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Assessing Drivers and Prevalence of Exotic and Indigenous Tree Species in Agroforestry Systems around Gishwati- Mukura National Park, Ngororero District, Rwanda

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

By

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Kigali, August 2025

CERTIFICATION

We hereby certify that this dissertation entitled" Assessing Drivers and Prevalence of Exotic and Indigenous Tree Species in Agroforestry Systems around Gishwati- Mukura National Park, Ngororero District, Rwanda" is the original work of **Mr. Theogene NSENGIYUMVA** (222022683), conducted under the supervision of **Prof. Beth A. Kaplin** and **Assoc. Prof. Venuste NSENGIMANA**.

To the best of our knowledge, this work has not been submitted previously, either in partor in full, for the award of any degree at the University of Rwanda or any other institution.

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DECLARATION

I declare to the best of my ability that this dissertation is a result of my own efforts and has never been submitted for any academic award to this university or any other university or institution.

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DEDICATION

I dedicate this dissertation to all who supported me with every input they had, to those who imparted me an academic foundation up to this level, and to all my friends and classmates for their motivation and constructive ideas that enlightened me along this dissertation

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LIST OF ABBREVIATIONS

- **ARCOS** — Albertine Rift Conservation Society Network
- **DBH** — Diameter at Breast Height
- **FGD** — Focus Group Discussion
- **FH** — Food for the Hungry
- **GMNP** — Gishwati–Mukura National Park
- **GIS** — Geographic Information System
- **GPS** — Global Positioning System
- **LAFREC** — A restoration project name
- **MINAGRI** — Ministry of Agriculture and Animal Resources
- **NFII** — Non-Farmer Informant Interviews
- **NGO** — Non-Governmental Organization
- **NNP** — Nyungwe National Park
- **RAB** — Rwanda Agriculture and Animal Resources Board
- **RDB** — Rwanda Development Board
- **REMA** — Rwanda Environment Management Authority
- **SPSS** — Statistical Package for the Social Sciences
- **TUBURA** — Tubura (One Acre Fund Rwanda)
- **UNESCO** — United Nations Educational, Scientific and Cultural Organization
- **VNP** — Volcanoes National Park

- **MuLaKiLa** — ARCOS Network agroforestry project (project name)

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ABSTRACT

Agroforestry is promoted to reconcile agricultural production with landscape restoration, but its biodiversity benefits can be undermined when on farm plantings are dominated by a few non-native taxa. This study investigates why exotic species predominate in smallholder plantings and how institutional seedling supply, farmer priorities, and landholding structure interact to determine on farm composition around Gishwati–Mukura National Park. We used a cross-sectional mixed methods design: ecological inventories (36 plots) combined with household interviews, focus group discussions and non-farmer informant interviews in three cells- Gashubi, Bungwe and Cyahafi (of Ngororero District-Rwanda)- deliberately selected because they hosted major recent agroforestry interventions. The results have shown that exotic species accounted for 68.3% (313/458) of individuals, with *Grevillea robusta* alone representing 58.3% (267 trees), *Persea americana* 5.2% (24 trees) and other exotics 4.8% (22). Indigenous trees made up 31.7% (145 trees), dominated by *Ficus* sp. (12.0%, 55) and *Markhamia lutea* (9.8%, 45). Seedlings/saplings (<2 cm DBH) were only 8.5% of records (39 trees) and 71.8% of seedlings were exotic (28/39), indicating weak indigenous regeneration (28.2% of seedlings). Indigenous representation rose with plot size (small = 8%; medium = 24%; large = 32%). Farmers ranked exotic *G. robusta* highest for timber/profit (92%); 72% reported income from *G. robusta* within five years. Reported barriers to indigenous adoption included slow growth (67%), limited seedlings (58%), insufficient extension (42%) and low market value (33%). Institutional influence was strong: 65% of farmers said extension agents predominantly encouraged exotics, and MuLaKiLa-supported plots showed ~38% indigenous coverage versus ~18% in non-supported plots. These results indicate exotic dominance is a rational, constraint-bounded choice reinforced by supply systems. We recommend scaling indigenous germplasm supply, plot-specific extension and demonstrations, and market or incentive mechanisms to make indigenous trees viable for livelihoods while restoring biodiversity and erosion-prone highlands

Keywords: Grevillea robusta dominance; seedling supply chains; institutional influence; smallholder farmers decision-making and landscape restoration.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Agroforestry, the deliberate integration of trees within agricultural systems, has emerged as a cornerstone of sustainable land use and climate resilience strategies globally. In sub-Saharan Africa, where agriculture underpins the livelihoods of the majority, agroforestry has been widely adopted for its potential to provide multiple benefits including food, fuel, fodder, timber, soil fertility enhancement, and biodiversity conservation (Nair, 2012; Leakey, 2017). Beyond direct livelihood support, agroforestry also contributes to ecosystem services such as carbon sequestration, hydrological regulation, soil erosion control, and habitat provision (Mbow et al., 2014; Mercer, 2004).

In Rwanda, agroforestry has been positioned as a strategic tool to reconcile agricultural productivity with environmental sustainability. National policy frameworks such as Vision 2050 and the National Forest Policy explicitly prioritize tree integration on farmlands as a means of combating soil erosion, enhancing biodiversity, and increasing household resilience to climate change (MINAGRI, 2020; World Bank, 2022). The government's target of achieving 30% tree cover on arable land by 2050 reflects the centrality of agroforestry to national restoration and development agendas.

However, despite these ambitions, Rwanda's smallholder agroforestry systems are characterized by a pronounced dominance of exotic tree species, particularly *Grevillea robusta*, *Eucalyptus* spp., and *Persea americana* (Ruticumugambi et al., 2024). These exotics are widely preferred for their rapid growth, adaptability, and direct market value as timber, poles, and fuelwood. By contrast, indigenous tree species—although ecologically valuable and culturally significant—remain underutilized in farm landscapes (Umuhoza et al., 2023). This pattern of adoption mirrors broader trends across East Africa, where fast-growing exotics have been prioritized for short-term returns, often at the expense of biodiversity and long-term ecosystem services (Chirwa et al., 2015).

The ecological implications of this imbalance are substantial. Exotic dominance is increasingly associated with biotic homogenization, whereby landscapes lose functional and species diversity as a narrow set of non-native trees replace heterogeneous indigenous vegetation (Turikunkiko & Nahayo, 2024). By contrast, empirical studies from other regions highlight the superior ecological performance of native-dominated agroforestry. For example, Manaye et al. (2021) demonstrated that agroforests dominated by indigenous trees in Ethiopia's highlands supported greater species richness and carbon stocks than exotic plantations, underscoring the value of indigenous species in restoration-sensitive areas.

The study area—Ngororero District in Rwanda's Western Province—offers a pertinent context to investigate these dynamics. Located along the buffer zone of the Gishwati–Mukura National Park (GMNP), a UNESCO Biosphere Reserve, Ngororero represents a critical interface where conservation and smallholder farming converge. The district is characterized by steep slopes, high rainfall, and intensive land use, which make it highly susceptible to soil erosion (Byizigiro et al., 2020). Agroforestry, therefore, is not only a livelihood practice but also a necessary ecological strategy to stabilize fragile landscapes. Importantly, farmlands surrounding GMNP also hold potential to act as ecological corridors, connecting fragmented forest habitats and enhancing biodiversity at the landscape scale (Harvey et al., 2008).

Despite government and NGO-led efforts to promote indigenous tree planting in this region through initiatives such as LAFREC (REMA), MuLaKiLa (ARCOS Network), and Tubura (One Acre Fund), the persistence of exotic tree species dominance suggests that farmer decision-making is driven by factors beyond policy prescriptions. Key issues include the accessibility of seedlings, farmers' perceptions of growth rates and crop compatibility, market demand, and the influence of project-driven seedling supply. Understanding these drivers is critical to align agroforestry practices with national biodiversity and restoration goals.

1.2 Problem Statement

Although agroforestry has been widely promoted in Rwanda, its contribution to biodiversity conservation is undermined by the predominance of exotic tree species in smallholder farms. *Grevillea robusta* alone constitutes more than half of all on-farm trees in some regions (Ruticumugambi et al., 2024). Farmers continue to plant exotics not necessarily because they reject indigenous species, but because exotics are readily supplied, grow faster, and provide direct income and household needs. Indigenous species, while valued for shade, soil fertility, and medicinal purposes, are perceived as slow-growing and difficult to access due to the absence of reliable seedling supply systems.

This imbalance raises pressing questions. If indigenous trees provide ecological and cultural benefits, why are they not more widely adopted? To what extent are farmer preferences genuine choices versus reflections of limited options shaped by institutional supply chains? How closely does on-farm tree composition align with what farmers say they need and value? Without addressing these questions, agroforestry programs risk perpetuating an exotic-dominated system that fails to deliver on Rwanda's biodiversity and restoration commitments, particularly in critical buffer zones like those surrounding GMNP.

1.3 Research Aim

The aim of this study is to determine why exotic species predominate in agroforestry systems within Ngororero District, and whether this is driven primarily by institutional supply, ecological adaptability, farmer perceptions, or access constraints.

1.4 Research Objectives

1. To assess farmer perceptions and constraints regarding both exotic and indigenous tree species (e.g., growth rate, profitability, crop compatibility).

2. To investigate how socio-economic status, landholding size, and program participation shape species choice, including whether farmers request or attempt to plant indigenous species beyond those supplied.

3. To document farmer use of exotic and indigenous species to analyze whether species composition in field inventories reflects stated use preferences.

1.5 Research Questions and Hypotheses

Q1. What perceptions and constraints influence the prevalence of exotic versus indigenous species?

- **H1 (alternative):** Exotics are prevalent due to faster growth, economic utility, ready availability and the belief that indigenous species have slower growth, are not available, and are less useful to farmers.
- **$H0_1$ (null):** There is **no significant association** between farmers' perceptions or constraints (growth rate, economic value, availability, knowledge/usefulness) and the prevalence of exotic versus indigenous species on farms.

Q2. How do socio-economic and project factors affect species abundance?

