UNIVERSITY *of* RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

SCHOOL OF SCIENCES

DEPARTMENT OF BIOLOGY

ACADEMIC YEAR: 2024-2025

MASTER'S PROGRAM IN BIODIVERSITY CONSERVATION AND NATURAL RESOURCES MANAGEMENT

SPATIAL DYNAMICS OF NATIVE AND EXOTIC TREES IN SOUTHWESTERN RWANDA: CASE STUDY OF NKUNGU AND NZAHAHA SECTORS OF RUSIZI DISTRICT

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

By

NDIKUBWIMANA Pascal

Reg. No: 221025480

Supervisors: Dr. RIZINJIRABAKE Fabien
Dr. MUJAWAMARIYA Myriam

Kigali, August 2025

APPROVAL

I, Ndikubwimana Pascal, hereby declare that this Master's dissertation entitled "Temporal and spatial dynamics of native and exotic trees in Southwestern Rwanda: Case Study of Nkungu and Nzahaha Sectors of Rusizi District, Rwanda" is the result of my work in partial fulfilment of the requirements for the award of a Master's degree in Biodiversity Conservation and Natural Resource Management at the University of Rwanda, College of Science and Technology and has not been submitted for any other degree at the University of Rwanda or any other institution. All sources that I have used or quoted have been indicated and acknowledged in the references.

Date:

Signed by:

1. **The student**
   NDIKUBWIMANA Pascal……………………………………
2. **The Supervisors:**

   Dr. RIZINJIRABAKE Fabien…………………………………..

   Dr. MUJAWAMARIYA Myriam ………………………………

DEDICATION

To my cherished family and friends, whose unwavering support, sacrifices, and encouragement laid the foundation for my academic journey; My Wife and Son, who provided me the tuition fees for this program, their continuous encouragement and motivation;

And to all smallholder farmers of Nkungu and Nzahaha Sectors, whose daily efforts in agroforestry and environmental conservation inspired this research.

ACKNOWLEDGEMENT

I am profoundly grateful to the Almighty God for granting me the strength and perseverance to accomplish this academic journey. My sincere thanks go to my supervisors, Dr. RIZINJIRABAKE Fabien and Dr. MUJAWAMARIYA Myriam, for their valuable guidance and constructive feedback throughout this research. I extend my heartfelt appreciation to the Albertine Rift Conservation Society (ARCOS) for their institutional support and all farmers from Nkungu and Nzahaha sectors for their participation in the study. Special thanks to my friends and classmates for their continuous encouragement. This work would not have been possible without your support.

Table of Contents

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

ICRAF: International center for research in Agroforestry

ISAR: Rwanda Institute for Research in Agriculture Science

REDD+: Reducing Emissions from Deforestation and Forest Degradation

ARCOS: Albertine Rift Conservation Society

NGO: Non-Governmental Organization

Mdn: Median

NbS: Nature-based Solution

DFMP: District forest management plan

P: P-Value

r = size effects

U: Mann–Whitney U statistic

ABSTRACT

This study assessed the spatial dynamics of native and exotic agroforestry tree species in Nkungu and Nzahaha sectors of Rusizi District, Southwestern Rwanda, an area increasingly affected by land degradation, biodiversity loss, and declining agricultural productivity. Understanding how farmers choose and distribute tree species in such vulnerable landscapes is essential for promoting sustainable agroforestry. However, empirical data on the balance between native and exotic species, their spatial arrangement, and the motivations behind species selection remain scarce in Rwanda's southwestern highlands. To address this gap, 100 agroforestry-practicing households were selected using Cochran's formula, as adapted by Gahutu Mbabarira and Nahayo (2020), ensuring statistical rigor with a 95% confidence level and 5% margin of error. Data were collected through structured household questionnaires, direct tree counts, and field observations to evaluate species composition, planting history, spatial patterns, and socio-economic drivers behind species preferences. The findings revealed a dominance of exotic tree species, with a native-to-exotic ratio of approximately 1:1.92. *Grevillea robusta* and *Markhamia lutea* emerged as the most commonly planted exotic and native species, respectively. Mann–Whitney U tests indicated a statistically significant difference in planting frequency between these categories ($p < 0.001$). Exotic species were often planted near homesteads and accessible zones, while native species were dispersed across marginal and less-managed areas. Farmers' tree selection was heavily influenced by institutional support (68%), economic profitability, and seedling availability. While native species were valued for their ecological functions, market pressures and limited propagation resources reinforced the preference for exotics. The study was conducted to fill a critical information gap regarding the ecological and socio-economic dimensions of tree species selection in agroforestry. By generating localized evidence on species use, distribution, and farmer preferences, the research provides practical guidance for policymakers, extension services, and restoration programs seeking to align agroforestry interventions with both productivity goals and biodiversity conservation in Rwanda and similar landscapes.

Keywords: Agroforestry, Native species, Exotic species, Temporal dynamics, Spatial distribution, Rwanda

CHAPTER 1. INTRODUCTION

1.1. Background

Agroforestry, the integration of trees and shrubs into agricultural lands, has become a globally recognized approach to address climate change, biodiversity loss, and land degradation (Sharma et al., 2023). Across the world, agroforestry is promoted as a sustainable land management practice that enhances soil fertility, supports food security, diversifies farmers’ income, and restores ecosystems (Foresta, 2013). In many tropical and subtropical regions, including Latin America, Southeast Asia, and Africa, agroforestry systems are central to national climate adaptation and mitigation policies (Foresta, 2013). In Sub-Saharan Africa, agroforestry is increasingly used as a solution to combat land degradation, rural poverty, and low agricultural productivity (FAO, 2020). Governments and NGOs across the region encourage tree planting in farms and pastures to restore soil health, provide shade, fodder, secure fuelwood and timber (Mbow, Smith, et al., 2014). However, the choice of tree species, particularly the balance between native and exotic species, has raised ecological concerns, as the benefits and risks of species introductions vary by context**.**

In Rwanda, agroforestry was formally introduced in 1969 through the “Projet agro-pastoral de Nyabisindu,” funded by Germany and implemented in Nyanza District (Uwera et al., 2023). It expanded further through research and development programs in the 1980s, led by ICRAF and the Rwanda Institute for Agricultural Sciences (ISAR) (Ndayambaje, 2013). Today, agroforestry is widely practiced and supported by national forest restoration and reforestation strategies. Agroforestry has been promoted for enhancing biodiversity, soil fertility, and community resilience (Gahutu Mbabarira, 2020). The dominance of exotic species in ecosystems, driven by their rapid growth and economic appeal, has sparked debate, as native species are typically more effective for biodiversity and sustainability.(Nkurikiye et al., 2024a). Furthermore, the integration of trees and shrubs with the crops within a single agricultural system promotes complementary production. This approach is beneficial because it allows for the use of alternative crop varieties to fill potential gaps caused by crop failures. This strategy not only enhances sustainability and resilience but also promotes greater diversity in agricultural practices (Ngango et al., 2023). However, the choice between native and exotic tree species remains a critical decision that impacts ecological balance and agricultural productivity in Rwanda. In the southwestern region of Rwanda, particularly Rusizi District, agroforestry systems are critical for addressing pressing environmental and agricultural challenges, including soil erosion, biodiversity loss, and declining crop productivity (Reinhard Endeki et al., 2023). Although agroforestry offers a viable pathway toward sustainability, the widespread adoption of exotic species such as *Eucalyptus* and *Grevillea* raises questions about ecological impacts, farmer preferences, and long-term resilience. A clear understanding of how native and exotic tree species are distributed and how their use changes over time is essential for designing balanced, sustainable systems.

Native species are well-adapted to local conditions and make significant contributions to biodiversity conservation (Jose, 2009). Exotic species, on the other hand, can provide quick economic benefits and higher yields but may lead to ecological problems such as invasiveness and reduced biodiversity (Christian, 2023). Understanding the ratios of these species and their spatial arrangement is crucial for developing sustainable agroforestry systems (Uwera et al., 2023). Moreover, the southwest part of Rwanda is experiencing significant environmental and agricultural challenges that threaten its sustainability. These include soil erosion arising from its topographic structure, loss of biodiversity, and declining agricultural productivity (Reinhard Endeki et al., 2023). Agroforestry has been deemed a viable solution, yet the choice between native and exotic tree species remains combative.

This study first seeks to quantify the current ratios of native versus exotic agroforestry tree species in Nkungu and Nzahaha Sectors of Rusizi District. Understanding the proportions of these species provides baseline information on biodiversity status and helps assess whether agroforestry practices favor ecological conservation or short-term economic gain. Secondly, the study aims to analyze the spatial distribution and selection criterion these tree species across farms. This analysis helps uncover how land use, elevation, and other landscape variables influence species presence and whether patterns of dominance have shifted over time due to policy, market, or environmental factors. Finally, the study explores the socio-economic and institutional drivers influencing farmers' tree selection decisions. By identifying key motivations and constraints, such as market access, extension services, or cultural knowledge, the research provides critical insight into how farmers balance ecological and economic priorities when managing agroforestry systems

1.2. Problem statement

Globally, agroforestry has emerged as a nature-based solution (NbS) to combat land degradation, enhance food and livelihood security, and support climate change mitigation (Franzel et al., 2004). It integrates trees with crops and livestock in ways that provide multifunctional benefits to rural communities. Despite these widely promoted benefits, many agroforestry systems globally rely heavily on a narrow set of fast-growing exotic tree species, which can lead to adverse ecological outcomes, including the loss of native biodiversity, reduced soil quality, and altered hydrological cycles (Dawson et al., 2013). Although widely adopted in policy frameworks, agroforestry practices often fail to evaluate the long-term ecological trade-offs between native and exotic species, particularly in terms of resilience and ecosystem services (Kirui et al., 2018; Mbow et al., 2014). In Sub-Saharan Africa, agroforestry has been promoted through national strategies for climate adaptation, rural development, and land restoration (Lasco et al., 2016). However, empirical studies across the region highlight a growing dominance of exotic species due to their commercial benefits, while native species are underutilized or ignored despite their ecological advantages (ICRAF, 2002). Regional research frequently overlooks the spatial and temporal dynamics of these tree species and the nuanced decision-making processes of farmers (Lasco et al., 2016). As a result, knowledge gaps remain concerning how tree species selection affects biodiversity, sustainability, and long-term land productivity in agroforestry systems.

