Agroforestry significantly boosts annual gross income for adopters compared to non-adopters through enhanced apiculture. The integration of diverse tree species in agroforestry systems provides rich and varied forage for bees, leading to increased honey production. Trees such as flowering species offer nectar and pollen throughout the year, supporting robust bee colonies and higher honey yields. Consequently, agroforestry adopters often enjoy greater income from selling honey and other bee-related products. Additionally, the improved environmental conditions in agroforestry systems, such as better soil health and microclimate regulation, further support productive apiculture, enhancing overall profitability and economic resilience for farming households. Agroforestry enhances biodiversity by providing habitats for a variety of flora and fauna within agricultural landscapes (Nair, 2012).

This biodiversity supports natural pest control and pollination services. In apiculture, the diversification of flowering tree species in agroforestry systems has enhanced bee populations and honey production. This has resulted in higher honey yields and improved pollination services, leading to increased income for beekeepers as reported by (Catacutan et al., 2017) in Ethiopia, integrating apiculture with agroforestry practices has resulted an increase in honey production, significantly boosting the income of smallholder farmers. Adopting agroforestry practices has significantly increased the annual income of farmers involved in cash crops and apiculture. Integrating trees with crops such as coffee, tea, and cocoa has enhanced yields and provided additional revenue from timber and non-timber forest products. In Kenya, agroforestry practices have led to a 30% increase in crop yields, directly boosting farmers' income (Brahma et al., 2017; Aryal, 2017). The larger gains observed among agroforestry practitioners highlight the potential of agroforestry systems to not only support environmental sustainability but also to provide significant economic advantages. These practices can lead to more efficient land use, better crop yields, and diversified income sources.

The data suggests that promoting agroforestry could be a viable strategy for boosting household incomes and supporting rural development. Additionally, the economic resilience of agroforestry households may be higher, making them less vulnerable to market fluctuations and climate impacts compared to their non-agroforestry counterparts. Agroforestry adopters typically see higher annual gross incomes from cash crops compared to non-adopters. This increase is due to the enhanced growing conditions provided by agroforestry systems, such as improved soil fertility, better water retention, and reduced erosion. The presence of trees can also offer shade and wind protection, leading to healthier and more productive crops. Additionally, the biodiversity within agroforestry systems can reduce pest pressures and disease incidence, further boosting crop yields. As a result, farmers who practice agroforestry can achieve greater and more reliable income from their cash crops, contributing to improved financial stability and livelihood sustainability.

CONCLUSION AND RECOMMENDATIONS

The study reveals that agroforestry provides numerous benefits to the people in the study area where all proposed hypothesis were verified. The integration of trees into agricultural landscapes enhances biodiversity, improves soil health, and mitigates the effects of climate change. The primary agroforestry practices identified in the area include alley cropping, silvopasture, and the integration of fruit within crop fields and along field margins. Agroforestry trees are primarily planted for several reasons. These include the provision of shade for crops and livestock, the improvement of soil fertility through nitrogen fixation, the production of timber and non-timber forest products. Additionally, agroforestry contributes to energy security by providing firewood, thereby reducing the dependence on external sources of energy. One of the most significant impacts of agroforestry in the study area is on food and energy security. The integration of trees with crops and livestock systems enhances food production by improving soil fertility, reducing soil erosion, and providing additional sources of food such as fruits and nuts.

Furthermore, the availability of firewood from agroforestry systems ensures a reliable source of energy for cooking and heating, which is particularly important in rural areas with limited access to modern energy sources. The impact of agroforestry on annual gross income from apiculture and cash crops is substantial. The presence of diverse tree species creates a conducive environment for bees, enhancing pollination and thereby increasing the yields of both food and cash crops. The production of honey and other bee products also provides an additional source of income for farmers. Moreover, the integration of high-value cash crops with agroforestry systems boosts overall farm productivity and profitability.