- **H2a (alternative):** Farmers involved in agroforestry programs tend to plant species provided by the programs and rarely request indigenous species not supplied.
- **$H0_2$ a (null):** There is **no significant difference** in species composition between farmers supported by agroforestry programs and those not supported.
- **H2b (alternative):** Limited indigenous seedling supply and insufficient technical support limit adoption of indigenous species.
- **$H0_2$ b (null):** Indigenous species adoption is **not significantly affected** by seedling supply availability or the level of technical support received by farmers.

Q3. How do farmers use both exotic and indigenous species, and does field composition reflect these uses and stated motivations?

- **H3 (alternative):** Exotic species dominance corresponds to usage priorities (e.g., poles, firewood).
- **$H0_3$ (null):** There is **no significant correspondence** between farmers' stated usage priorities (e.g., poles, firewood, timber, shade) and the observed dominance of exotic versus indigenous species in their fields.

1.6 Significance of the Study

This study is significant for several reasons:

- **Policy relevance:** It provides evidence on the drivers of exotic dominance, offering actionable recommendations to align agroforestry practices with Rwanda's Vision 2050 and National Forest Policy biodiversity targets.
- **Scientific contribution:** By triangulating farmer perceptions, program supply patterns, and ecological inventories, the study advances understanding of the socio-ecological factors shaping agroforestry adoption.
- **Practical implications:** Findings will guide NGOs, cooperatives, and government agencies in designing agroforestry programs that balance farmer livelihoods with biodiversity conservation, particularly in sensitive buffer zones like GMNP.
- **Community empowerment:** The study highlights farmer perspectives and constraints, ensuring that indigenous knowledge and local priorities inform future interventions.

CHAPTER TWO: LITERATURE REVIEW

Agroforestry is increasingly recognized as a cornerstone of sustainable land use in the tropics, providing multiple ecological and socio-economic benefits (Dawson et al., 2014; Muthuri et al., 2023). In Rwanda, where agriculture is the mainstay of rural livelihoods, agroforestry is integrated into national restoration and climate adaptation agendas (World Bank, 2022). However, the predominance of exotic tree species in farm landscapes raises ecological and policy concerns, particularly in biodiversity-sensitive buffer zones such as those adjacent to Gishwati–Mukura National Park (Ruticumugambi et al., 2024).

Agroforestry, defined as the deliberate integration of woody perennials with crops and/or livestock, enhances soil fertility, biodiversity, and livelihoods (Muthuri et al., 2023; Muyabe et al., 2025). Exotic species such as *Grevillea robusta, Eucalyptus spp*., and *Persea americana* are widely planted due to their rapid growth and market value (Ruticumugambi et al., 2024). By contrast, indigenous species such as *Markhamia lutea*, *Polyscias fulva,* and *Erythrina abyssinica* are valued for ecological and cultural reasons but remain underutilized (Backes, 2001; Umuhoza et al., 2023).

Smallholders globally select tree species based on growth rate, timber and fuel value, crop compatibility, and market demand (Vega & Page, 2023; Dawson et al., 2014). For example, long-term studies in East Africa demonstrate that Grevillea robusta provides poles and fuelwood but can reduce adjacent maize yields due to root and crown competition (Lott et al., 2000; Smith et al., 1999). Similarly, while Eucalyptus is favored for rapid growth, it has been criticized for depleting water resources and suppressing understory diversity (Chirwa et al., 2015).

At the global scale, simplified agroforestry dominated by a few exotics can contribute to biotic homogenization, where landscapes lose distinct species assemblages (Harvey et al., 2008; Raveloaritiana et al., 2021). In contrast, diversified agroforestry that incorporates indigenous species supports higher biodiversity and ecological resilience (Harvey et al., 2008; Manaye et al., 2021).

In East Africa, Grevillea robusta and Eucalyptus became dominant on smallholder farms during the 1980s, largely due to NGO and government seedling distribution programs (Chirwa et al., 2015; Muthuri et al., 2023). Farmers often plant what is supplied by projects, which explains the persistence of exotic dominance (Vega & Page, 2023).

While exotics meet short-term livelihood needs, indigenous species provide superior long-term ecological services. For instance, agroforestry systems dominated by indigenous trees in Ethiopia's highlands were found to support greater species richness and carbon stocks than exotic plantations (Manaye et al., 2021). Yet, adoption of indigenous species remains limited by seedling scarcity, lack of silvicultural knowledge, and weak markets (Muthuri et al., 2023).

Rwanda's Vision 2050 and National Forest Policy prioritize agroforestry as a strategy for combating erosion, restoring biodiversity, and enhancing climate resilience (World Bank, 2022; Muyabe et al., 2025). The LAFREC project demonstrated how large-scale restoration in Gishwati focused on soil stabilization and livelihoods, but often relied on exotics due to ease of propagation and survival (World Bank, 2022).

Empirical studies confirm exotic dominance on Rwandan farms. Ruticumugambi et al. (2024) documented that Grevillea robusta, Eucalyptus spp., and Persea americana accounted for the majority of trees in surveyed agroforests. Similarly, Umuhoza et al. (2023) found that farmers in Eastern Rwanda favored exotics for their productivity, though some acknowledged that indigenous species were better for crop compatibility. Recent research by Bulonvu et al. (2025) has highlighted the importance of native trees and forests from smallholder farmers' perspectives in South-Western Rwanda, while the role of local knowledge in tree selection has been documented by Njenga et al. (2015) in their study of farmers' perceptions of trees and agroforestry in Rwanda.

Seedling availability plays a decisive role. Public and private nurseries in Rwanda primarily produce exotics due to reliable seed sources and market demand (Ruticumugambi et al., 2024). Large-scale restoration programs also supply species that can survive across diverse sites with minimal management (World Bank, 2022).

Farmers and extension agents perceive exotics as fast-growing, economically profitable, and multipurpose (Umuhoza et al., 2023). Indigenous species, although recognized for medicinal uses and harmony with crops, are viewed as slow-growing and difficult to access (Backes, 2001; Vega & Page, 2023).

Over-reliance on exotics risks reducing landscape-level diversity through homogenization (Harvey et al., 2008; Turikunkiko & Nahayo, 2024). This has implications for resilience to pests, diseases, and climate change. Conversely, diversified agroforestry systems incorporating indigenous species provide critical ecosystem services, including soil stabilization, pollination habitats, and carbon sequestration (Muthuri et al., 2023; Manaye et al., 2021). In Rwanda's fragile highland ecosystems, this is particularly critical for safeguarding biodiversity around GMNP, especially considering ongoing land use changes and their impacts on water erosion (Nambajimana et al., 2020; Byizigiro et al., 2020).

Despite growing evidence, few studies explicitly distinguish between farmer preferences and prevalence of species driven by external supply. Linked datasets combining field inventories with farmer narratives are rare in Rwanda. Furthermore, little research exists on the specific dynamics of GMNP buffer zones, where landscape connectivity for biodiversity is urgent, particularly given recent restoration initiatives (World Bank, 2025).

Globally and regionally, exotic tree dominance in smallholder agroforestry is shaped by both farmer demand (perceived fast growth and profitability) and institutional supply (nursery and project offerings). Rwanda mirrors this pattern, with Grevillea robusta and Eucalyptus as dominant exotics, while indigenous species remain marginalized. Literature highlights the ecological risks of this imbalance—particularly biotic homogenization—and the lost opportunity to leverage indigenous trees for biodiversity and restoration (Bulonvu et al., 2025). This sets the stage for the current study, which seeks to disentangle supply versus demand drivers in Ngororero District.

CHAPTER THREE: METHODOLOGY

3.1 Research Design

This study adopted a cross-sectional mixed-methods research design to investigate the drivers and prevalence of exotic and indigenous tree species in agroforestry systems around the Gishwati-Mukura National Park (GMNP) in Ngororero District. The choice of this design was deliberate because it provides an opportunity to capture both the ecological realities of on-farm species composition and the socio-economic and institutional perspectives that shape farmers' decisions. Quantitative data were collected through household surveys and plot-based ecological inventories, while qualitative data were gathered through focus group discussions and non-farmer informant interviews. By integrating these complementary sources of evidence, the study ensured a triangulated understanding of agroforestry adoption dynamics. According to Creswell and Plano Clark (2017), mixed methods research enhances validity and reliability by allowing cross-verification of findings, while Bulonvu et al (2025) emphasize its relevance in agroforestry studies where both farmer knowledge and ecological data must be jointly analyzed.

The study therefore combined numerical assessment of exotic and indigenous species composition with qualitative insights into farmers' motivations, constraints, and institutional influences. Such an approach was particularly important given the complexity of agroforestry systems, which are simultaneously ecological and social in nature. The design allowed the researcher to test hypotheses concerning species dominance while also identifying nuanced socio-cultural and institutional factors that cannot be easily captured through quantitative data alone.