Rwanda is among the African countries integrating agroforestry into national restoration efforts and agricultural policy. In Rusizi District, agroforestry practices have intensified amid growing concerns over land degradation, biodiversity loss, and food insecurity (Ndokoye, 2024). Urban expansion, coupled with population pressure, has accelerated deforestation and land conversion. While agroforestry has been promoted as a solution to these problems, most of the adopted species are exotic, such as *Eucalyptus* and *Grevillea*, due to their fast growth and perceived profitability (Noeldeke, 2022). This trend raises concerns about sustainability, ecological imbalance, and reduced resilience to environmental stressors. Despite their economic value, exotic species often exhibit invasive tendencies and can outcompete native trees, thereby disrupting local ecosystems (Nair, 2012). Yet, the spatial distribution and temporal patterns of native versus exotic trees in southwestern Rwanda remain poorly understood. There is insufficient data on the ecological trade-offs involved, such as impacts on soil fertility, water use efficiency, and biodiversity conservation. Moreover, little is known about the social, cultural, and institutional factors that shape farmers' preferences for tree species in this region, where agroforestry plays a key role in land restoration and livelihood resilience. This research aims to bridge these knowledge gaps by analyzing the proportions of native and exotic agroforestry tree species in Nkungu and Nzahaha Sectors of Rusizi District. It also investigates the drivers behind farmers’ tree species selection and the ecological implications of those decisions. The study’s findings will offer evidence-based insights to guide agroforestry policy, farmer support programs, and biodiversity conservation efforts, contributing to the development of more balanced and sustainable agroforestry systems in Rwanda and similar contexts in Sub-Saharan Africa. The lack of comprehensive data on how these different tree species establish and spread over time and space complicates the evaluation of their ecological impacts, including effects on biodiversity, soil properties, and ecosystem services. Additionally, insufficient knowledge about the factors influencing farmers' choices between native and exotic species further hinders efforts to assess how these decisions shape landscape composition and the sustainability of agroforestry practices. This knowledge gap hampers evidence-based decision-making for agroforestry development policies and sustainable land management strategies in Southwestern Rwanda, particularly in the context of increasing pressure on land resources and the need to balance environmental conservation with agricultural productivity. This research aims to fill this gap by providing detailed insights into the region’s spatiotemporal status and trends of agroforestry tree species. This research holds substantial significance for multiple stakeholders and various aspects of agroforestry development in Southwestern Rwanda and beyond. First, it provides an essential scientific understanding of how native and exotic tree species interact and evolve within agroforestry systems, filling critical knowledge gaps in ecological research. This knowledge is vital for policymakers and land managers who need evidence-based information to develop effective agroforestry policies and sustainable land management strategies. The study’s findings will help farmers to make more informed decisions about tree species selection, potentially improving their agricultural productivity and economic returns while ensuring environmental sustainability.

1.3. Objectives

1.3.1. Main objectives

This study aims to examine how farmers in Rusizi District select native and exotic agroforestry tree species to support sustainable agroforestry and develop effective policies. It also contributes to biodiversity conservation and tree-planting efforts to create resilient agroforestry landscapes. The findings will guide agroforestry planning and policy decisions, thereby promoting sustainable land use in Rwanda.

1.3.2. Specific Objectives:

1. To quantify native and exotic agroforestry tree species in Nkungu and Nzahaha sectors of Rusizi District.
2. To investigate the spatial distribution of native and exotic agroforestry tree species across farms in the study area.
3. To examine socio-economic and ecological factors that influence farmers' selection of agroforestry tree species.

1.4. Research Questions

1. What are the current native versus exotic agroforestry tree species in the Nkungu and Nzahaha sectors?
2. How are these species spatially distributed across farms in the study area?
3. What are the socio-economic and ecological factors influencing farmers' choices of native or exotic tree species in agroforestry systems in the study area? in agroforestry systems in the study area?

1.5. Hypotheses

1. The number of exotic agroforestry tree species is significantly higher than that of native species in the Nkungu and Nzahaha sectors, likely due to their faster growth rates, higher economic benefits, and greater accessibility through seedling availability support compared to native species.
2. The spatial distribution of native and exotic tree species differs significantly, with exotic species more commonly found near homesteads and accessible areas. while native species are more scattered or found in marginal land, because farmers tend to plant exotic species in areas where they can closely monitor and manage them due to their economic returns, while native species, often naturally regenerated or less prioritized and managed.

3. Farmers' selection of agroforestry tree species is significantly influenced by socio-economic factors (such as income level, land size, and market access) and ecological awareness, with economic pressures encouraging the choice of exotic species for their fast returns, and

ecological values motivating the retention or planting of native species for long-term environmental sustainability.

1.6. Significance of the Study

This study provides valuable insights into the temporal and spatial dynamics of both native and exotic agroforestry tree species in the Nkungu and Nzahaha sectors of Rusizi DistrictNative tree species, defined as indigenous trees that naturally occur and have evolved within the Rwandan ecosystemplay a crucial role in supporting local ecological stability, enriching soil fertility, and maintaining traditional agroecological knowledge. In contrast, exotic species refer to non-indigenous trees introduced from other regions or countries that are now cultivated in local agroforestry systems. By understanding the farmers’ preferences and spatial distribution and functional roles of both native and exotic species, the research supports more informed agroforestry practices that balance productivity with ecological resilience.

CHAPTER 2. LITERATURE REVIEW

2.1. Agroforestry as a sustainable land use strategy in Rwanda and East Africa

Agroforestry systems are gaining recognition as sustainable land-use methods that blend agricultural productivity with biodiversity conservation, climate resilience, ecological, economic, and social functions, especially in areas experiencing demographic pressures and land degradation (Kumar et al., 2024). In Rwanda, agroforestry has become essential for the resilience of smallholder agriculture, as it enhances soil fertility, mitigates the effects of climate variability, and zones provide valuable insights into the structural and functional diversity of agroforestry systems in Bugarama (Imbo lowlands) and Busogo (Volcanic highlands) (Uwera et al., 2023). Agroforestry practices contribute to reversing land degradation caused by intensive farming and population pressure (Bapfakurera et al., 2023). Particularly in southwestern Rwanda, where ecological degradation threatens both livelihoods and biodiversity, integrating agroforestry within smallholder farming systems offers a pathway toward sustainable rural development (Ndayambaje et al., 2012). It emphasizes diversified livelihoods (Mukeshimana & Rizinjirabake, 2024). A study conducted in two distinct agroecological that variations in agroecological conditions significantly affect tree species composition, distribution, and management practices(Nkurikiye et al., 2024b). This study revealed significant research needs in emerging areas that aim to investigate the temporal and spatial dynamics of both native and exotic agroforestry trees in lesser-explored regions, such as the Nkungu and Nzahaha sectors of the Rusizi District. The potential of agroforestry systems, which provide ecosystem services such as soil fertility enhancement, microclimate regulation, and carbon sequestration, underpins their prioritization in national restoration and climate adaptation policies (Reinhard Endeki et al., 2023).

2.2. Farmer preferences and socioeconomic drivers influencing agroforestry adoption

Understanding farmers' decision-making processes is essential for effectively promoting agroforestry practices. Recent studies utilizing discrete choice experiments, including the research conducted by Nkurikiye et al. (2024), illuminate the factors that farmers consider paramount when selecting tree species. These studies indicate that farmers often prioritize species that are fast-growing and multipurpose, particularly those that can provide crucial resources such as fodder for livestock, fuelwood for cooking and heating, and timber for construction. Furthermore, financial incentives play a significant role in shaping their choices, along with the availability of extension services and the perceived profitability of different agroforestry systems.

The study conducted by Bapfakurera et al. (2023) highlights the crucial role of actively involving farmers in both training sessions and participatory planning initiatives. This engagement is particularly vital for achieving successful reforestation efforts using native species. The authors emphasize that understanding the socioeconomic conditions and institutional frameworks within which farmers operate is essential for fostering effective agroforestry adoption (Ngango et al., 2023). These contexts significantly influence farmers' decisions and capabilities; therefore, addressing local needs, cultural practices, and organizational support systems can greatly enhance the likelihood of successful reforestation and agroforestry practices. By prioritizing farmer participation and contextual understanding, we can create more sustainable and effective environmental interventions. These findings resonate with a broader body of literature that advocates for a holistic approach in agroforestry interventions. It emphasizes the necessity of integrating the knowledge and experiences of farmers, respecting their cultural preferences, and considering their access to markets (Reubens et al., 2011). Such an approach is vital for designing effective strategies that enhance agroforestry practices and the livelihoods of farming communities.

2.3. Ecological suitability and species selection: balancing native and exotic trees

The selection of appropriate plant species that are well-suited to the local ecological conditions is a crucial factor in ensuring the success of agroforestry initiatives (Malawska & Topping, 2018). Developed an innovative multi-criteria decision-support tool aimed at assisting in the selection process of species based on a variety of ecological attributes, socio-economic functions, and stakeholder preferences (Gahutu Mbabarira and Nahayo, 2020). This tool highlighted the importance of preventing mismatches in species suitability, as these variances can substantially impede restoration efforts and the overall efficacy of agroforestry practices (Ndayambaje et al., 2012). In the context of Rwanda, certain native species, such as *Markhamia platycaryx* and various *Ficus* species, play a crucial role in providing critical habitat for wildlife and enhancing biodiversity. Conversely, exotic species like *Grevillea robusta* are recognized for their ability to accumulate biomass quickly, which can be beneficial in certain situations. However, there are potential risks associated with these fast-growing species; if they are less managed properly, they can pose threats to the health of the ecosystem (Bapfakurera et al., 2023; Tsegaye et al., 2023). Recent research conducted in agroecological zones similar to those found in Rwanda suggested that incorporating a mixture of native and exotic species within agroforestry systems can optimize ecological functions while simultaneously meeting the needs and preferences of farmers. However, this approach requires diligent monitoring of species interactions and a thorough understanding of the long-term impacts that these mixed systems may entail (Reinhard Endeki et al., 2023).

2.4. Temporal and spatial dynamics of agroforestry tree diversity

The composition and diversity of tree species within agroforestry systems exhibit a dynamic nature, shaped by various factors, including land-use changes over time, environmental conditions, and socio-economic influences. In their study, Abebe and Wiersum (2010) reported significant alterations in the diversity of species found in home gardens over time in southern Ethiopia. These shifts were largely attributed to evolving household preferences as well as fluctuations in market demands, underscoring how socio-economic factors can drive changes in biodiversity. In another case study from southwestern Rwanda (Ndayambaje et al., 2012), the spatial variability of tree distribution was explored, identifying both native and exotic species. They linked these variations to topographical features, such as slope, as well as soil fertility levels and different farm management practices. This relationship reveals the critical need for agroforestry planning that is sensitive to local environmental conditions and adaptable to the changing priorities of farmers, ensuring that biodiversity is maintained and enhanced in diverse ecological contexts. (Joseph Mayindo Mayelea, 2023) emphasized the critical role of diversity in agroforestry systems for two reasons. First, diverse agroforestry systems significantly enhance the resilience of ecosystems to the various challenges posed by climate variability. This resilience is crucial, as it enables ecosystems to better withstand disturbances such as extreme weather events, pest outbreaks, and changing soil conditions, ensuring that our soil remains productive and functional over time. Second, diversity is essential for sustaining carbon stocks within these ecosystems. Mayindo Mayelea and Sakurai (2023) underscore that carbon stocks are not evenly distributed across different tree species and geographical sites, which can have implications for both carbon sequestration and biodiversity conservation. Thus, an informed approach to the management and conservation of tree diversity within agroforestry systems is necessary. Such an approach not only supports ecological integrity but also contributes to the economic viability of farming practices (Reinhard Endeki et al., 2023). This multifaceted relationship illustrates the complex links between ecological, health, economic sustainability, and adaptive farming techniques. By advocating for increased tree diversity, we can promote healthier ecosystems that are resilient to climate change and provide long-term benefits to farmers and local communities (Noeldeke, 2022).