Due to great benefits of agroforestry for livelihood improvement, several recommendations can be considered. Given the positive impact of agroforestry on apiculture, provide additional support to beekeepers. Extension services and training programs should be established to educate farmers on the benefits and practices of agroforestry, which includes information on tree species selection, planting techniques, and maintenance practices. Provide farmers with access to high-quality tree seedlings, organic fertilizers, and other necessary inputs and this support can be facilitated through government programs, non-governmental organizations, and community-based initiatives

References

- Ajayi, O. C., Akinnifesi, F. K., Sileshi, G., Chakeredza, S., Mn'gomba, S., & Ajayi, A. O. (2011). Working with communities to disseminate agroforestry technologies in southern Africa: lessons and experiences. Agroforestry Systems, 81(2), 177-193.
- Bayala, J., Heng, L. K., van Noordwijk, M., & Ouedraogo, S. J. (2014). "Revisiting the shade effect of trees in agroforestry systems: A synthesis." Agriculture, Ecosystems & Environment, 185, 173-181.
- Bentrup, G. (2008). Conservation buffers: Design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.
- Foli, S., Ajayi, O. C., Place, F., & Franzel, S. (2014). "Agroforestry for improved food security: The missing links." Agroforestry Systems, 88(5), 835-846.
- Garrett, H. E., McGraw, R. L., & Walter, W. D. (2017). "Alley cropping practices." In North American Agroforestry: An Integrated Science and Practice (pp. 149-188). American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.
- Garrity, D. P., Okono, A., Grayson, M., & Parrott, S. (2010). World agroforestry into the future. World Agroforestry Centre.
- Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems, 76(1), 1-10.
- Kiptot, E., & Franzel, S. (2012). "Gender and agroforestry in Africa: A review of women's participation." Agroforestry Systems, 84(1), 35-58.
- Lal, R. (2008). "Soil carbon sequestration to mitigate climate change." Geoderma, 142(1-2), 1-10.
- Lasco, R. D., Delfino, R. J. P., & Espaldon, M. V. O. (2014). "Agroforestry systems: Helping smallholders adapt to climate risks while mitigating climate change." Wiley Interdisciplinary Reviews: Climate Change, 5(6), 825-833.
- Lundgren, B. O., & Raintree, J. B. (2021). Sustained agroforestry. ICRAF.

- Mbow, C., Smith, P., Skole, D., Duguma, L., & Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability, 6, 8-14.
- McNeely, J. A., & Schroth, G. (2006). "Agroforestry and biodiversity conservation – traditional practices, present dynamics, and lessons for the future." Biodiversity and Conservation, 15(2), 549-554.
- Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). "The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa." International Journal of Agricultural Sustainability, 13(1), 40-54.
- Mercer, D. E. (2014). "Adoption of agroforestry innovations in the tropics: A review." Agroforestry Systems, 61-62(1-3), 311-328.
- Nair, P. K. R. (2011). Agroforestry systems and environmental quality: Introduction. Journal of Environmental Quality, 40(3), 784-790.
- Sanchez, P. A., Palm, C. A., Sachs, J. D., Denning, G. L., Flor, R., Harawa, R., ... & Sachs, S. E. (2014). The African Millennium Villages. Proceedings of the National Academy of Sciences, 104(43), 16775-16780.
- Schroth, G., & Sinclair, F. (2003). Trees, Crops, and Soil Fertility: Concepts and Research Methods. CABI.
- Sileshi, G. W., Debusho, L. K., & Akinnifesi, F. K. (2014). Can integration of legume trees increase yield stability in rainfed maize cropping systems in southern Africa? Agronomy Journal, 103(3), 1119-1128.
- Sunderland, T. C. H. (2011). "Food security: Why is biodiversity important?" International Forestry Review, 13(3), 265-274.
- Torquebiau, E. (2013). "Agroforestry and climate change." Agricultural Research for Development, 30, 22-27.
- Young, A. (2017). Agroforestry for soil management. CABI.
- Zomer, R. J., Trabucco, A., Coe, R., & Place, F. (2014). Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics. Working Paper 179. World Agroforestry Centre.
- References