3.2 Study Area

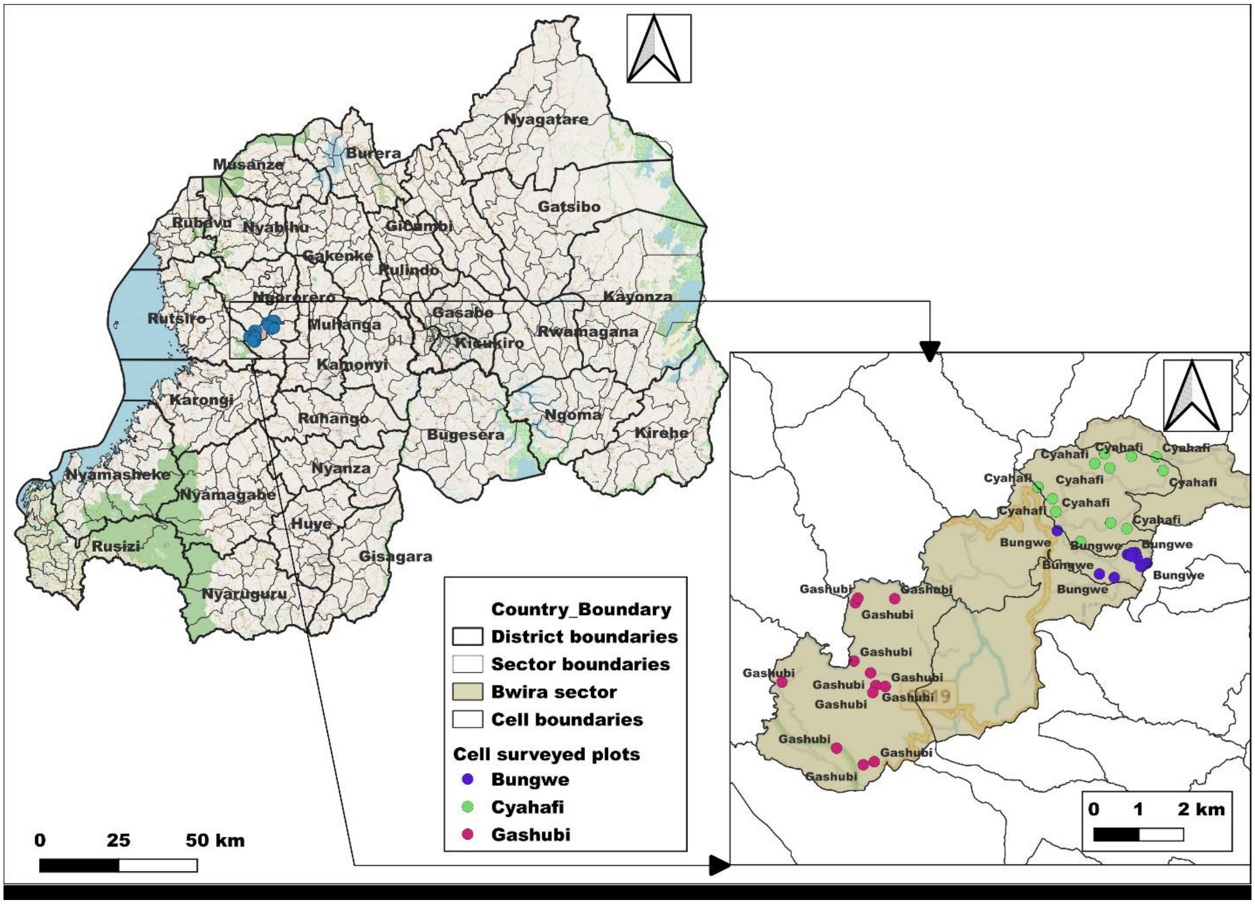

Figure 1: Map showing the sampled plots at Cyahafi, Bungwe and Gashubi cells

The research was conducted in Ngororero District, Western Province, Rwanda, specifically in three cells of Bwira Sector: Gashubi, Bungwe, and Cyahafi (Figure 1). These sites were deliberately chosen because they have all hosted major agroforestry interventions in recent years, including the MuLaKiLa Project implemented by ARCOS Network, Tubura Project under One Acre Fund, Food for the Hungry (FH), and the LAFREC initiative. Farmers in these areas were therefore expected to have been exposed to different agroforestry practices and tree planting programs, making them particularly suitable for exploring how institutional interventions influence species adoption and management

Ngororero District is part of the Congo-Nile Divide highlands, characterized by altitudinal ranges between 1,460 and 2,979 meters above sea level. The area experiences a tropical highland climate with mean annual rainfall ranging between 1,300 and 1,550 millimeters and mean temperatures between 17 and 20 °C (Nambajimana et al., 2020). Its volcanic soils, though fertile, are situated on steep slopes where more than 90 percent of the cultivated land exceeds 15 degrees in gradient. This makes the area highly susceptible to soil erosion, with estimates from Satinskyi catchment suggesting annual soil loss exceeding 38 tons per hectare (Byizigiro et al., 2020). Such ecological fragility underscores the importance of agroforestry as a land restoration and erosion control strategy.

Over the past two decades, Bwira Sector has hosted several agroforestry interventions including the Landscape Approach to Forest Restoration and Conservation (LAFREC) led by the Rwanda Environment Management Authority, the MuLaKiLa project implemented by the ARCOS Network, Tubura under One Acre Fund, and Food for the Hungry's agroforestry program. While these interventions have introduced a range of tree species, evidence from Rwanda and elsewhere suggests that exotic species such as *Grevillea robusta* and *Eucalyptus* spp. continue to dominate, often at the expense of indigenous species that hold higher ecological value (Ruticumugambi et al., 2024). This setting therefore provides an ideal context to assess the interplay between institutional supply, farmer preferences, and ecological realities in shaping agroforestry practices.

3.3 Sampling Design and Data Collection Methods

The study employed a purposive and stratified sampling design in order to capture both social and ecological diversity within the study area. A total of thirty-six farmers were purposively selected across the three cells (Gashubi, Bungwe, and Cyahafi)-see figure 1, with twelve participants from each of the three cells for a total of 36 participants. The selection process involved consultation with local leaders and review of records from ongoing agroforestry programs, including Tubura, MuLaKiLa, Food for the Hungry (FH), and the LAFREC initiative. This ensured that participants represented households actively involved in agroforestry and land restoration practices. To enhance representativeness, the sample also deliberately incorporated gender balance, with at least forty percent of respondents being women. This approach acknowledged the central role of women in agroforestry decision-making and sought to capture potential gendered differences in knowledge, access, and preferences regarding tree species.

Household interviews constituted the primary tool for assessing farmers' perceptions, motivations, and constraints regarding exotic and indigenous tree species. A semi-structured questionnaire was designed to elicit both quantitative responses, using Likert-scale items, and qualitative insights through open-ended questions. Themes explored included knowledge of tree species, perceived benefits and disadvantages, seedling availability, and participation in agroforestry projects. Interviews were conducted with the adult household member responsible for land management, ensuring that data reflected informed decision-making perspectives.

Focus group discussions (FGDs) complemented household interviews by providing a participatory platform through which farmers could collectively express and validate their views. Three FGDs were conducted per cell: male-only, female-only, and a mixed group. Participatory ranking exercises were employed to compare exotic and indigenous species on criteria such as profitability, growth rate, crop compatibility, and cultural significance. Seasonal calendars were also developed to map the utility of different species across the agricultural year. These exercises allowed for community-level priorities to emerge while capturing gender-specific perspectives.

Sampling trees on farms was also conducted. A complete sampling frame of eligible farm plots was assembled for each cell (Gashubi, Bungwe, Cyahafi) using land-use lists, and project beneficiary records, and a short field reconnaissance (transect walk) to identify unmapped plots. Each plot was measured and assigned to one of three size strata: small (<1,000 m^2), medium (1,000–2,000 m^2) and large (>2,000 m^2). Within each cell and stratum, four plots were selected by simple random sampling using a random number generator applied to a numbered list of eligible plots, yielding a balanced sample of four small, four medium and four large plots per cell (12 per cell, 36 total). If a randomly selected owner declined or a plot was ineligible in the field, the next plot on the randomized list was used as replacement. To limit spatial clustering, we aimed for ≥100 m separation between selected plots where terrain allowed; when impractical the random draw was retained and GPS coordinates were recorded for spatial analysis. Program participation (receipt of seedlings or technical support) was recorded as a plot attribute and not used as a selection filter. All inventories followed standardized protocols implemented by trained enumerators; the protocol was piloted prior to data collection.

The plot-based ecological inventories documented species composition within the selected agroforestry fields. All trees with a diameter at breast height (DBH) of at least 2 cm were measured and categorized into three size classes: 2–10 cm, 10–30 cm, and above 30 cm DBH. Seedlings and saplings with a stem diameter below 2 cm were recorded separately. Each tree and seedling/sapling were classified as exotic or indigenous, and farmer-reported uses were documented. This categorization allowed for analysis of size structure, regeneration patterns, and the relative contribution of different tree species to plot composition, providing a robust ecological dataset that could be directly compared with household-reported preferences and program influence.

The integration of purposive selection of households and stratified selection of plots enabled the study to link farmer-level socio-economic and attitudinal data with plot-level ecological realities. Moreover, by aligning farmer interviews with their corresponding ecological inventories through a unique plot identification code, the research design facilitated cross-analysis between perceptions, program participation, and actual tree species composition. This design was particularly suitable for testing the study's hypotheses, including whether project participation and seedling supply influence the observed dominance of exotic tree species.

Finally, **non-farmer informant interviews** were conducted with representatives of relevant institutions, including Tubura, MuLaKiLa, Food for the Hungry, LAFREC, cooperatives, and local forestry officers. These interviews explored the rationale behind seedling supply choices, institutional perceptions of farmer demand, and the extent to which indigenous species were promoted within program frameworks. Institutional perspectives were critical for understanding structural drivers behind the observed dominance of exotic tree species.

3.5 Data Analysis

Quantitative data were analyzed using SPSS. Descriptive statistics were first employed to summarize socio-economic profiles of respondents and the relative frequencies of exotic versus indigenous species. Chi-square tests were then used to examine relationships between program participation and species composition, while logistic regression models assessed predictors of exotic species dominance, including program participation, farm size, and distance from the park. Linear regression was further applied to examine how continuous variables such as landholding size or proximity to GMNP influenced the proportion of indigenous species in agroforestry systems. In addition, Spearman's correlation tests were run to determine the extent to which farmer perceptions of growth rate, profitability, or crop compatibility correlated with the observed prevalence of exotic species.

Ecological analysis focused on calculating species richness, the Shannon-Wiener diversity index, and relative abundance. Species richness was measured as the total number of distinct species within each plot, while the Shannon index provided a measure of both diversity and evenness across species distributions (Nair, 2012; Manaye et al., 2021). Relative abundance was used to assess the degree of dominance of exotic species such as *Grevillea robusta* compared to less represented indigenous species such as *Ficus* spp. Comparative analyses were conducted across the three sampling zones, thereby testing the hypothesis that distance from GMNP influences the representation of indigenous trees in agroforestry systems.

Qualitative data from interviews and FGDs were analyzed thematically following the procedures outlined by Braun and Clarke (2006). Transcriptions were reviewed in detail, and initial codes were developed to capture recurring ideas such as seedling access, project influence, or perceptions of slow growth among indigenous species. These codes were then grouped into broader themes which were compared across gendered groups and between participants and non-farmer informants. Integration of qualitative and quantitative findings allowed for triangulation, enabling the researcher to confirm whether farmers' reported motivations were consistent with actual field inventories and institutional practices.