2.5. Carbon Sequestration and Climate Change Adaptation

Recent assessments of carbon stocks in agroforestry systems throughout East Africa reveal significant potential for carbon sequestration, especially when native multipurpose tree species are preserved or strategically introduced into these systems (Nsengumuremyi et al., 2021). The research highlights that species, including *Calliandra Colothyrusus* and *Sena spectabulis*, have a critical role in enhancing above-ground biomass carbon storage, thus significantly contributing to the overall carbon pool. However, it's essential to note that total carbon stocks can vary greatly depending on the specific composition of tree species utilized and the management practices implemented in these agroforestry setups.

In Rwanda, the integration of native tree species within agroforestry not only facilitates greater carbon capture but also boosts ecosystem stability and enhances the resilience of farmers to climate-related shocks. This dual benefit is crucial as it aligns with national commitments to initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and other international climate frameworks (Mukundente et al., 2020). Therefore, targeted tree planting initiatives that focus on native species, coupled with comprehensive capacity-building programs for farmers, are essential strategies for maximizing both environmental and agricultural resilience in the face of climate change.

2.6. Participatory approaches and capacity building for agroforestry sustainability

Successful agroforestry interventions depend on active farmer participation and extension support. Bapfakurera et al. (2023) highlight that participatory planning, coupled with financial and technical assistance, improves native species planting outcomes. Knowledge co-production involving farmers, researchers, and policy makers fosters context-specific solutions, enhancing adoption and sustainability (Nkurikiye et al., 2024). Decision support tools integrating scientific and indigenous knowledge, such as those proposed by Reubens et al. (2012), facilitate inclusive species selection and management planning. Strengthening agroforestry stakeholders’ networks and extension services is essential to disseminate best practices, support monitoring, and scale up agroforestry benefits across Rwanda’s smallholder landscapes.

2.7. Research gaps and future directions

While the ecological and socioeconomic advantages of agroforestry are well documented, there remain critical gaps in our understanding of the fine-scale temporal dynamics related to species composition and the interactions between native and exotic species within these diverse mixed systems (Ndayambaje, 2013). These gaps indicated a need for more comprehensive longitudinal studies that observe changes over multiple seasons but also dive into the decision-making processes employed by farmers throughout the growing cycles (Gahutu Mbabarira and Nahayo, 2020; Kiyani et al., 2017). Such research could greatly benefit from the integration of remote sensing data, which would aid in capturing and analyzing the complex spatial-temporal patterns that develop in agroforestry landscapes over time.

In addition to these observational studies, there is an urgent requirement for investigations aimed at optimizing agroforestry configurations (Gahutu Mbabarira and Nahayo, 2020). Researchers should focus on developing systems that can simultaneously enhance biodiversity, boost carbon sequestration rates, and improve the livelihood outcomes of farmers and the communities they support. This multifaceted approach could help create sustainable agroforestry practices that benefit both the environment and the economy. Furthermore, it is essential to explore the role of various policy instruments, which could facilitate better market linkages and incentivize the adoption of climate-smart practices. Such initiatives could play a crucial part in promoting sustainable agroforestry and encouraging adaptation to climate change, ultimately fostering resilient agricultural systems (Ntawuruhunga et al., 2024). The synthesis of these research areas has the potential to create a holistic understanding of agroforestry's impact and enhance its implementation in diverse ecological and socioeconomic contexts.

CHAPTER 3. MATERIALS AND METHODS

3.1. Study area description

This study was conducted in two contrasting sectors of Rusizi District: Nkungu and Nzahaha (Figure 1). The area is characterized by a tropical highland climate with bimodal rainfall distribution, long rains from March to May, and short rains from September to November. The annual precipitation averages between 1,200-1,500 mm, and mean annual temperatures vary from 17-24 °C depending on altitude(ESMP/Rusizi, 2023) Nkungu Sector lies adjacent to the Cyamudongo Natural Forest, a biodiversity-rich montane forest that influences land-use practices. In contrast, Nzahaha Sector borders the Rusizi River Basin, characterized by relatively lowland terrain and riverine ecological conditions. Both sectors feature diverse topographical structures, including steep hills prone to soil erosion and narrow valleys conducive to intensive land use. Nzahaha and Nkungu sectors lie within the central-southern portion of Rusizi District. Nzahaha ranges from 1,400-1,670 m in elevation and is located (-2.660, 28.921);(-2.653, 28.921); while Nkungu is between 1,400-1,600 m(-2.530,28.966). Rainfall in both sectors is typically 1,200-1,300 mm annually, and average temperatures range from 18-20 °C. Soils in this region include humic and haplic Acrisols, Ferralsols, and some alluvial clays in valley bottoms, providing moderate fertility suitable for agroforestry and mixed cropping. Socio-economically, the two sectors are rural and dominated by smallholder agriculture. Residents depend heavily on crop production and agroforestry for subsistence and income.

According to the 2022 Rwanda Population and Housing Census (National Institute of Statistics of Rwanda, 2022), in Rusizi District, 66.6% of the population is rural, while 33.4% is urban. Most of the district's sectors, including Nkungu and Nzahaha, are rural and heavily dependent on agriculture. Specifically, sectors such as Nzahaha and Nkungu report that over 90% of households are engaged in farming, with agroforestry practices being particularly prominent in these areas. Agroforestry interventions in the study area are supported by Cyamudongo project in Nkungu sector and currently by the Albertine Rift Conservation Society (ARCOS), aiming to address environmental challenges such as land degradation, declining soil fertility, and unsustainable farming practices. These initiatives align with national efforts to enhance ecological resilience and agricultural sustainability. Agroforestry practices feature both native and exotic tree species, with species like *Grevillea*, *Eucalyptus*, and *Ficus* widely adopted. However, population growth and urban expansion exert significant pressure on land, increasing the risk of biodiversity loss and land degradation (ESMP/Rusizi, 2023).

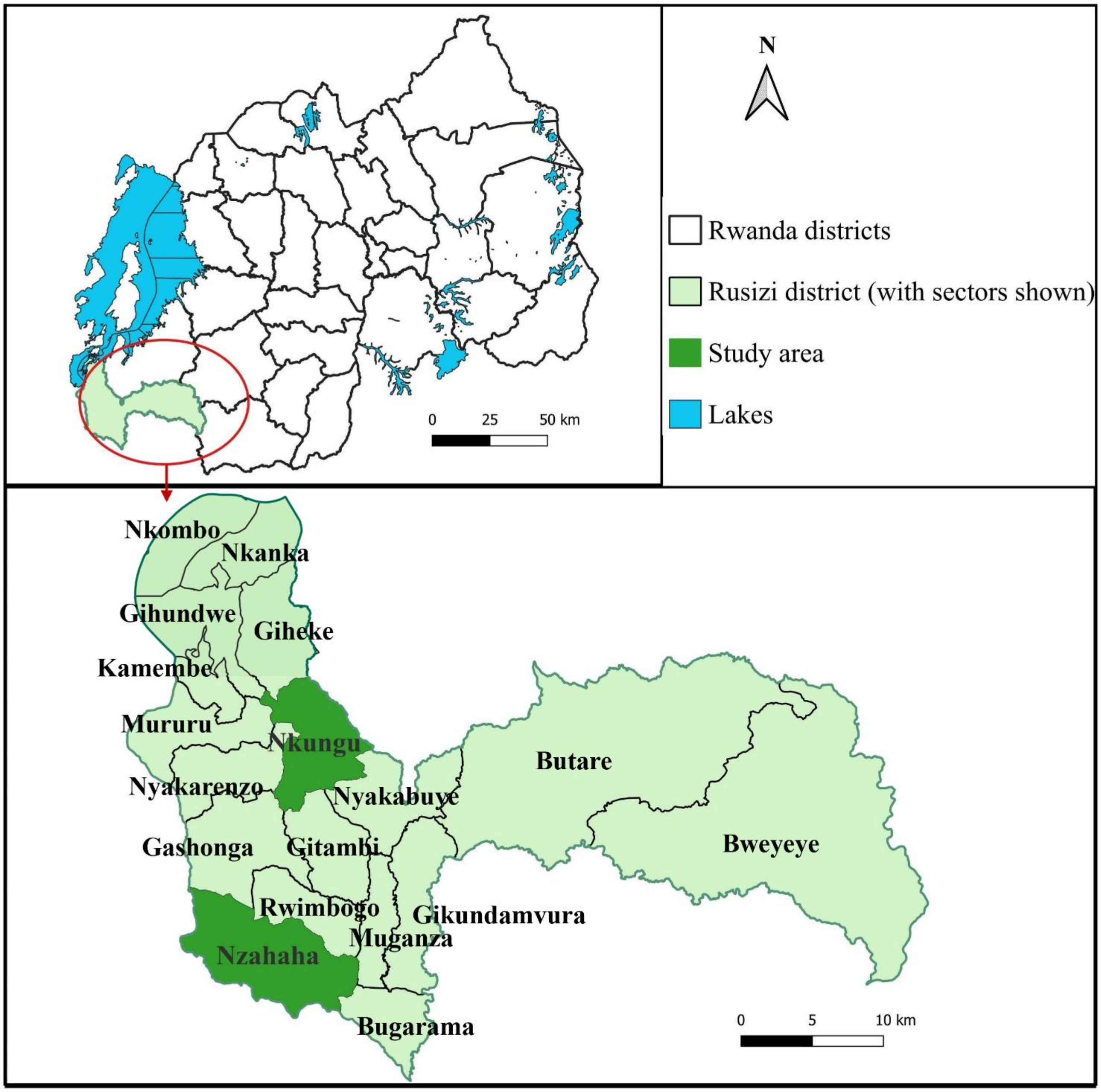

Figure 1: Location of the study area (Nkungu and Nzahaha Sectors)

3.2. Sampling strategy

Due to limited resources, to estimate an appropriate sample size for this study, Cochran's formula (Cochran, 1977) was considered $n_0 = \frac{Z^2 \cdot p \cdot (1-p)}{e^2}$

(Equation 1)

where n_o = corrected sample size, Z = 1.96 for 95% confidence interval, p = 0.5 estimated proportion for maximum variability, and e = 0.05 Margin of error, was taken at confidence interval of 95%. Using Equation 1 based on a standard proportion formula for sample size determination, as stated by Chanuan et al., (2021), a total of 90.25≈100 respondents was determined to be an appropriate sample size for this study

The sample was drawn from four cells in Nkungu Sector: Mataba, Ryamuhirwa, Kiziguro, and Gatare, and two cells in Nzahaha Sector: Rwinzuki and Nyenji. These specific sectors and cells were purposively chosen due to their distinct agroecological conditions. The following Table 1 summarizes the sampled population from each cell of the study area.

Table 1: Sampled population from each cell of the study area as calculated by Cochran's formula using data from the 5th population census

Sector	**Cells**	**Total Number of households (NISR, 2022)**	**Total Number of selected households**
Nkungu 21696	Mataba	2,017	10
	Ryamuhirwa	4,045	25
	Kiziguro	3292	5
	Gatare	2142	10
Nzahaha 30399	Rwinzuki	9214	15
	Nyenji	12129	35
Total		**52095**	**100**

3.3. Data Collection

This study targeted both the households in Nkungu and Nzahaha Sectors of Rusizi District that practice agroforestry practices in their farmland. An intensive household survey was carried out by using the questionnaire between May and June 2025. Based on problemstated and the research objective, a well-designed form of questions were used as closed and open ended questions, and it was set in English language during the interviews an focus group discussions the enumerator used to translate in Kinyarwanda for effective communication and interviewer responded in Kinyarwanda and recorded in English. And you will find the form of questions guided during the data collection process. Direct observations and measurements were made to verify the data collected through surveys. Thereafter, the study investigated the types of trees used in agroforestry practices as well as the factors influencing tree selection among those who practice them.