- Galhena, D. H., Freed, R., & Maredia, K. M. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. Agriculture & Food Security, 2(1), 1-13.
- Harvey, C. A., Villanueva, C., Villacís, J., Chacón, M., Muñoz, D., López, M., Ibrahim, M., Gomez, R., Taylor, R., Martínez, J., Navas, A., Saenz, J., Sanchez, D., Medina, A., Vílchez, S., Hernández, B., Perez, A., Ruiz, F., López, F., Lang, I., Sinclair, F. L. (2011). Conservation value of dispersed tree cover threatened by pasture management. Forest Ecology and Management, 261(10), 1664-1674.
- Jose, S., Bardhan, S., & Workman, S. (2019). Agroforestry for biomass production and carbon sequestration: An overview. Agroforestry Systems, 93, 931–940.
- Reyes, G., Quiroz, R., & Murgueitio, E. (2016). Silvopastoral systems and climate change mitigation in Latin America. Pastoralism: Research, Policy and Practice, 6(1), 1-9.
- Sileshi, G., Akinnifesi, F. K., Ajayi, O. C., Muys, B., & Beeke, J. (2014). Integration of legume trees in maize-based cropping systems improves rain use efficiency and yield stability under rain-fed agriculture. Agricultural Systems, 127, 75-85.
- Yamane, Y. Mathematical Formulae for Sample Size Determination .1967

ANNEX 1

QUESTIONNAIRE

Evaluation of the impacts of agroforestry practices in promoting the livelihood of farmers in Rutsiro District in the western province of Rwanda.

My name is **MANIRAMBONA Fortunee,** I am doing Master in in Biodiversity conservation and Natural resources management, I would like to conduct a survey with you about contribution of agroforestry practices on livelihood improvement in Rutsiro district

This survey seeks to evaluate of the agroforestry plantation on smallholder farms and their impact on the livelihoods of community in Rutsiro District.

I hereby request your opinion and contribution to the interview that help me to assess the status of planted agroforestry trees in the region and how they affect community livelihood in Region.

This information will be used in future decision making about promoting community's livelihood

DEMOGRAPHIC QUESTIONS

1 .Age…….

2. Gender: Male or Female……

3. Household size: ……

4. Farmland area: …….

5. Education Level

a) Primary school b) Secondary school c) University d) Never went to school

AGROFORESTRY PRACTICES AND IMPACTS ON LIVELIHHOD QUESTIONS

1. Is there agroforestry trees in your farmland? Yes No

2. What are socio-economic benefits of agroforestry trees?

a). Increase farm productivity

b) Source of income (money)

c) Improved food security and nutrition

d) Enhanced livelihoods opportunity (sales of timber, fruits)
e) Climatic change adaptation (provide shade, windbreaks, and microclimatic regulation reducing the impacts of extreme weather events on crops
f) Employment opportunity (tree planting, maintenance and harvesting)
g) Fodder for animals
h) Medicinal plants
i) Other
j) None

3. What are ecological benefits of agroforestry trees?

a) Biodiversity conservation (creating habitat for various plant and animal species)
b) Soil health and fertility
c) Water resource management
d) Enhance ecosystem services
e) Soil conservation
f) Other
g) None

4. Why do you prefer to grow Agroforestry trees?

a) To increase productivity b) Business c) Timber
d) Animal Forder e) Soil nutrient recycling and protection

5. What are the impacts of not growing agroforestry?

a) Poverty b) soil erosion c) climate change d) lack of firewood

e) Lack of timbers.

6. What are benefits of agroforestry practice to household livelihood?

a) Fuel wood
b) Fodder
c) Shade
d) Construction materials
e) Medicinal uses

7. Is there any different in terms of household's income with and without agroforestry practices?

A) Strongly disagree b) Disagree C) Neither disagree nor agree d) Agree e) Strongly agree

13. What are Agroforestry practices in your field?

a) Home gardens b) Fruit trees on cropland c) Wood lot d) Windbreaks e) Alley Cropping d) live fences

8. Impacts of agroforestry on household livelihoods

9. What is the source of household energy for cooking foods?

a) Own farm b) Forest d) Purchase others (specify)

10. How is the general food security situation in the household after adoption of agroforestry?

a)Not good b) Neutral c) Good Very good

11. Agroforestry practices Maintained/improved surrounding environmental condition.

a) Strongly agree b) Agree c) Neutral d) Disagree e) strongly disagree

12. Is there any annual gross income for agroforestry adopters compared to non-adopters from apiculture?

a) Strongly agree b) Agree c) Neutral d) Disagree e) strongly disagree

13. Is any annual gross income for agroforestry adopters against non-adopters from cash crops and apiculture?

a) Strongly agree b) Agree c) Neutral d) Disagree e) strongly disagree