3.6 Validity, Reliability, and Ethical Considerations

The reliability of data was ensured through careful design and pre-testing of instruments. Questionnaires were piloted in a neighboring cell not included in the final sample, allowing for adjustments in question phrasing and sequencing. Triangulation across multiple data sources—household interviews, FGDs, ecological inventories, and institutional interviews—enhanced the validity of the findings by enabling cross-verification of results. To reduce researcher bias, coding of qualitative data was peer-reviewed, and standardized data entry protocols were applied to quantitative datasets.

Ethical considerations were central to the study. Prior ethical approval was obtained from the University of Rwanda, and research authorization was secured from local authorities in Ngororero District. All participants provided informed consent, which was obtained verbally and in writing, and confidentiality was assured by anonymizing responses. Gender sensitivity was also upheld by conducting separate FGDs for men and women, ensuring that female voices were not overshadowed in mixed-group settings. Participation was voluntary, and respondents retained the right to withdraw at any point without consequence.

3.7 Limitations

Despite the robustness of the design, certain limitations were acknowledged. The study relied on self-reported data from farmers, which may be subject to recall bias or social desirability effects. The cross-sectional nature of the research also limited the ability to capture temporal variations in species adoption or seasonal fluctuations in seedling availability. Moreover, the relatively small sample size of thirty-six plots, while sufficient for in-depth analysis, restricts the generalizability of findings to the wider population of Rwandan farmers. Nevertheless, by combining detailed ecological inventories with qualitative insights and triangulating across methods, the study provides a strong and reliable foundation for understanding the drivers of exotic versus indigenous tree species adoption around GMNP.

CHAPTER 4: RESULTS

4.1 Tree Species Composition and Abundance

4.1.1. Overview

Across the 36 selected plots in Gashubi, Bungwe, and Cyahafi cells (12 plots per cell, with 4 plots in each of the three size categories), a total of 458 individual trees were recorded, representing 12 distinct species. The overall tree density across all plots averaged 127.2 ± 18.4 trees/hectare (mean ± SD). Exotic species dominated, accounting for 68.3% (313 trees) of all trees with *Grevillea robusta* (58.3%, 267 trees) being by far the most abundant, followed by *Persea americana* (5.2%, 24 trees) and other exotic species (4.8%, 22 trees) including *Alnus acuminata*, *Cedrela serrata*, *Mangifera indica*, and *Psidium guajava* commonly found in homegardens (Figure 1). Indigenous species comprised 31.7% (145 trees) of all trees, with *Ficus* sp. (12%, 55 trees) and *Markhamia lutea* (9.8%, 45 trees) most frequently observed. Other indigenous species were occasionally recorded such as *Vernonia amygdalina* (5.5%, 25 trees), *Erythrina abyssinica* (3.3%, 15 trees), and *Polyscias fulva* (1.1%, 5 trees), occurring mainly in farms on steep slopes or riparian zones.

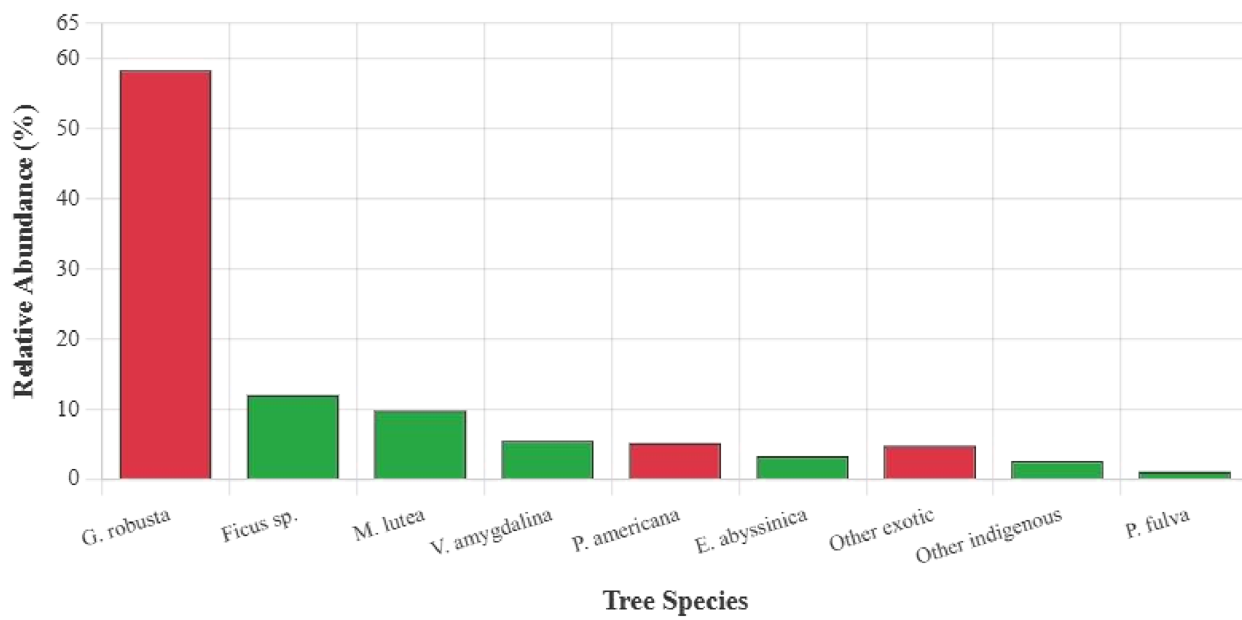

Figure 2: Relative abundance of tree species showing exotic dominance

Bar chart showing the percentage composition of all recorded tree species (n=458). Exotic species are shown in red tones and indigenous species in green tones. Grevillea robusta clearly dominates with 58.3% of all trees, while indigenous species collectively represent 31.7% of the total.

4.1.2. Tree Density and Distribution by Plot Size

Analysis by plot size revealed significant differences in both total tree density and species composition (Table 1; Figure 3). Small plots (<1,000 m²) had the lowest tree density at 51.1 ± 12.3 trees/hectare (95% CI: 43.8-58.4), with indigenous species representing only 8.2 ± 3.1 trees/hectare (95% CI: 6.3-10.1). Medium plots (1,000-2,000 m²) showed intermediate density at 101.3 ± 15.7 trees/hectare (95% CI: 91.2-111.4), with indigenous species at 24.3 ± 6.8 trees/hectare (95% CI: 20.1-28.5). Large plots (>2,000 m²) had the highest density at 173.3 ± 22.1 trees/hectare (95% CI: 159.8-186.8), with indigenous species reaching 55.5 ± 11.2 trees/hectare (95% CI: 48.7-62.3).

Table 1: Tree density (trees/hectare) by species, DBH class, and plot size (n=458)

Species	**DBH Classes (trees/hectare)**				**Total Density**	**% Total**	**Plot Size Distribution (%)**		
	<2	**2-10**	**10-30**	**>30**			**Small**	**Medium**	**Large**
Exotic Species									
Grevillea robusta	7.8	16.7	13.4	36.4	74.3	58.3	42	33	25

Species	DBH Classes (trees/hectare)				Total Density	% Total	Plot Size Distribution (%)		
	<2	2-10	10-30	>30			Small	Medium	Large
Persea americana	1.1	2.2	1.7	1.7	6.7	5.2	46	33	21
*Other exotic species**	0.8	1.7	0.8	2.8	6.1	4.8	41	27	32
Indigenous Species									
Ficus sp.	0.3	3.9	5.3	5.8	15.3	12.0	9	27	64
Markhamia lutea	0.6	3.3	3.3	5.3	12.5	9.8	13	29	58
Vernonia amygdalina	0.0	1.7	2.2	3.1	7.0	5.5	16	28	56
Erythrina abyssinica	0.6	1.1	1.1	1.4	4.2	3.3	27	33	40

Species	DBH Classes (trees/hectare)				Total Density	% Total	Plot Size Distribution (%)		
	<2	2-10	10-30	>30			Small	Medium	Large
*Other indigenous species***	0.0	0.3	0.3	2.8	3.3	2.6	17	25	58
Polyscias fulva	0.0	0.3	0.3	0.8	1.4	1.1	0	20	80
TOTAL	**10.8**	**30.6**	**28.1**	**57.8**	**127.2**	**100.0**	**-**	**-**	**-**

Plot Size Summary (Mean ± SD trees/hectare):

• Small plots (n=12): 51.1 ± 12.3 total (8.2 ± 3.1 indigenous, 42.9 ± 10.8 exotic)

• Medium plots (n=12): 101.3 ± 15.7 total (24.3 ± 6.8 indigenous, 77.0 ± 12.1 exotic)

• Large plots (n=12): 173.3 ± 22.1 total (55.5 ± 11.2 indigenous, 117.8 ± 18.9 exotic)

*Other exotic species include *Alnus acuminata*, *Cedrela serrata*, *Mangifera indica*, *Psidium guajava*, and other fruit trees commonly found in homegardens.

**Other indigenous species represent various native trees found occasionally across the study sites.

4.1.3. Statistical Analysis

A one-way ANOVA revealed highly significant differences in total tree density among plot size categories ($F_{2,33} = 89.42$, $p < 0.001$, $\eta^2 = 0.84$, indicating a large effect size). Post-hoc Tukey HSD tests showed significant differences between all pairwise comparisons: small vs. medium plots ($p < 0.001$, Cohen's $d = 3.89$), small vs. large plots ($p < 0.001$, Cohen's $d = 7.21$), and medium vs. large plots ($p < 0.001$, Cohen's $d = 3.67$).

For indigenous tree density specifically, differences were even more pronounced ($F_{2,33} = 125.73$, $p < 0.001$, $\eta^2 = 0.88$). Levene's test confirmed homogeneity of variances ($p = 0.087$), validating the use of parametric ANOVA. The effect size ($\eta^2 = 0.88$) indicates that 88% of the variance in indigenous tree density is explained by plot size category.