3.4. Data analysis

We employed descriptive statistical analysis to summarize and understand the data. For further analysis, we used R software version 4.3.2, which enabled us to analyze the information clearly and visually. The Mann-Whitney U distribution test was applied to assess the socio-economic characteristics of farmers and the specific attributes of farms concerning exotic and native agroforestry species in the Nzahaha and Nkungu sectors, as these data set exhibited non-normal distributions. Additionally, we performed chi-square tests of independence to examine the relationships between the reasons for planting agroforestry trees and the influencing factors, as well as to assess differences in the frequency of cited reasons. The effect size was measured using the rank-biserial correlation coefficient (r). Statistical significance was set at $\alpha = 0.05$ for all analyses. We focused on identifying specific characteristics between exotic and native species.

CHAPTER 4. RESULTS

4.1. Proportions of native and exotic agroforestry trees in the study areas

The study found that exotic agroforestry tree species were significantly more abundant than native species in both Nkungu and Nzahaha sectors. Across all surveyed farms, exotic species made up approximately 65-75% of all recorded trees, while native species represented only 25-35%. The most commonly planted exotic species included *Grevillea robusta*, *Eucalyptus spp.*, and *Calliandra calothyrsus*, valued for their fast growth and market potential. In contrast, native species such as *Ficus spp.*, *Markhamia lutea*, and *Albizia gummifera* were less prevalent and often retained rather than newly planted.

Comparison between sectors showed a slightly higher proportion of native species in Nzahaha compared to Nkungu, which may be attributed to differences in farmer awareness, proximity to remnant natural vegetation, or historical land use practices. Moreover, the ratio of indigenous to exotic agroforestry species in both Nkungu and Nzahaha sectors was approximately 1:1.92, indicating a higher prevalence of exotic species across the study area. A Mann–Whitney U test indicated a statistically significant difference in the number of agroforestry tree species per farmer, with exotic species (Mdn = 5) being more frequently planted than indigenous species (Mdn = 2), U = 3957, $p < 0.001$, r = 0.55. This suggests a medium to large effect size, indicating a consistent preference for exotic species across farms.

In contrast, the difference in the number of indigenous species per farmer between Nzahaha (Mdn = 2) and Nkungu (Mdn = 2.5) was not statistically significant, U = 115, p = 0.314, r = 0.09, indicating a negligible effect. Similarly, the number of exotic species planted per farmer did not differ significantly between Nzahaha (Mdn = 5) and Nkungu (Mdn = 5), U = 56.5, p = 0.813, r = 0.03. Regarding planting history, no significant temporal difference was found between the establishment years of indigenous (Mdn = 17 years) and exotic (Mdn = 17.5 years) species, U = 4778, p = 0.944, r

= 0.01, suggesting similar timelines of integration into farming systems.

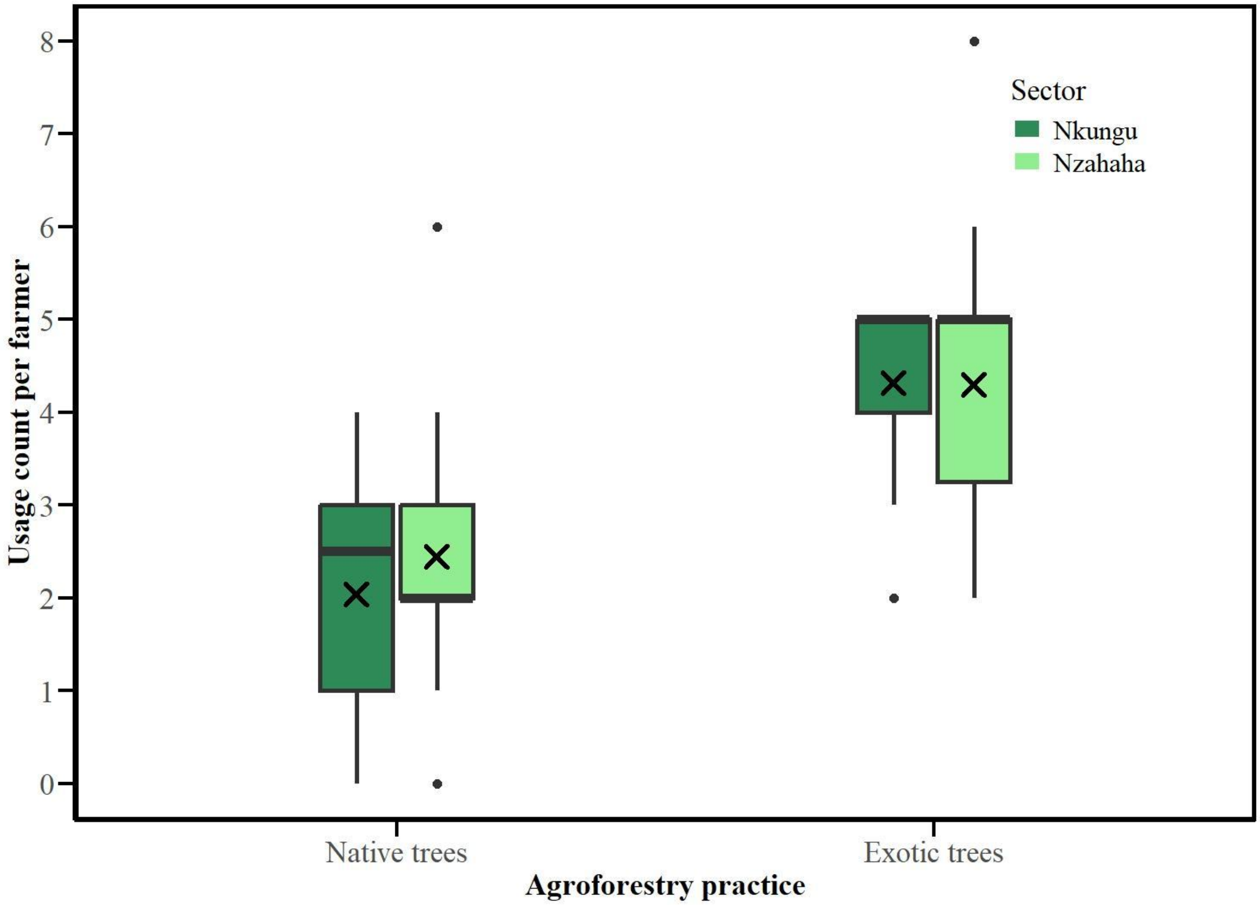

Figure2. Usage count per farmer for native and exotic agroforestry trees in Nkungu and Nzahaha sectors

4.2. Analyzing the spatial distribution patterns of native and exotic agroforestry tree species across farms in the study areas.

The spatial analysis showed that exotic species were mainly found around homesteads, on farm boundaries, and in compact block plantations. In contrast, native species were more dispersed or located in less intensively managed farm areas such as woodlots, fallow lands, and field margins. Spatial differences also varied by topography: exotic trees dominated lowland zones where market access and extension services were more available, while native trees were more common in upland and less accessible farms. The top three indigenous agroforestry species in Nkungu sector were *Markhamia lutea* (25.6%), P*olycias fulva* 16.01%) *and Ficus thonningii* (12.2%). In Nzahaha sector, the leading indigenous species were *Markhamia lutea* (25.9%), *Erythrna abyssinica* (15.1%), and

Maesa lanceolate (14.3%). Among exotic species, *Grevillea robusta*, *Cedrela serrata*, and *Calliandra calothyrsus* were the top three in both Nkungu and Nzahaha sectors, with usage proportions of 20.8%, 20.4%, and 13.9% in Nkungu, and 21.3%, 14.8%, and 13.4% in Nzahaha, respectively. Overall, *Markhamia lutea* was the most frequently recorded indigenous species, while *Grevillea robusta* was the most dominant exotic species across both sectors (Figure 3).

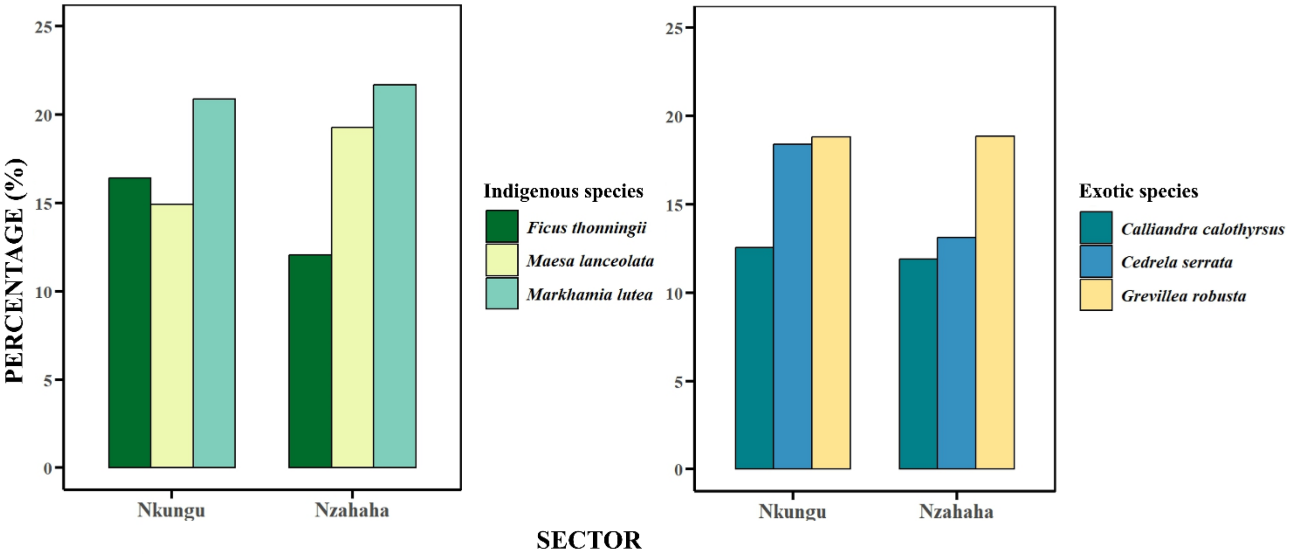

Figure 3. The top three indigenous and exotic agroforestry species in Nkungu and Nzahaha sectors. "Others" represent the remaining species.

4.3. Socio-economic and ecological factors that influence farmers' selection of agroforestry tree species

A chi-square test revealed significant differences in the frequency of reasons cited for planting agroforestry trees, $\chi^2(5) = 16.83$, $p = 0.0048$, indicating uneven distribution among reasons. Timber was the most frequently mentioned reason, while fruit production was the least cited (Figure 3). A follow-up chi-square test found no significant association between reason cited and sector, χ^2 (5) = 0.75, p = 0.980, suggesting patterns of reasons were similar between Nzahaha and Nkungu. Farmers preferred exotic species due to their fast growth rates, straight stems, and known commercial value. In contrast, native species were valued more for ecological functions such as soil improvement, shade, fodder, and traditional uses, yet were less often prioritized due to limited seedling availability and lack of promotion in farmer trainings. Landholding size, education level, and years of farming experience also influenced species selection. Larger-scale farmers tended to invest more in exotic woodlots, while smaller farms had a more mixed composition.