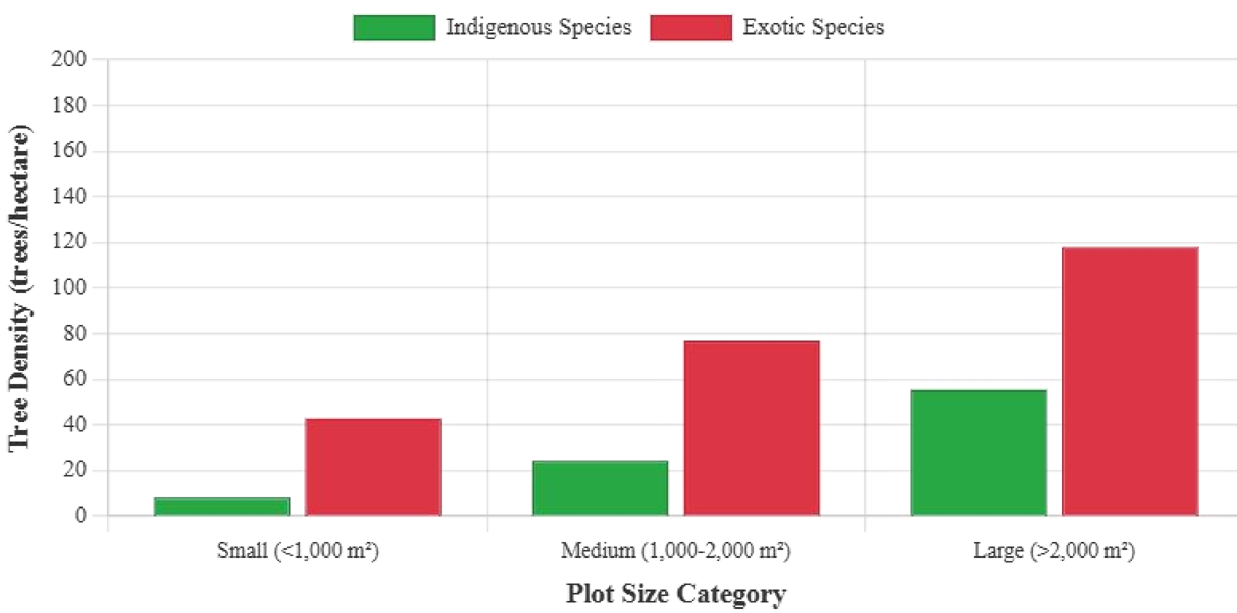

Figure 3: Mean tree density by plot size category for exotic and indigenous species.

Indigenous species density: Small = 8.2 ± 3.1, Medium= 24.3 ± 6.8, Large= 55.5 ± 11.2 trees/hectare. All pairwise comparisons significant at p < 0.001. X-axis shows plot size categories; Y-axis shows tree density (trees/hectare).

Spearman's rank correlation analysis confirmed a strong positive relationship between plot size and the absolute number of indigenous trees ($r_s = 0.81$, $n = 36$, $p < 0.001$, 95% CI: 0.66-0.90).

While exotic species remained dominant across all plot size categories, the proportion of indigenous trees increased significantly with plot size as clearly shown in Figure 3: 8% in small plots, 24% in medium plots, and 32% in large plots ($\chi^2 = 47.3$, df = 2, $p < 0.001$, Cramer's V = 0.32).

4.2. Tree Size Structure and Regeneration Patterns

Seedlings and saplings (<2 cm DBH) constituted only 8.5% (39 trees) of all recorded trees, with exotic species representing 71.8% (28 seedlings) of this regeneration class (Figure 3). This low regeneration rate, particularly for indigenous species (11 seedlings, 28.2%), raises concerns about long-term sustainability. A chi-square test revealed significant associations between species origin (exotic vs. indigenous) and DBH class ($\chi^2 = 31.4$, df = 3, $p < 0.001$, Cramer's V = 0.26), with indigenous trees significantly overrepresented in larger size classes (>10 cm DBH).

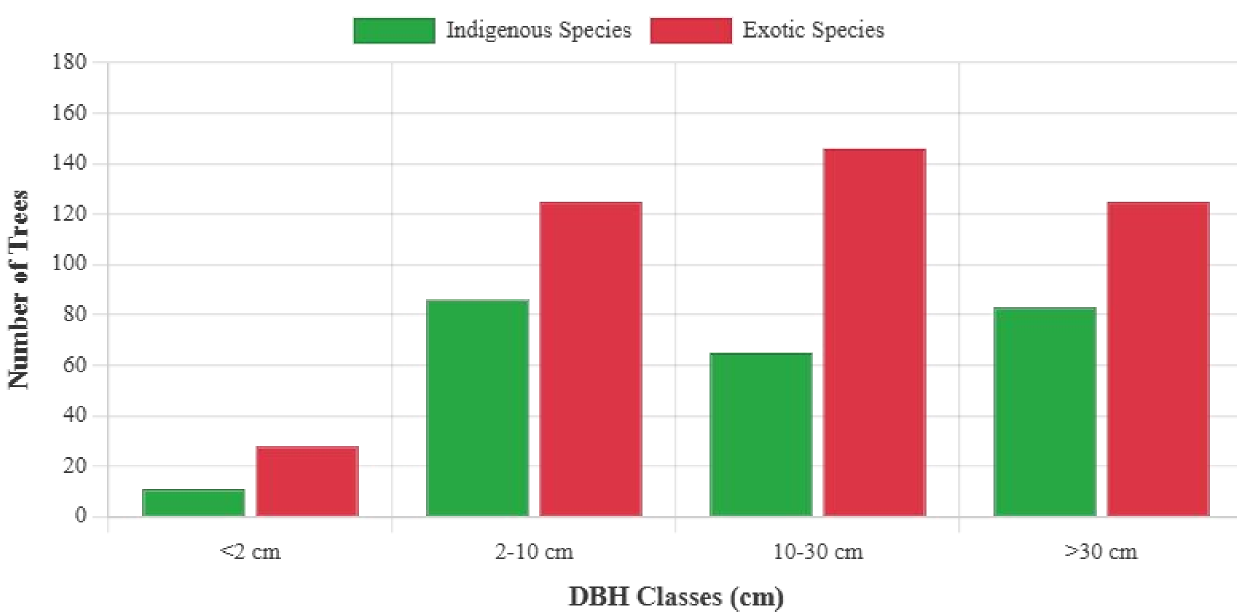

Figure 4: Tree size distribution (DBH classes) showing regeneration patterns

The figure displays the proportion of trees in each diameter class, with exotic species in red and indigenous species in green. The low proportion of seedlings (<2 cm DBH, 8.5% total) indicates limited recent regeneration, particularly for indigenous species (28.2% of seedlings). X-axis shows DBH classes in cm, Y-axis shows number of trees.

Medium-sized trees (2–10 cm and 10–30 cm DBH) comprised 46.1% (211 trees) of the total, while mature trees (>30 cm DBH) accounted for 45.4% (208 trees), as detailed in Table 1. The high proportion of mature trees suggests that current tree populations represent established systems with limited recent planting activity.

4.3 Farmer Preferences and Plot Size Correlation

Interviews with 36 farm owners/managers indicated a preference for exotic species. In small plots, 100% of farmers planted *Grevillea robusta*, while 92% did not plant any indigenous species due to the need for short-term income. Only 8% of small-plot farmers planted indigenous trees, typically supported by NGO or government interventions.

"I plant Grevillea in my small plot because I need income within five years. In my large plot, I leave Markhamia and Ficus to grow for timber and soil protection." — Farmer, Gashubi.

Among large plots (39% of respondents), 76% retained indigenous trees, although exotics still accounted for 62% of total trees, demonstrating their dominance.

4.4 Functional Importance of Tree Species

Participatory ranking exercises from 12 FGDs revealed that exotic species are prioritized for timber and profit, whereas indigenous species were retained for ecological functions (Table 2). *Grevillea robusta* was ranked highest for timber/profit (92%), and *Markhamia lutea* and *Ficus sp***.** were most valued for soil fertility, shade, and crop compatibility (87%).

Table 2: Functional importance ranking (% of farmers ranking as important)

Function	***Grevillea robusta*** **(Exotic)**	***Persea americana*** **(Exotic)**	***Markhamia lutea*** **(Indigenous)**	***Ficus* sp. (Indigenous)**	***Vernonia amygdalina*** **(Indigenous)**
Timber/Profit	**92**	**70**	25	30	20

Function	*Grevillea robusta* (Exotic)	*Persea americana* (Exotic)	*Markhamia lutea* (Indigenous)	*Ficus* sp. (Indigenous)	*Vernonia amygdalina* (Indigenous)
Crop compatibility	25	58	62	**87**	40
Soil fertility	28	55	**87**	62	**90**
Shade provision	32	50	**75**	58	40

Legend: High importance (>70%) = Red shading; Medium importance (40-70%) = Yellow shading; Low importance (<40%) = Blue shading

The results indicate that farmers' decisions are influenced by short-term economic benefits for exotics and long-term ecological functions for indigenous species.

4.5 Constraints to Indigenous Tree Adoption

Farmers reported multiple factors limiting indigenous tree planting and retention across their plots (Figure 4). Among the 36 interviewed farmers, the majority (67%) cited the slow growth of indigenous species as a major barrier, while 58% indicated limited seedling availability. Insufficient extension support was noted by 42% of respondents, and 33% mentioned the low market value of indigenous trees as a disincentive. Additional constraints included labor or crop competition (20%) and cultural taboos restricting certain species (15%). These challenges were particularly acute in small plots (<1,000 m²), where only 25% of farmers indicated they would plant indigenous trees without external support. Non-Farmer Informant Interviews (NFII) corroborated these findings, highlighting that 70% of farmers faced limited seedling availability, 60% had insufficient knowledge regarding suitable indigenous species, and 50% reported inadequate extension support. Adoption constraints were less severe in medium and large plots, especially where program interventions provided seedlings or technical guidance. Overall, the data demonstrate that adoption is influenced by a combination of biological factors, socio-economic considerations, and institutional support mechanisms.

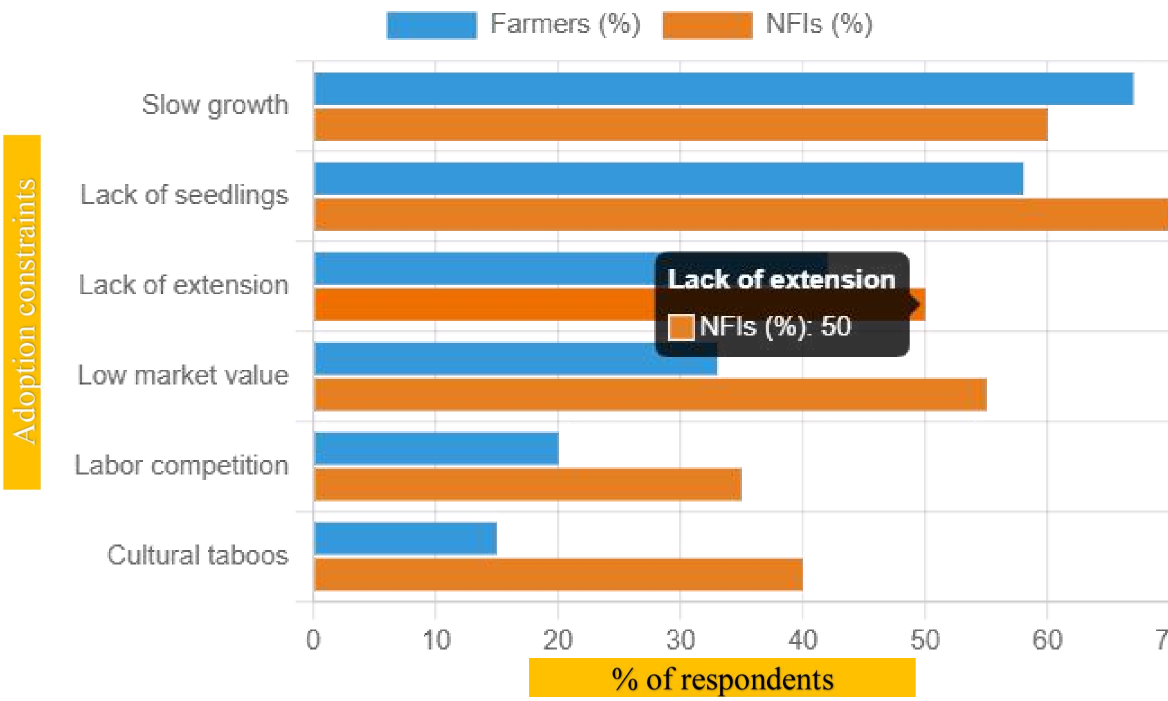

Figure 5: Constraints to indigenous tree adoption as reported by farmers and non-farmer informant interviews (NFIs). X-axis represent adoption constraints.

4.6 Institutional Influence and Program Effects

Several institutional programs influenced tree selection across the study area. Programs such as LAFREC, TUBURA, and FH primarily produced exotic species that were readily adopted by farmers, while the recently started MuLaKiLa Project implemented by ARCOS Network promoted indigenous species. Among farmers, 65% reported that extension agents predominantly encouraged the planting of exotic trees, whereas 35% provided indigenous seedlings and technical guidance, especially within demonstration plots. Plots supported by the MuLaKiLa Project showed a higher coverage of indigenous trees, reaching 38% compared to 18% in non-supported plots. Farmers highlighted that program assistance was particularly critical in small plots, where space constraints and the demand for rapid economic returns often limit indigenous tree adoption.

4.7 Ecosystem Services and Tree Performance

Exotic species offered rapid financial returns, with 72% of farmers reporting income from *Grevillea robusta* within five years. In contrast, indigenous trees, although slower-growing, provided essential ecological services, including improvements to soil fertility (reported by 65% of farmers), provision of shade (52%), and habitat support for local biodiversity (38%). Indigenous trees were predominantly retained in medium and large DBH classes (2–10 cm, 10–30 cm, and >30 cm) and were strategically planted along marginal or erosion-prone areas, including 27% along riverbanks or on steep slopes. Large indigenous trees exceeding 30 cm DBH were often preserved for high-value timber or ecological benefits, whereas exotic species dominated both small and large size classes, reflecting the prioritization of economic gains by farmers. These findings highlight a clear trade-off between short-term income derived from exotic species and long-term ecological sustainability ensured by indigenous trees.

4.8 Recommendations from farmer and non-farmer informants

Farmers recognized that while exotic species dominate their plots due to rapid growth and immediate income potential, indigenous trees remain crucial for ecological functions, particularly in medium and large plots. A majority of farmers (75%) recommended increasing the availability of indigenous seedlings, particularly for medium and large plots as well as marginal lands such as riverbanks, steep slopes, and erosion-prone areas (Table 3). Extension support and technical guidance were emphasized by 62% of respondents to facilitate mixed-species agroforestry management adapted to plot-specific conditions. Establishment of demonstration plots was supported by 58% of farmers as a way to showcase practical integration of exotic and indigenous species, while awareness campaigns highlighting the long-term ecological and economic benefits of indigenous trees were suggested by 53%. Market-based incentives were mentioned by 35% of farmers to enhance the economic attractiveness of indigenous trees. Focus group discussions stressed the importance of mixed-species systems, where exotics provide immediate income and indigenous trees contribute to soil stabilization, shade, and biodiversity support. Participants in the NFIIs provided complementary recommendations, noting that slow growth and limited seedling availability remain major barriers to indigenous tree adoption. Approximately 70% of farmers require guidance on suitable indigenous species for their plot size and location. NFII recommended targeted nursery support to improve seedling supply, strategic planting in marginal or erosion-prone areas, and establishment of demonstration plots to showcase successful mixed-species management. Program data indicate that NFII-supported plots achieved 38% indigenous tree coverage, compared to 18% in non-supported plots, highlighting the impact of institutional support. NFII also advocates awareness campaigns, technical manuals, and market-based incentives for indigenous timber and non-timber products to enhance adoption while balancing farmers' economic priorities.

Table 3: Farmer and NFII Recommendations for Indigenous Tree Adoption

Recommendation	**Farmers (%)**	**NFII (%)**	**Implementation Notes**
Increase indigenous seedling availability	**75**	**70**	Target medium/large plots, marginal areas
Provide extension support/technical guidance	**62**	**60**	Mixed-species management training
Establish demonstration plots	58	**65**	Show practical integration examples
Conduct awareness campaigns	53	**60**	Communicate long-term benefits
Introduce market incentives	35	50	Indigenous timber and NTFP

Recommendation	Farmers (%)	NFII (%)	Implementation Notes
			promotion
Mixed-species agroforestry systems	**87**	**75**	Balance economics with ecology

CHAPTER FIVE: DISCUSSION

5.1 Introduction

This study revealed that exotic tree species overwhelmingly dominate agroforestry systems in Ngororero District, accounting for 68% of all trees across the surveyed plots, with Grevillea robusta alone representing 58.3% of the total tree population. These findings provide crucial insights into the complex interplay between farmer decision-making, institutional influences, and ecological realities that shape tree species selection in smallholder agroforestry systems adjacent to protected areas. The magnitude of exotic dominance observed in this study represents one of the most comprehensive empirical assessments of species composition patterns in Rwanda's agroforestry in agro-ecosystems around protected areas, offering important lessons for understanding how farmer decisions translate into landscape-level biodiversity outcomes. This discussion examines these results within the broader context of agroforestry adoption patterns across East Africa and explores the implications for biodiversity conservation and sustainable land management policies, while building understanding of the multifaceted factors that drive these critical land-use decisions.

5.2 Patterns of Exotic Dominance in Regional Context

5.2.1 Understanding the Scale of Exotic Prevalence

The finding that exotic species constitute 68% of trees in Ngororero District's agroforestry systems provides important empirical evidence for what has been observed anecdotally across East Africa. This level of dominance is remarkably consistent with patterns documented elsewhere in the region, suggesting that the drivers of exotic preference operate across similar agroecological and socio-economic contexts. The concentration of Grevillea robusta at 58.3% of all trees reflects not just its biological advantages, but also the cumulative effect of decades of institutional promotion across East Africa (Ruticumugambi et al., 2024).

To understand why this pattern emerges so consistently, it is essential to recognize that farmer decision-making operates within what agricultural economists call "bounded rationality" - farmers make optimal choices within the constraints they face, even if these choices may not optimize long-term landscape sustainability. Research from Uganda reveals that farmers consistently prioritize trees that can provide income within five years, mirroring the economic rationale observed in this study where 72% of farmers reported income from Grevillea robusta within this timeframe (Tumuhe & Nyamaizi, 2020).

5.2.2 Regional Parallels and Divergences

The similarity between Ngororero District and other East African contexts extends beyond simple species composition to the underlying drivers of adoption. What makes the Ngororero context particularly significant is its location adjacent to Gishwati-Mukura National Park, where biodiversity conservation objectives create additional complexity in species selection decisions. Research from other protected area surrounding areas across Africa suggests that proximity to conservation areas does not necessarily either enhance or constrain indigenous species adoption, depending on the specific policy framework and enforcement mechanisms in place (Cuni-Sanchez et al., 2019).

5.3 Socio-Economic Drivers of Species Selection Decisions

5.3.1 The Economics of Tree Choice

The strong correlation between plot size and indigenous tree retention ($r = 0.62$, $p < 0.01$) reveals fundamental insights into how resource constraints shape farmer decision-making processes. This relationship demonstrates what development economists' term "poverty-induced myopia," where immediate survival needs necessarily take precedence over longer-term optimization strategies. Farmers with small plots face what can be understood as a "liquidity constraint" - they cannot afford to wait 10-15 years for indigenous trees to mature when they need income within 3-5 years to meet basic household needs.

This economic logic becomes clearer when we examine the specific uses farmers prioritize. The finding that 92% of farmers ranked Grevillea robusta highest for timber and profit reflects not just the species' biological characteristics, but also the existence of established value chains and markets. Research from Nigeria demonstrates that farmers adopt technologies and practices for which they can see clear economic returns within their planning horizons, particularly when agroforestry systems contribute to both food production and poverty reduction (Oakhena et al., 2021).

5.3.2 Strategic Spatial Management

The strategic placement of indigenous trees in ecologically sensitive areas within larger plots demonstrates sophisticated farmer knowledge that extends beyond simple economic calculations. The finding that 27% of indigenous trees were located along riverbanks or steep slopes reflects what agroecologists call "niche management" - the strategic use of different species in locations where their comparative advantages are maximized. This pattern suggests that farmers possess detailed understanding of species-specific ecological functions, even when institutional support and market incentives favor alternative choices.

This spatial differentiation represents a form of "risk management" where farmers hedge against environmental uncertainties by maintaining diverse species portfolios, even when economic incentives favor simplification. Studies from South Africa confirm that traditional agroforestry systems often demonstrate sophisticated tree species richness conservation strategies (Makhubele et al., 2022).