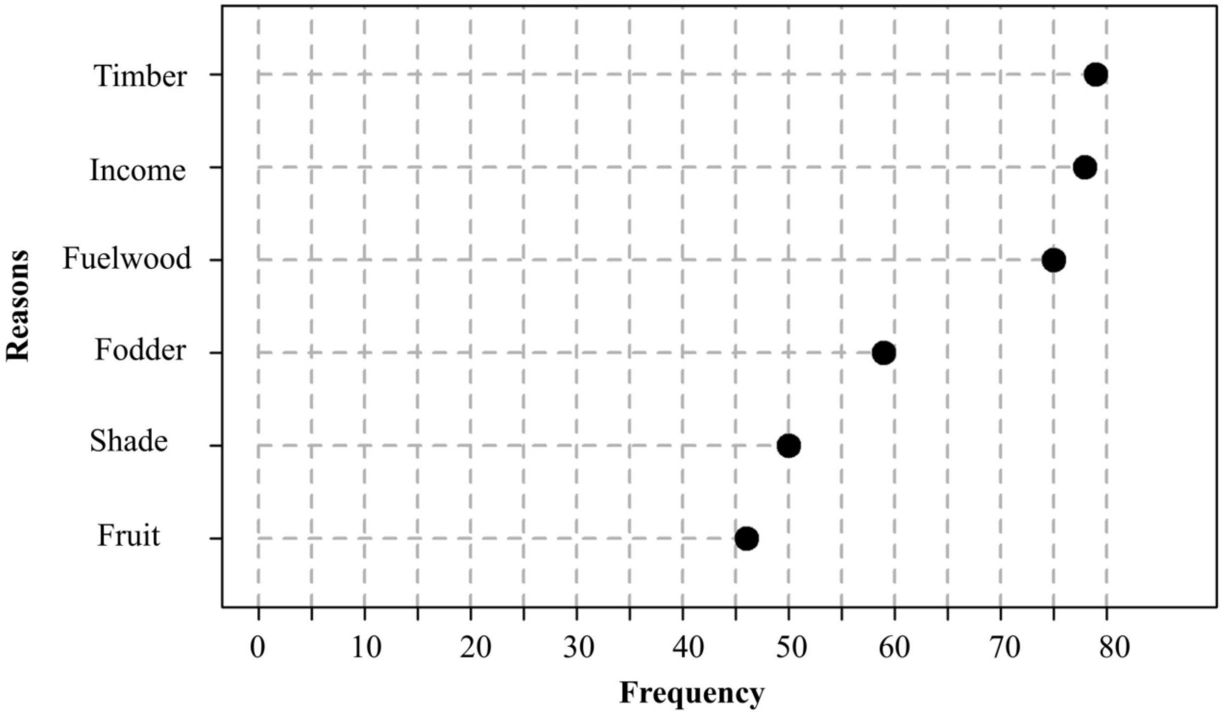

Figure 4: Frequency of reported reasons for growing agroforestry trees among surveyed farmers

4.4. Factors influencing agroforestry species planting

In addition to species composition, farmers were asked to indicate the primary factors influencing their choice of agroforestry tree species. The results revealed that the majority of farmers (68%) cited advice from NGOs and agricultural extension agents as a key influence, followed by economic profitability (58%), seedling availability (47%), and personal knowledge or traditional practices (44%). Other contributing factors included market demand (39%) and soil improvement potential (35%). These findings suggest that institutional support, especially from NGOs and extension services, plays a pivotal role in shaping agroforestry decisions in both Nkungu and Nzahaha sectors. At the same time, nearly half of the farmers rely on their knowledge or inherited practices, indicating the continuing relevance of indigenous knowledge systems. This dual influence supports the interpretation made in the discussion and conclusion that agroforestry adoption is both farmer-driven and institutionally guided.

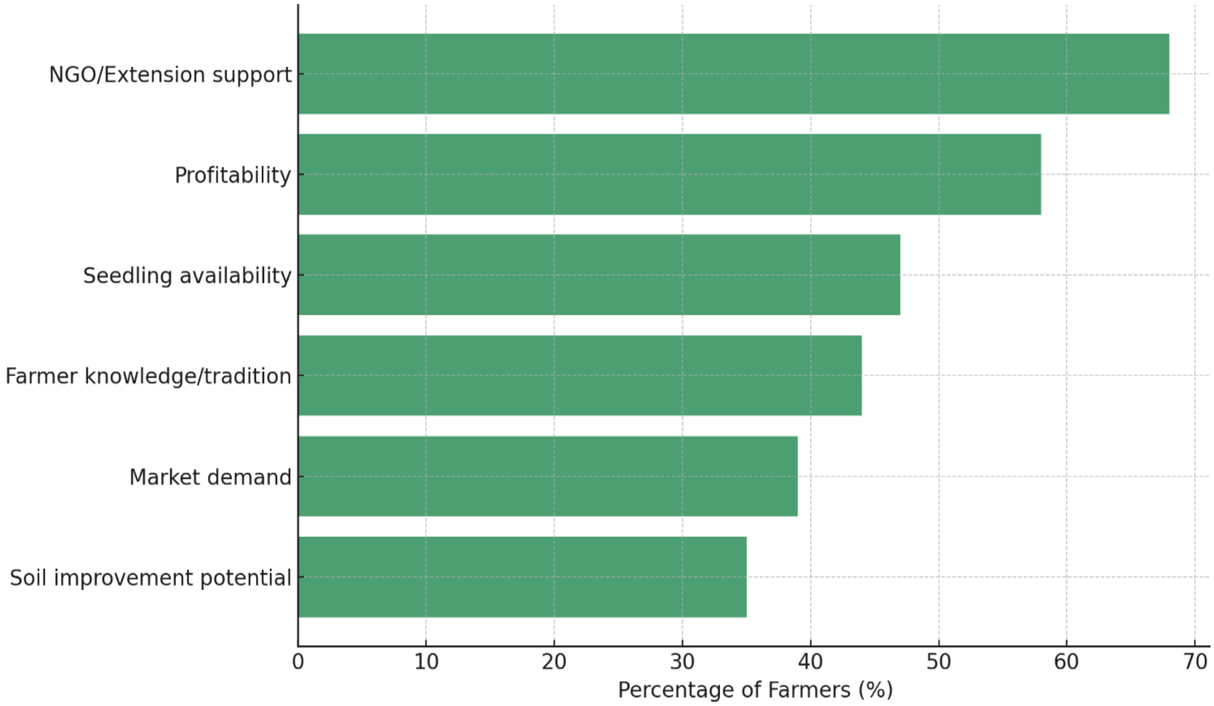

Figure 5: Factors influencing agroforestry tree species selection among surveyed farmers

CHAPTER 5. Discussion

This study provides valuable insights into spatial dynamics of native and exotic agroforestry trees in the Nkungu and Nzahaha sectors of Rusizi District. The observed 1:1.92 ratio of indigenous to exotic species indicates a strong preference for exotic species across the study area. This trend is consistent with findings from Ndayisaba et al. (2016), who reported the widespread adoption of exotic species such as *Grevillea robusta* and *Calliandra callothyrsus* in Rwanda due to their rapid growth, high timber yield, and adaptability. Similarly, (Franzel et al., 2004) noted that farmers in East Africa often prefer exotic species for their market value and ecosystem services, especially where land pressures demand fast results. The Mann-Whitney U test confirmed a statistically significant difference in the number of exotic versus indigenous species per farmer ($p < 0.001$), reinforcing the dominance of exotic species in local agroforestry systems. However, this result contrasts with findings by De Leeuw et al. (2014) in Kenya, where indigenous species like *Faidherbia albida* were prioritized for their soil fertility benefits and cultural significance. This divergence may reflect differences in institutional support and extension services, with projects in Rwanda historically emphasizing exotics for their quick returns and alignment with reforestation targets (Nsengumuremyi et al., 2021).

Interestingly, no significant difference was found between sectors regarding the number of exotic or indigenous species per farmer. This uniformity may stem from shared agroforestry promotion initiatives, particularly those led by the Albertine Rift Conservation Society (ARCOS), which has supported similar programs across both sectors. These findings agree with Wittemann et al. (2024) and Bapfakurera et al. (2023)who observed that consistent NGO-led interventions can lead to homogeneous adoption patterns across otherwise ecologically diverse regions.

In terms of species composition, *Grevillea robusta* and *Markhamia Lutea* emerged as the most dominant exotic and indigenous species, respectively. These results align with previous studies by (Ndayambaje & Mohren, 2011), which identified Grevillea as the most favored agroforestry species in Rwanda due to its timber value and compatibility with intercropping. Similarly, Kalaba et al. (2010) in Zambia noted *Markhamia lutea* as a key native species because of its rapid growth and ecological versatility. However, the continued use of native species like *Markhamia lutea*, *Ficus thonningii*, and *Maesa lanceolata* across both sectors indicates that traditional knowledge and ecological functions (such as providing shade and supporting biodiversity) still influence tree choices. This supports findings by Atangana et al. (2014), who argued that even in systems dominated by exotics, farmers keep indigenous trees for their ecological resilience and multipurpose roles, contributing to agroecological balance and biodiversity conservation.

The absence of significant temporal differences in the age of planted indigenous and exotic species (medians of 17 and 17.5 years, respectively) suggests that both types have been integrated into farming systems for a comparable duration. This finding aligns with(Ndoli et al., 2021), who observed a long-term coexistence of both tree types in agroforestry systems in Southern Rwanda. However, it contradicts assumptions in some conservation literature that exotic tree planting is a more recent phenomenon driven solely by development projects(Binam et al., 2017).

The reasons for planting trees varied significantly across the sample ($\chi^2 = 16.83$, $p = 0.0048$), with timber production being the most frequently cited purpose, followed by fuelwood and soil conservation. Surprisingly, fruit production was the least mentioned, despite the nutritional and economic value of fruit trees. This contradicts the findings of Kehlenbeck et al. (2007)in Uganda and

Kenya, where fruit trees were among the top agroforestry choices due to household nutrition strategies. The difference could be attributed to limited market access, lack of propagation materials, or insufficient technical support for fruit tree management in Rusizi. The lack of significant association between reason for planting and sector ($p = 0.980$) suggests that farmers in both Nkungu and Nzahaha share similar livelihood priorities and ecological challenges. This homogeneity reinforces the idea that agroforestry decisions are less influenced by agro-ecological variation than by institutional support and farmer knowledge, a view supported by Coulibaly et al. (2017) in their work on West African agroforestry systems. Collectively, these results underscore the complementary roles of indigenous and exotic species in local agroforestry systems. While exotics dominate numerically due to fast growth and economic benefits, indigenous species remain essential for maintaining ecological functions and cultural values. This coexistence reflects a locally adapted, farmer-driven model of agroforestry, balancing productivity with resilience, a dynamic also emphasized by Luedeling et al.(2014) in their meta-analysis of African agroforestry systems.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSIONS

This research indicates that agroforestry systems in the Nkungu and Nzahaha areas of Rusizi District primarily consist of exotic tree species, while still maintaining a presence of indigenous trees. The widespread choice of exotic species is mainly driven by their rapid growth and economic benefits, whereas indigenous species play essential ecological and cultural roles. The consistency in species composition and reasons for planting across different sectors suggests that institutional support and farmer knowledge significantly shape agroforestry practices, often overshadowing local ecological differences. The combined use of both native and exotic species over similar periods illustrates a careful, farmer-led approach to agroforestry that seeks to balance productivity with sustainability. Nevertheless, the limited use of fruit trees points to possible opportunities for diversification that could improve household nutrition and income, indicating a need for targeted initiatives to enhance propagation materials and technical assistance. Considering these insights, agroforestry promotion initiatives should persist in encouraging a diverse species mix that harnesses the advantages of both indigenous and exotic trees. Strengthening farmer knowledge through extension services and improving market access, particularly for fruit and multipurpose tree species, will be essential in cultivating resilient and productive agroforestry systems that support local livelihoods and conserve biodiversity.

6.2. RECOMMENDATIONS

To promote biodiversity conservation and support farmers' livelihoods in Rusizi District, agroforestry development should focus on integrating native tree species along with economically valuable exotic species. This involves improving access to native seedlings through local nurseries and including native species in public and NGO-led distribution campaigns. Extension services should adopt a more balanced approach that educates farmers about both the ecological benefits of native species, such as improving soil fertility, providing shade, enhancing biodiversity, and the economic opportunities from well-managed agroforestry systems. Localized agroforestry guidelines need to reflect different topographies and socio-economic conditions, encouraging region-appropriate planting strategies. Policy frameworks should offer incentives for biodiversity-friendly practices, including monitoring systems to track the diversity of agroforestry systems over time. Strengthening participatory research that utilizes indigenous knowledge to assess the performance of native species under local conditions can further empower farmers and inform best practices for sustainable management. Ultimately, integrating agroforestry into broader land restoration initiatives, such as the District Forest Management Plans and the Green Rwanda strategy, will help institutionalize sustainable practices, enhance climate resilience, and ensure long-term ecological and economic benefits for rural communities.

REFERENCES

A. Gahutu Mbabarira., & N. (2020). Impact Assessment of Agroforestry Practices on Community Socio-Economic Livelihoods in Rwanda. *Inter. J. Envi. Agri. Resea*, *6*(1), 59.

Abebe, T., Wiersum, K. F., & Bongers, F. (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of southern Ethiopia. *Agroforestry Systems*, *78*(3), 309–322. https://doi.org/10.1007/s10457-009-9246-6

Bapfakurera, E. N., Habimana, S., Uwamahoro, P. C., Uwizeyimana, V., & Musabwayire, C. (2023). *Opportunities and challenges in native species reforestation on smallholder farms in Rwanda : A Review*. *4*(1).

Binam, J. N., Place, F., Djalal, A. A., & Kalinganire, A. (2017). Effects of local institutions on the adoption of agroforestry innovations: evidence of farmer managed natural regeneration and its implications for rural livelihoods in the Sahel. *Agricultural and Food Economics*, *5*(1). https://doi.org/10.1186/s40100-017-0072-2

Chanuan, U., Kajohnsak, C., & Nittaya Sintao. (2021). Sample Size Estimation using Yamane and Cochran and Krejcie and Morgan and Green Formulas and Cohen Statistical Power Analysis by G*Power and Comparisons. *APHEIT International Journal*, *10*(2), 76–88.

Christian, H.-M. (2023). The Main Drivers of Biodiversity Loss: A Brief Overview. *Journal of Ecology & Natural Resources*, *7*(3). https://doi.org/10.23880/jenr-16000346

Coulibaly, J. Y., Chiputwa, B., Nakelse, T., & Kundhlande, G. (2017). Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agricultural Systems*, *155*, 52–69. https://doi.org/10.1016/j.agsy.2017.03.017

Dawson, I. K., Guariguata, M. R., Loo, J., Weber, J. C., Lengkeek, A., Bush, D., Cornelius, J., Guarino, L., Kindt, R., Orwa, C., Russell, J., & Jamnadass, R. (2013). What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. *Biodiversity and Conservation*, *22*(2), 301–324. https://doi.org/10.1007/s10531-012-0429-5

De Leeuw, J., Njenga, M., Wagner, B., & Iiyama, M. (2014). *An assessment of the resilience* *provided by trees in the drylands of Eastern Africa*. *January*.

Elias, M., & Fabien, R. (2024). *Perception and Knowledge of Local Community on the Use of Indigenous Tree Species for Ecosystem Restoration in Gasabo District , Rwanda*. *6*(1), 1–19.

ESMP/Rusizi. (2023). *(ESMP) FOR SECOND ADDITIONAL FINANCING FOR THE RWANDA*. *May*.

FAO, L. R. through A. mechanisms. (2020). Food and Agriculture Organization of the United Nations (FAO). Agroforestry for landscape restoration. *Agroforestry for Landscape Restoration*.

Foresta, H. de. (2013). Advancing agroforestry on the policy agenda – a guide for decision-makers. In *Forests, Trees and Livelihoods* (Vol. 22, Issue 3). https://doi.org/10.1080/14728028.2013.806162

Franzel, S., Denning, G. L., Lillesø, J. P. B., & Mercado, A. R. (2004). Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. *Agroforestry Systems*, *61–62*(1–3), 329–344. https://doi.org/10.1023/B:AGFO.0000029008.71743.2d

ICRAF. (2002). Trees on the farm: assessing the adoption potential of agroforestry practices in Africa. In *Trees on the farm: assessing the adoption potential of agroforestry practices in Africa*. https://doi.org/10.1079/9780851995618.0000

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview. *Agroforestry Systems*, *76*(1), 1–10. https://doi.org/10.1007/s10457-009-9229-7

Joseph Mayindo Mayelea, b*; S. T. (2023). Contribution of Agroforestry Practices on Species Diversity and Carbon 2 Sequestration for Climate Change Adaptation: 3 A case of Juba County, South Sudan. *Climate Change , Juba*, *16*, 56.

Kehlenbeck, K., Arifin, H. S., & Maass, B. L. (2007). *Plant diversity in homegardens in a socio-economic and agro-ecological context BT - Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Constraints of Land Use and Conservation* (T. Tscharntke, C. Leuschner, M. Zeller, E. Guhardja, & A. Bidin (eds.); pp. 295–317). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-30290-2_15

Kirui, B., Busuru, C., & Obwoyere, G. O. (2018). *Propagation And Regeneration Of Important Indigenous Tree Species In Kakamega Forest, Kenya*. *5*(8). www.ijiras.com%7C

Kiyani, P., Andoh, J., Lee, Y., & Lee, D. K. (2017). Benefits and challenges of agroforestry adoption: a case of Musebeya sector, Nyamagabe District in southern province of Rwanda. *Forest Science and Technology*, *13*(4), 174–180. https://doi.org/10.1080/21580103.2017.1392367

Kumar, S., Alam, B., Taria, S., Singh, P., Yadav, A., & Arunachalam, A. (2024). Agroforestry Solutions for Climate Change and Environmental Restoration. In *Agroforestry Solutions for Climate Change and Environmental Restoration* (Issue April). https://doi.org/10.1007/978-981-97-5004-7

Lasco, R. D., Espaldon, M. L. O., & Habito, C. M. D. (2016). Smallholder farmers' perceptions of climate change and the roles of trees and agroforestry in climate risk adaptation: evidence from Bohol, Philippines. *Agroforestry Systems*, *90*(3), 521–540. https://doi.org/10.1007/s10457-015-9874-y

Luedeling, E., Kindt, R., Huth, N. I., & Koenig, K. (2014). Agroforestry systems in a changing climate-challenges in projecting future performance. *Current Opinion in Environmental Sustainability*, *6*(1), 1–7. https://doi.org/10.1016/j.cosust.2013.07.013

Malawska, A., & Topping, C. J. (2018). Applying a biocomplexity approach to modelling farmer decision-making and land use impacts on wildlife. *Journal of Applied Ecology*, *55*(3), 1445–1455. https://doi.org/10.1111/1365-2664.13024

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*(1), 8–14. https://doi.org/10.1016/j.cosust.2013.09.002

Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P. A., & Kowero, G. (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, *6*(1), 61–67. https://doi.org/10.1016/j.cosust.2013.10.014

Mukundente, L., Ndunda, E., & G, G. (2020). Socio-economic and institutional factors affecting smallholders farmers to adopt agroforestry practices in southern province of Rwanda. *International Journal of Agricultural Science and Food Technology*, *6*(1), 068–074. https://doi.org/10.17352/2455-815x.000057

Nair, P. K. R. (2012). Carbon sequestration studies in agroforestry systems: A reality-check. *Agroforestry Systems*, *86*(2), 243–253. https://doi.org/10.1007/s10457-011-9434-z

National Institute of Statistic of Rwanda. (2022). *Fifth Population and Housing Census, Rwanda, 2022 District Profile Rusizi September 2023*. 6.

Ndayambaje, J. D. (2013). Trees and woodlots in Rwanda and their role in fuelwood supply. In *Trees and woodlots in Rwanda and their role in fuelwood supply*.

Ndayambaje, J. D., Heijman, W. J. M., & Mohren, G. M. J. (2012). Household Determinants of Tree Planting on Farms in Rural Rwanda. *Small-Scale Forestry*, *11*(4), 477–508. https://doi.org/10.1007/s11842-012-9196-0

Ndayisaba, F., Guo, H., Bao, A., Guo, H., Karamage, F., & Kayiranga, A. (2016). Understanding the spatial temporal vegetation dynamics in Rwanda. *Remote Sensing*, *8*(2), 1–17. https://doi.org/10.3390/rs8020129

Ndokoye, P. (2024). *Analysing the Impacts of Rusizi Urban Growth on Kivu Coastline: Evidence in Gihundwe and Kamembe Sectors*. *October*. https://doi.org/10.53819/81018102t5334

Ndoli, A., Mukuralinda, A., Schut, A. G. T., Iiyama, M., Ndayambaje, J. D., Mowo, J. G., Giller, K. E., & Baudron, F. (2021). On-farm trees are a safety net for the poorest households rather than a major contributor to food security in Rwanda. *Food Security*, *13*(3), 685–699. https://doi.org/10.1007/s12571-020-01138-4

Ngango, J., Musabanganji, E., Maniriho, A., Nkikabahizi, F., & Mukamuhire, A. (2023). Examining the adoption of agroforestry in Southern Rwanda: a double hurdle approach. *Forest Science and Technology*, *19*(4), 260–267. https://doi.org/10.1080/21580103.2023.2254317

Nkurikiye, J. B., Uwizeyimana, V., Van Ruymbeke, K., Vanermen, I., Verbist, B., Bizoza, A. R., & Vranken, L. (2024a). Farmers’ preferences for adopting agroforestry in the Eastern Province of

Rwanda: A choice experiment. *Trees, Forests and People, 16*(February), 100592. https://doi.org/10.1016/j.tfp.2024.100592

Nkurikiye, J. B., Uwizeyimana, V., Van Ruymbeke, K., Vanermen, I., Verbist, B., Bizoza, A. R., & Vranken, L. (2024b). Farmers’ preferences for adopting agroforestry in the Eastern Province of Rwanda: A choice experiment. *Trees, Forests and People, 16*(May), 100592. https://doi.org/10.1016/j.tfp.2024.100592

Noeldeke, B. (2022). Promoting Agroforestry in Rwanda: the Effects of Policy Interventions Derived from the Theory of Planned Behaviour. *Hannover Economic Papers (HEP), No. 693.*, 1–39.