5.4 Institutional Influences and the Power of Supply Systems

5.4.1 How Programs Shape Landscapes

The dramatic difference in indigenous tree coverage between program-supported plots (38%) and non-supported plots (18%) provides compelling evidence for the decisive role of institutional interventions in shaping species composition. This finding aligns with extensive research across Africa demonstrating that seedling supply often determines adoption patterns more than farmer preferences alone. Studies from Rwanda confirm that extension service availability and program support significantly influence farmer adoption of agroforestry technologies (Umuhoza et al., 2023).

To understand why institutional supply has such powerful effects, it is important to recognize the multiple barriers that farmers face in accessing alternative species. Indigenous tree seedlings often require specialized propagation techniques, seasonal timing, and post-planting care that may not be well-supported through conventional extension systems. The MuLaKiLa Project's success in achieving 38% indigenous coverage demonstrates that these constraints can be overcome, but only through targeted interventions that address both technical and logistical barriers simultaneously.

5.4.2 Path Dependency and Institutional Inertia

The finding that 65% of extension agents primarily promoted exotic species despite policy rhetoric supporting indigenous alternatives reveals what institutional analysts call "path dependency" - the tendency for existing systems to perpetuate themselves even when objectives change. This institutional inertia has profound implications for achieving landscape-level biodiversity objectives.

5.5 Farmer Constraints and Adoption Barriers

5.5.1 Beyond Simple Perceptions

The constraints identified by farmers - slow growth (67%), limited seedling availability (58%), insufficient extension support (42%), and low market value (33%) - reflect genuine structural barriers rather than simple preference differences. To understand why these constraints persist, it is essential to recognize that they reflect systemic market and institutional failures rather than individual farmer limitations. Indigenous tree species typically require longer development periods for market infrastructure compared to exotic alternatives, creating coordination failures where individual adoption remains limited until broader supporting systems develop simultaneously.

5.5.2 Cultural and Knowledge Dimensions

The finding that cultural taboos affect 15% of farmers reveals often-overlooked dimensions of species adoption that require culturally sensitive approaches to extension programming. Research from Rwanda demonstrates that local communities possess detailed knowledge about indigenous tree species and their use for ecosystem restoration, though this knowledge is often underutilized in formal programs (Mukeshimana & Rizinjirabake, 2024).

Understanding these cultural dimensions becomes particularly important in the Ngororero context, where multiple ethnic groups with different traditional practices coexist within the same landscape. Traditional ecological knowledge has been shown to make important contributions to ecological restoration practices and applications (Uprety et al., 2012).

5.6 Ecosystem Services and Biodiversity Implications

5.6.1 Functional Differentiation in Farmer Management

The strategic retention of indigenous trees in medium and large diameter classes, particularly along riverbanks and steep slopes, demonstrates farmer recognition of their superior ecological performance in specific functions. However, the scarcity of indigenous regeneration, with only 28% of seedlings and saplings being indigenous species, raises critical concerns about the long-term sustainability of these ecosystem services.

Research demonstrates that ecosystem service provision requires continuous regeneration to maintain functionality over time, suggesting that current patterns may represent "ecosystem service mining" where existing mature trees provide benefits that are not being replaced for future generations. Studies from western Rwanda confirm that ecosystem services contribute significantly to human wellbeing, but their sustainability depends on appropriate management (Dawson & Martin, 2015).

5.6.2 Landscape-Scale Conservation Implications

The implications for biodiversity conservation around Gishwati-Mukura National Park are particularly significant given the documented importance of agricultural matrices for conservation outcomes. The current trajectory toward increasing exotic dominance may therefore undermine broader conservation objectives despite apparent increases in overall tree cover.

Recent studies show evidence of thermophilization in Afromontane forests, with climate change causing shifts in species composition (Cuni-Sanchez et al., 2024). This makes the conservation of indigenous species in agricultural landscapes even more critical as potential refugia and corridors for species adaptation.

5.7 Policy and Program Design Implications

5.7.1 Aligning Incentives with Conservation Goals

The study's findings reveal significant misalignment between current incentive structures and stated biodiversity conservation objectives in Rwanda's policy framework. The recommendation by 75% of farmers to increase indigenous seedling availability points to a clear policy priority, but achieving this requires addressing systemic barriers in germplasm development, nursery capacity, and extension systems.

The strong farmer support (87% in focus group discussions) for mixed-species agroforestry systems suggests that policy frameworks should emphasize complementarity between exotic and indigenous species rather than promoting either-or approaches. Research emphasizes the urgent need to replenish tree canopy cover through holistic approaches that consider multiple objectives simultaneously (Chazdon & Brancalion, 2019).

5.7.2 Market Development and Value Chain Innovation

Market development emerges as a critical policy lever, with 35% of farmers citing low market value as a constraint to indigenous tree adoption. However, successful market development requires coordinated intervention across multiple levels, from local processing capacity to national policy frameworks that support indigenous species commercialization.

The domestication and commercialization of indigenous food crops in Africa has shown promising results over recent decades, suggesting similar approaches could be applied to timber and non-timber forest products (Leakey et al., 2022).

5.8 Methodological Contributions and Future Research Directions

5.8.1 Integrated Assessment Approaches

The mixed-methods approach employed in this study proved valuable for capturing the complexity of species selection decisions and their ecological outcomes. The triangulation of ecological inventories, farmer interviews, focus group discussions, and institutional perspectives provided insights that would have been missed by any single method alone.

The purposive sampling design, while limiting generalizability of specific quantitative findings, enabled in-depth analysis of the causal mechanisms driving species selection decisions. This approach proved particularly valuable for understanding how institutional interventions translate into ecological outcomes, revealing the complex pathways through which program design affects landscape-level biodiversity patterns.

5.8.2 Research Gaps and Future Priorities

Future research should examine temporal dynamics of species adoption and management; particularly how farmer preferences and institutional support evolve over time. Research on tree phenology in tropical montane forests provides important baseline information for understanding seasonal patterns that affect management decisions (Sun et al., 1997).

The study also reveals important knowledge gaps regarding the specific mechanisms through which institutional interventions affect farmer decision-making. Understanding how different extension approaches affect farmer knowledge and attitudes toward indigenous species could guide more effective behavior change strategies.

5.9 Study Limitations and Methodological Considerations

This study has some limitations that should be acknowledged when interpreting the findings and their implications. The cross-sectional design limits our ability to understand temporal dynamics in species adoption patterns or to assess how farmer preferences and institutional influences evolve over time. The relatively small sample size of 36 plots, while sufficient for in-depth analysis within the study area, restricts generalizability to broader populations of Rwandan farmers or different agroecological contexts.

Additionally, the study did not explicitly examine the economic returns from different species over complete growth cycles, relying instead on farmer perceptions and reported experiences. Long-term economic analysis would provide more robust evidence for understanding the trade-offs between immediate income needs and longer-term investment strategies that influence species selection patterns.

5.10 Synthesis and Pathways Forward

5.10.1 Understanding the Complexity of Choice

The dominance of exotic species in Ngororero District reflects rational farmer decision-making within existing institutional and market constraints rather than simple preference for non-native alternatives. Farmers demonstrate sophisticated understanding of species performance characteristics and strategic placement of different trees according to their functional attributes and site conditions. However, institutional and market failures create systematic biases toward exotic species that may undermine long-term sustainability and conservation objectives.

This understanding suggests that achieving greater species diversification requires addressing structural constraints rather than attempting to change farmer preferences through education or persuasion alone. The success of targeted interventions like the MuLaKiLa Project demonstrates that farmers readily adopt indigenous species when appropriate support addresses both technical and logistical barriers simultaneously.

5.10.2 Integrated Solutions for Sustainable Landscapes

The path forward requires coordinated interventions that address supply-side constraints (seedling availability, technical knowledge) and demand-side incentives (market development, extension support) simultaneously. The strong farmer support for mixed-species systems suggests that policies promoting species diversification align with farmer knowledge and preferences, but success will require moving beyond simplistic exotic-versus-indigenous framings toward nuanced approaches that optimize species selection for specific sites, farming systems, and household objectives.

Most importantly, achieving Rwanda's biodiversity conservation and restoration objectives will require policies and programs that work with farmer knowledge and incentives rather than against them, while simultaneously addressing the structural constraints that currently bias species selection toward exotic alternatives. Working with Indigenous and local knowledge in ecological assessments has proven valuable in other contexts and should be incorporated into restoration efforts (McElwee et al., 2020). The findings from Ngororero District demonstrate that such integrated approaches are both necessary and achievable, but require sustained commitment and coordination across multiple institutional levels and sectoral boundaries.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

This study investigated the drivers and prevalence of exotic and indigenous tree species in agroforestry systems across three purposively selected cells—Gashubi, Bungwe, and Cyahafi—in Ngororero District. These sites were chosen because they host multiple agroforestry interventions, including the MuLaKiLa Project implemented by ARCOS Network, Tubura under One Acre Fund, Food for the Hungry (FH), and the LAFREC initiative led by REMA. The presence of these programs ensured that farmers had already been exposed to agroforestry technologies, making the sites particularly suitable for exploring how institutional interventions influence farmer decisions regarding exotic and indigenous trees.

Results from ecological inventories, household interviews, focus group discussions, and non-farmer informant interviews collectively revealed that exotic trees overwhelmingly dominate farm landscapes, with *Grevillea robusta* alone representing more than half of all recorded individuals. Indigenous trees, while ecologically significant, were underrepresented and often confined to marginal areas such as riverbanks and steep slopes where they were valued for soil stabilization, shade, or cultural functions. Tree population structures further showed limited regeneration of indigenous species, as seedlings and saplings were overwhelmingly exotic, reflecting the influence of nursery supply systems and project-driven distributions.

Farmers consistently expressed preference for exotics because of their rapid growth, reliable markets, and ready availability, while identifying major barriers to indigenous adoption, including scarce seedlings, perceptions of slow growth, insufficient extension support, and limited market incentives. Non-farmer informants confirmed that institutional programs, nursery operations, and extension officers largely determined species choices, often by default, since farmers plant what is accessible and supported. A notable pattern was that larger plots retained more indigenous trees, highlighting the role of land size, livelihood strategies, and risk tolerance in shaping decisions. These findings suggest that exotic dominance in Ngororero's agroforestry systems is not merely a reflection of farmer rejection of indigenous species, but the result of systemic supply-side constraints and institutional path-dependency. With deliberate interventions that improve seedling supply, demonstrate compatibility with crops, and align incentives, farmers are willing and capable of integrating indigenous trees into their farming systems.