Nsengumuremyi, C., Fischer, E., & Nsabimana, D. (2021). *The impact of sustainable Agroforestry on Carbon stock and Biodiversity conservation around Cyamudongo isolated rain forest in Rusizi and Huye Districts, Rwanda*. *Ph.D*, 237.

Ntawuruhunga, D., Ngowi, E. E., Mangi, H. O., Salanga, R. J., & Leonard, K. L. (2024). Assessing climate-smart agroforestry practices: a study of tree species composition, distribution, and utilities in two contrasting agroecosystems of Rwanda. *Agroforestry Systems, 98*(8), 2913–2932. https://doi.org/10.1007/s10457-024-01063-x

Reinhard Endeki, Shadrack Kinyua Inoti, & Stanley M. Makindi. (2023). Impacts of agroforestry technologies on livelihood improvement in Vihiga County, Kenya. *International Journal of Scientific Research Updates, 5*(1), 001–011. https://doi.org/10.53430/ijsru.2023.5.1.0194

Reubens, B., Moeremans, C., Poesen, J., Nyssen, J., Tewoldeberhan, S., Franzel, S., Deckers, J., Orwa, C., & Muys, B. (2011). Tree species selection for land rehabilitation in Ethiopia: From fragmented knowledge to an integrated multi-criteria decision approach. *Agroforestry Systems, 82*(3), 303–330. https://doi.org/10.1007/s10457-011-9381-8

Sharma, H., Pant, K. S., Bishist, R., Lal Gautam, K., Ludarmani, Dogra, R., Kumar, M., & Kumar, A. (2023). Estimation of biomass and carbon storage potential in agroforestry systems of north western Himalayas, India. *Catena, 225*(February). https://doi.org/10.1016/j.catena.2023.107009

Tsegaye, N. T., Negewo, D. A., & Mitiku, S. T. (2023). *East African Journal of Forestry & Agroforestry*. *6*(1), 137–147.

Uwera, M. H., Mugunga, C. P., & Mukangango, M. (2023). Assessing Agroforestry Species, Practices, Uses, and Tree Diversity in Two Contrasting Agro-Ecological Zones of Rwanda. *Forestist*, *73*(1), 63–69. https://doi.org/10.5152/forestist.2022.22048

Wittemann, M., Mujawamariya, M., Ntirugulirwa, B., Uwizeye, F. K., Zibera, E., Manzi, O. J. L., Nsabimana, D., Wallin, G., & Uddling, J. (2024). Plasticity and implications of water-use traits in contrasting tropical tree species under climate change. *Physiologia Plantarum*, *176*(3), 1–15. https://doi.org/10.1111/ppl.14326

A. Gahutu Mbabarira., & N. (2020). Impact Assessment of Agroforestry Practices on Community Socio-Economic Livelihoods in Rwanda. *Inter. J. Envi. Agri. Resea*, *6*(1), 59.

Abebe, T., Wiersum, K. F., & Bongers, F. (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of southern Ethiopia. *Agroforestry Systems*, *78*(3), 309–322. https://doi.org/10.1007/s10457-009-9246-6

Bapfakurera, E. N., Habimana, S., Uwamahoro, P. C., Uwizeyimana, V., & Musabwayire, C. (2023). *Opportunities and challenges in native species reforestation on smallholder farms in Rwanda : A Review*. *4*(1).

Binam, J. N., Place, F., Djalal, A. A., & Kalinganire, A. (2017). Effects of local institutions on the adoption of agroforestry innovations: evidence of farmer managed natural regeneration and its implications for rural livelihoods in the Sahel. *Agricultural and Food Economics*, *5*(1). https://doi.org/10.1186/s40100-017-0072-2

Chanuan, U., Kajohnsak, C., & Nittaya Sintao. (2021). Sample Size Estimation using Yamane and Cochran and Krejcie and Morgan and Green Formulas and Cohen Statistical Power Analysis by G*Power and Comparisons. *APHEIT International Journal*, *10*(2), 76–88.

Christian, H.-M. (2023). The Main Drivers of Biodiversity Loss: A Brief Overview. *Journal of Ecology & Natural Resources*, *7*(3). https://doi.org/10.23880/jenr-16000346

Coulibaly, J. Y., Chiputwa, B., Nakelse, T., & Kundhlande, G. (2017). Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agricultural Systems*, *155*, 52–69. https://doi.org/10.1016/j.agsy.2017.03.017

Dawson, I. K., Guariguata, M. R., Loo, J., Weber, J. C., Lengkeek, A., Bush, D., Cornelius, J., Guarino, L., Kindt, R., Orwa, C., Russell, J., & Jamnadass, R. (2013). What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. *Biodiversity and Conservation*, *22*(2), 301–324. https://doi.org/10.1007/s10531-012-0429-5

De Leeuw, J., Njenga, M., Wagner, B., & Iiyama, M. (2014). *An assessment of the resilience provided by trees in the drylands of Eastern Africa*. *January*.

Elias, M., & Fabien, R. (2024). *Perception and Knowledge of Local Community on the Use of Indigenous Tree Species for Ecosystem Restoration in Gasabo District , Rwanda*. *6*(1), 1–19.

ESMP/Rusizi. (2023). *(ESMP) FOR SECOND ADDITIONAL FINANCING FOR THE RWANDA*. *May*.

FAO, L. R. through A. mechanisms. (2020). Food and Agriculture Organization of the United Nations (FAO). Agroforestry for landscape restoration. *Agroforestry for Landscape Restoration*.

Foresta, H. de. (2013). Advancing agroforestry on the policy agenda – a guide for decision-makers. In *Forests, Trees and Livelihoods* (Vol. 22, Issue 3). https://doi.org/10.1080/14728028.2013.806162

Franzel, S., Denning, G. L., Lillesø, J. P. B., & Mercado, A. R. (2004). Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. *Agroforestry Systems*, *61–62*(1–3), 329–344. https://doi.org/10.1023/B:AGFO.0000029008.71743.2d

ICRAF. (2002). Trees on the farm: assessing the adoption potential of agroforestry practices in Africa. In *Trees on the farm: assessing the adoption potential of agroforestry practices in Africa*. https://doi.org/10.1079/9780851995618.0000

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview. *Agroforestry Systems*, *76*(1), 1–10. https://doi.org/10.1007/s10457-009-9229-7

Joseph Mayindo Mayelea, b*; S. T. (2023). Contribution of Agroforestry Practices on Species Diversity and Carbon 2 Sequestration for Climate Change Adaptation: 3 A case of Juba County, South Sudan. *Climate Change , Juba*, *16*, 56.

Kehlenbeck, K., Arifin, H. S., & Maass, B. L. (2007). *Plant diversity in homegardens in a socio-economic and agro-ecological context BT - Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Constraints of Land Use and Conservation* (T. Tscharntke, C. Leuschner, M. Zeller, E. Guhardja, & A. Bidin (eds.); pp. 295–317). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-30290-2_15

Kirui, B., Busuru, C., & Obwoyere, G. O. (2018). *Propagation And Regeneration Of Important Indigenous Tree Species In Kakamega Forest, Kenya*. *5*(8). www.ijiras.com%7C

Kiyani, P., Andoh, J., Lee, Y., & Lee, D. K. (2017). Benefits and challenges of agroforestry adoption: a case of Musebeya sector, Nyamagabe District in southern province of Rwanda. *Forest Science and Technology*, *13*(4), 174–180. https://doi.org/10.1080/21580103.2017.1392367

Kumar, S., Alam, B., Taria, S., Singh, P., Yadav, A., & Arunachalam, A. (2024). Agroforestry Solutions for Climate Change and Environmental Restoration. In *Agroforestry Solutions for Climate Change and Environmental Restoration* (Issue April). https://doi.org/10.1007/978-981-97-5004-7

Lasco, R. D., Espaldon, M. L. O., & Habito, C. M. D. (2016). Smallholder farmers' perceptions of climate change and the roles of trees and agroforestry in climate risk adaptation: evidence from Bohol, Philippines. *Agroforestry Systems*, *90*(3), 521–540. https://doi.org/10.1007/s10457-015-9874-y

Luedeling, E., Kindt, R., Huth, N. I., & Koenig, K. (2014). Agroforestry systems in a changing climate-challenges in projecting future performance. *Current Opinion in Environmental Sustainability*, *6*(1), 1–7. https://doi.org/10.1016/j.cosust.2013.07.013

Malawska, A., & Topping, C. J. (2018). Applying a biocomplexity approach to modelling farmer decision-making and land use impacts on wildlife. *Journal of Applied Ecology*, *55*(3), 1445–1455. https://doi.org/10.1111/1365-2664.13024

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*(1), 8–14. https://doi.org/10.1016/j.cosust.2013.09.002

Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P. A., & Kowero, G. (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, *6*(1), 61–67. https://doi.org/10.1016/j.cosust.2013.10.014

Mukundente, L., Ndunda, E., & G, G. (2020). Socio-economic and institutional factors affecting smallholders farmers to adopt agroforestry practices in southern province of Rwanda. *International Journal of Agricultural Science and Food Technology*, *6*(1), 068–074. https://doi.org/10.17352/2455-815x.000057

Nair, P. K. R. (2012). Carbon sequestration studies in agroforestry systems: A reality-check. *Agroforestry Systems*, *86*(2), 243–253. https://doi.org/10.1007/s10457-011-9434-z

National Institute of Statistic of Rwanda. (2022). *Fifth Population and Housing Census, Rwanda, 2022 District Profile Rusizi September 2023*. 6.

Ndayambaje, J. D. (2013). Trees and woodlots in Rwanda and their role in fuelwood supply. In *Trees and woodlots in Rwanda and their role in fuelwood supply*.

Ndayambaje, J. D., Heijman, W. J. M., & Mohren, G. M. J. (2012). Household Determinants of Tree Planting on Farms in Rural Rwanda. *Small-Scale Forestry*, *11*(4), 477–508. https://doi.org/10.1007/s11842-012-9196-0

Ndayisaba, F., Guo, H., Bao, A., Guo, H., Karamage, F., & Kayiranga, A. (2016). Understanding the spatial temporal vegetation dynamics in Rwanda. *Remote Sensing*, *8*(2), 1–17. https://doi.org/10.3390/rs8020129

Ndokoye, P. (2024). *Analysing the Impacts of Rusizi Urban Growth on Kivu Coastline: Evidence in Gihundwe and Kamembe Sectors*. *October*. https://doi.org/10.53819/81018102t5334

Ndoli, A., Mukuralinda, A., Schut, A. G. T., Iiyama, M., Ndayambaje, J. D., Mowo, J. G., Giller, K.

E., & Baudron, F. (2021). On-farm trees are a safety net for the poorest households rather than a major contributor to food security in Rwanda. *Food Security*, *13*(3), 685–699. https://doi.org/10.1007/s12571-020-01138-4

Ngango, J., Musabanganji, E., Maniriho, A., Nkikabahizi, F., & Mukamuhire, A. (2023). Examining the adoption of agroforestry in Southern Rwanda: a double hurdle approach. *Forest Science and Technology*, *19*(4), 260–267. https://doi.org/10.1080/21580103.2023.2254317

Nkurikiye, J. B., Uwizeyimana, V., Van Ruymbeke, K., Vanermen, I., Verbist, B., Bizoza, A. R., & Vranken, L. (2024a). Farmers' preferences for adopting agroforestry in the Eastern Province of Rwanda: A choice experiment. *Trees, Forests and People*, *16*(February), 100592. https://doi.org/10.1016/j.tfp.2024.100592

Nkurikiye, J. B., Uwizeyimana, V., Van Ruymbeke, K., Vanermen, I., Verbist, B., Bizoza, A. R., & Vranken, L. (2024b). Farmers' preferences for adopting agroforestry in the Eastern Province of Rwanda: A choice experiment. *Trees, Forests and People*, *16*(May), 100592. https://doi.org/10.1016/j.tfp.2024.100592

Noeldeke, B. (2022). Promoting Agroforestry in Rwanda: the Effects of Policy Interventions Derived from the Theory of Planned Behaviour. *Hannover Economic Papers (HEP), No. 693.*, 1–39.

Nsengumuremyi, C., Fischer, E., & Nsabimana, D. (2021). *The impact of sustainable Agroforestry on Carbon stock and Biodiversity conservation around Cyamudongo isolated rain forest in Rusizi and Huye Districts, Rwanda*. *Ph.D*, 237.

Ntawuruhunga, D., Ngowi, E. E., Mangi, H. O., Salanga, R. J., & Leonard, K. L. (2024). Assessing climate-smart agroforestry practices: a study of tree species composition, distribution, and utilities in two contrasting agroecosystems of Rwanda. *Agroforestry Systems*, *98*(8), 2913–2932. https://doi.org/10.1007/s10457-024-01063-x

Reinhard Endeki, Shadrack Kinyua Inoti, & Stanley M. Makindi. (2023). Impacts of agroforestry technologies on livelihood improvement in Vihiga County, Kenya. *International Journal of Scientific Research Updates*, *5*(1), 001–011. https://doi.org/10.53430/ijsru.2023.5.1.0194

Reubens, B., Moeremans, C., Poesen, J., Nyssen, J., Tewoldeberhan, S., Franzel, S., Deckers, J., Orwa, C., & Muys, B. (2011). Tree species selection for land rehabilitation in Ethiopia: From fragmented knowledge to an integrated multi-criteria decision approach. *Agroforestry Systems*, *82*(3), 303–330. https://doi.org/10.1007/s10457-011-9381-8

Sharma, H., Pant, K. S., Bishist, R., Lal Gautam, K., Ludarmani, Dogra, R., Kumar, M., & Kumar, A. (2023). Estimation of biomass and carbon storage potential in agroforestry systems of north western Himalayas, India. *Catena*, *225*(February). https://doi.org/10.1016/j.catena.2023.107009

Tsegaye, N. T., Negewo, D. A., & Mitiku, S. T. (2023). *East African Journal of Forestry & Agroforestry*. *6*(1), 137–147.

Uwera, M. H., Mugunga, C. P., & Mukangango, M. (2023). Assessing Agroforestry Species, Practices, Uses, and Tree Diversity in Two Contrasting Agro-Ecological Zones of Rwanda. *Forestist*, *73*(1), 63–69. https://doi.org/10.5152/forestist.2022.22048

Wittemann, M., Mujawamariya, M., Ntirugulirwa, B., Uwizeye, F. K., Zibera, E., Manzi, O. J. L., Nsabimana, D., Wallin, G., & Uddling, J. (2024). Plasticity and implications of water-use traits in contrasting tropical tree species under climate change. *Physiologia Plantarum*, *176*(3), 1–15. https://doi.org/10.1111/ppl.14326

APPENDICES

Appendix 1. List of indigenous agroforestry species and their reported usage proportions in Nkungu Sector

Species	Frequency	Percentage (%)
Markhamia lutea	14	15.55
Ficus thonningii	11	12.22
Maesa lanceolate	10	11.11
Erythrina abyssinica	7	7.77
Syzygium guinensis	4	4.44
Combretum molle	3	3.33
Markhamia platycalyx	3	3.33
Ficus sycomorus	2	2.22
Podocarpus latifolius	2	2.22
Vachellia sieberiana	2	2.22
Albizia gummifera	1	1.11
Dombeya torrida	1	1.11
Iboza riparia	1	1.11
Macaranga kilimandscharica	1	1.11
Mimosa scabrella	1	1.11
Mitragyna rubrostipulata	1	1.11
Prunus africana	1	1.11

Polyscias fulva	1	1.11
Trema orientalis	1	1.11

Appendix 2. List of indigenous agroforestry species and their reported usage proportions in Nzahaha sector

Species	Frequency	Percentage (%)
Markhamia lutea	18	16.07
Maesa lanceolate	16	14.28
Ficus thonningii	10	8.92
Dombeya goetzenii	6	5.35
Mitragyna rubrostipulata	6	5.35
Erythrina abyssinica	5	4.46
Polyscias fulva	3	2.67
Iboza riparia	2	1.78
Ricinus communis	2	1.78
Syzygium guineense	2	1.78
Trema orientalis	2	1.78
Vachellia sieberiana	1	0.89
Combretum molle	1	0.89
Dombeya torrida	1	0.89
Entendrophragma exelsium	1	0.89
Ficus sycomorus L.	1	0.89
Jacaranda mimosifolia	1	0.89
Markhamia platycalyx	1	0.89

Podocarpus latifolius	1	0.89
Mitragyna rubrostipulata	1	0.89
Spathodea campanulata	1	0.89
Vernonia amygdalina	1	0.89

Appendix. 3. List of exotic agroforestry species and their reported usage proportions in the Nkungu sector

Species	Frequency	Percentage (%)
Grevillea robusta	45	20.83
Cedrela serrata	44	20.37
Calliandra calothyrsus	30	13.88
Leucaena leucocephala	26	12.03
Alnus acuminate	25	11.57
Persea Americana	17	7.87
Mangifera indica	10	4.63
Eucalyptus sp.	7	3.24
Citrus lemon	4	1.85
Citrus sinensis	3	1.38
Hesperocyparis lusitanica	2	0.92
Solanum betaceum	2	0.92
Passiflora edulis	1	0.46

Appendix. 4. List of exotic agroforestry species and their reported usage proportions in Nzahaha sector

Species	Frequency	Percentage (%)
Grevillea robusta	46	21.29
Cedrela serrata	32	14.81
Calliandra calothyrsus	29	13.42
Leucaena leucocephala	24	11.11
Alnus acuminate	23	10.64
Percea Americana	17	7.87
Citrus lemon	11	5.09
Mangifera indica	11	5.09
Solanum betaceum	6	2.77
Psidium guajava	4	1.85
Passiflora edulis	3	1.38
Carica papaya	2	0.92
Citrus reticulate	2	0.92
Coffea sp.	2	0.92
Citrus sinensis	1	0.46
Eucalyptus sp.	1	0.46
Nuts	1	0.46

Appendices 5: DATA Collection Questionnaire

Appendix 1: Questionnaire

Instructions to Enumerator: Introduce yourself, explain the purpose of the survey, ensure informed consent, and clarify that the information will be used for research purposes only and treated with confidentiality.

Section A: General Information

1. Name of respondent (Optional): …………………………….
2. Gender: ☐ Male ☐ Female
3. Age:……. years
4. Cell: ………………………….
5. Village: …………………..
6. Education level:

☐ No formal education ☐ Primary ☐ Secondary ☐ Tertiary

7. Occupation: ☐ Farmer ☐ Trader ☐ Civil servant ☐ Other (specify):……………
8. Household size…………………persons
9. Length of residence in this area: ……………… years

Section B: Land and Agroforestry Practices

10. Do you practice agroforestry on your land? ☐ Yes ☐ No
11. If yes, how many years have you been practicing agroforestry? ………
12. What is the total size of your land?....... hectares
13. How much of this land is under agroforestry? ……….. hectares
14. What types of agroforestry systems do you use? (Check all that apply):

☐ Boundary planting

☐Intercropping

☐Woodlots

☐ Home gardens

☐ Taungya system

☐ Alley cropping

☐ Others (specify)...........

15. What are your main reasons for practicing agroforestry? (Rank top 3)

☐ Soil conservation

☐ Fuelwood

☐ Fodder

☐ Timber

☐ Fruit

☐ Shade

☐ Income generation

☐ Others: ………………

Section C: Tree Species Composition and Use

16. List the major **native** tree species on your farm and their uses:

S/N	Species name	Year of Plantation	Purpose (timber, shade, firewood etc….)

17. List the major **exotic** tree species on your farm and their uses:

S/N	Species name	Year of Plantation	Purpose (timber, shade, firewood etc….)

18. Which type of species is more dominant on your farm?

☐ Native ☐ Exotic ☐ Both equally

19. What factors influence your choice of tree species? (Choose top 3)

☐ Growth rate

☐ Economic val

☐ Environmental benefits

☐ Availability of seedlings

☐ Cultural reasons

☐ Advice from NGOs/government

☐ Others: ………………..

Section D: Temporal Changes and Spatial Distribution

20. Have you noticed any changes in the number or types of tree species on your land over the past 5 years? ☐ Yes ☐ No
21. If yes, describe the changes:

………………………………………………………………………………………………………

………………………………………………………………………………………………………

22. What are the main causes of these changes?

☐ Climate change

☐ Market demand

☐ Government/NGO programs

☐ Land use change

☐ Others: …………………….

23. How do you distribute agroforestry trees on your farm? (e.g., along boundaries, scattered, clustered):…………………………………………………………….

…………………………………………………………………….

Section E: Institutional and External Support

24. Have you received any support related to agroforestry from NGOs or government institutions?

☐ Yes ☐ No

25. If yes, specify the type of support

☐ Seedlings

☐ Training

☐ Technical advice

☐ Financial support

☐ Others: ………………………………….

26. Which organization(s) provided the support?

…………………………………………………………………………………

27. How effective has the support been in improving agroforestry practices?

☐ Very effective ☐ Somewhat effective ☐ Not effective

Section F: Perceptions and Challenges

28. What are the major benefits you have observed from agroforestry?

………
……

29. What challenges do you face in managing native and exotic agroforestry trees?
    ☐ Pests and diseases
    ☐ Lack of knowledge
    ☐ Lack of seedlings
    ☐ Poor market access
    ☐ Land scarcity
    ☐ Others: ………………….
30. In your opinion, which tree species (native or exotic) are more beneficial in the long term? Why?..……
    ………………………………………………………………………………………

End of Questionnaire

Enumerator's Name: ……………………………………………
Date: …………………………………………………………..
Signature of respondent: ………