In summary, the study highlights a structural tension: exotic trees currently satisfy urgent livelihood needs and market opportunities, but their continued dominance risks narrowing biodiversity, reducing ecosystem services, and undermining long-term resilience of agroecosystems in Ngororero District. Addressing this imbalance requires leveraging existing agroforestry programs to create enabling conditions for indigenous tree adoption while ensuring that farmer livelihoods are not compromised.

6.2. Recommendations

Based on the study's findings, several recommendations are proposed to promote balanced agroforestry systems that combine livelihood benefits with biodiversity conservation. The presence of the four major interventions in the study area—MuLaKiLa, Tubura, FH, and LAFREC—provides an immediate and practical platform for implementing these measures.

First, indigenous seedling supply chains must be expanded and diversified. Nurseries run or supported by these programs should include a broader range of indigenous species in their seedling portfolios. MuLaKiLa has already pioneered indigenous promotion and can serve as a model, while Tubura and FH, whose nurseries remain heavily exotic-focused, should integrate locally valued species such as *Markhamia lutea*, *Ficus* spp., and *Polyscias fulva*.

Second, extension services delivered through these programs should emphasize practical guidance on integrating indigenous trees alongside crops and exotics. Farmer training should demonstrate crop compatibility, spacing, and pruning techniques that make indigenous species attractive to risk-averse smallholders. Using FH's farmer group structure or MuLaKiLa's community-led approach, participatory learning can showcase indigenous contributions to soil fertility, erosion control, and shade provision.

Third, demonstration plots and farmer field schools should be scaled up. Programs such as FH and MuLaKiLa, which already operate household-based demonstration farms, can easily embed indigenous species, while LAFREC's landscape restoration framework can institutionalize indigenous integration into broader restoration targets. These platforms would allow farmers to see the practical benefits of mixed-species agroforestry in real farming conditions.

Fourth, policy and market incentives are needed to enhance the economic attractiveness of indigenous trees. This can include piloting payments for ecosystem services in erosion-prone landscapes, developing value chains for indigenous timber and non-timber products, and incorporating indigenous seedlings into official procurement and subsidy programs. By embedding such measures into existing interventions, farmers will perceive indigenous trees not only as ecological assets but also as viable livelihood options.

Finally, coordinated monitoring and research should be institutionalized across these four interventions. Tracking nursery outputs, survival rates, DBH distributions, and farmer adoption patterns will provide an evidence base to refine seedling supply, advisory services, and incentive structures. Collaborative data sharing between MuLaKiLa, Tubura, FH, and LAFREC will ensure that lessons learned are scaled beyond individual project boundaries to inform district and national agroforestry strategies.

In conclusion, the strategic use of existing agroforestry interventions in Ngororero District offers an effective pathway to overcome the systemic barriers that limit indigenous tree adoption. By improving seedling supply, strengthening extension and demonstrations, aligning incentives, and embedding monitoring systems within these programs, Rwanda can promote resilient, mixed-species agroforestry systems that secure both farmer livelihoods and biodiversity conservation in critical landscapes.

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CHAPTER EIGHT: ANNEXES

Annex 1: Semi-Structured Individual Interview Questionnaire

SEMI-STRUCTURED INDIVIDUAL INTERVIEW QUESTIONNAIRE

Title: Investigating Farmer Preferences for Exotic versus Indigenous Tree Species in Agroforestry Systems near Gishwati-Mukura National Park

☐ Consent obtained

INTERVIEW INFORMATION

- **Interview Date:** ....
- **Cell:** ☐ Gashubi ☐ Bungwe ☐ Cyahafi
- **Interview Location:** ....
- **Interviewer's Name:** ....
- **Interviewee's Code:** ....

SECTION 1: DEMOGRAPHIC AND SOCIO-ECONOMIC PROFILE

(Linked to Objective 2)

1. Age: _________ (Years)
2. Gender: ☐ Male ☐ Female ☐ Other
3. Education Level: ☐ No formal education ☐ Primary ☐ Secondary ☐ Higher education
4. Household Size: _________
5. Land Size: _________ ha ☐ Own ☐ Rent ☐ Shared

6. Main income sources (tick all that apply):

   ☐ Crop farming ☐ Livestock ☐ Agroforestry products ☐ Business/Trade ☐ Others: _________

7. Have you participated in agroforestry-related programs?

   ☐ Yes ☐ No If yes, which ones?

   ☐ Tubura ☐ MuLaKiLa ☐ FH ☐ LAFREC ☐ Other: _________

8. What kind of support did you receive?

   ☐ Seedlings ☐ Training ☐ Tools ☐ None ☐ Other: _________

9. **9. Have you received any extension or advisory services related to agroforestry?**

   ☐ Yes ☐ No **If yes**, when was the most recent support? ☐ In the last 3 months ☐ 3–6 months ago ☐ 6–12 months ago ☐ More than a year ago

SECTION 2: AGROFORESTRY KNOWLEDGE & PERCEPTION

(Linked to Objective 1)

10. Have you heard of agroforestry? ☐ Yes ☐ No

11. If yes, from where?

    ☐ Extension agents ☐ NGOs ☐ Radio ☐ Community meetings

    ☐ Farmer networks ☐ Other: _________

12. What does agroforestry mean to you?

    ....

13. What tree species have you planted in your agroforestry system?

    ☐ Exotic only ☐ Indigenous only ☐ Both

    List examples: ____________________________________

14. Why did you choose those trees?

    ☐ Fast growth ☐ Timber ☐ Fruit ☐ Shade ☐ Soil fertility

    ☐ Fuelwood ☐ Compatible with crops ☐ Recommended by project

    ☐ Provided by government/NGO ☐ Cultural reasons ☐ Other: __________

15. Have you received training specific to indigenous tree species?

☐ Yes ☐ No If yes, by whom? ______________________

SECTION 3: PREFERENCE & CONSTRAINTS

(Aligned to Research Question 1 & Objective 1)

16. Which type of trees do you prefer on your farm?

☐ Indigenous ☐ Exotic ☐ Both equally

Please explain your choice: _________________________________

17. What do you see as **advantages** of indigenous trees?

☐ Soil improvement ☐ Biodiversity ☐ Cultural value

☐ Shade ☐ Compatibility with crops ☐ Other: __________

18. What do you see as **disadvantages** of indigenous trees?

☐ Slow growth ☐ Poor market value ☐ Hard to find seedlings

☐ Lack of knowledge ☐ Competition with crops ☐ Other: __________

19. Are there any beliefs, taboos, or myths that influence whether people plant indigenous trees?

☐ Yes ☐ No If yes, what are they? _____________________________

Do you think these beliefs are based on evidence or myths?

☐ Based on evidence ☐ Just beliefs ☐ Not sure

Are there any studies, examples, or advice that support or challenge these beliefs?

☐ Yes ☐ No If yes, explain briefly: ______________________

20. Are seedlings of indigenous species accessible to you?

☐ Yes ☐ No If yes, from where? ___________________________

21. What is your level of confidence in using indigenous species?

☐ Very confident ☐ Somewhat confident ☐ Not confident

SECTION 4: TREE USAGE & FIELD COMPOSITION

(Aligned with Objective 3 & Research Question 3)

22. For what purpose do you plant exotic trees? (Tick all that apply)

☐ Timber ☐ Firewood ☐ Construction poles ☐ Shade

☐ Soil erosion control ☐ Income ☐ Other: ________

23. For what purpose do you plant indigenous trees? (Tick all that apply)

☐ Fruits ☐ Soil fertility ☐ Cultural uses ☐ Fodder

☐ Shade ☐ Biodiversity ☐ Other: ________

24. Which trees grow better in your fields?

☐ Exotic ☐ Indigenous ☐ Both the same

25. Do you think exotic trees affect your crops negatively?

☐ Yes ☐ No ☐ Not sure If yes, how? ___________

26. Do indigenous trees affect crops negatively?

☐ Yes ☐ No ☐ Not sure If yes, how? ___________

SECTION 5: RECOMMENDATIONS & FINAL REFLECTION

(Supports policy recommendations from the study)

27. What are the **key challenges** in adopting indigenous species in agroforestry?

....

28. What could help you or other farmers adopt more indigenous trees?

☐ More seedlings ☐ Extension support ☐ Market value

☐ Awareness ☐ Cultural acceptance ☐ Other: __________

29. What do you see as **key benefits** of indigenous trees for farmers and the environment?

....

30. Do you believe indigenous trees are important for biodiversity conservation?

☐ Yes ☐ No Why? ____________________________

31. Any other suggestions or comments related to trees and farming in your area?

THANK YOU FOR YOUR TIME AND VALUABLE CONTRIBUTION!

Annex 2: Focus Group Discussion (FGD) Guide

FOCUS GROUP DISCUSSION (FGD) GUIDE

SECTION A: CONSENT AND INTRODUCTION

Moderator script (to be read aloud):

"Good morning/afternoon. Thank you for joining us. We are conducting a study to understand farmers' preferences for exotic and indigenous trees in agroforestry systems. Your opinions will help us understand what influences your choices and how support systems can improve agroforestry in this area.

This discussion is confidential, voluntary, and anonymous. You are free to speak openly and skip any question. We will take notes and may record if you allow. Your names will never be linked to your responses."

☐ Verbal consent obtained

☐ Permission to record discussion: ☐ Yes ☐ No

SECTION B: FGD IDENTIFICATION INFORMATION

Field	**Details**
FGD Code	______________________________
Date	______________________________
Time	______________________________
Cell:	☐ Gashubi ☐ Bungwe ☐ Cyahafi

Field	Details
Moderator	______________________________
Note-taker	______________________________
FGD Location (venue)	______________________________
Proximity to Park	☐ Near (Gashubi) ☐ Mid-range (Bungwe) ☐ Far (Cyahafi)
No. of Participants	Males: ___ Females: ___ Total: ___
Average Age Range	______________________________
Group Category	☐ Mixed ☐ Women-only group ☐ Men-only group

SECTION C: DISCUSSION THEMES AND QUESTIONS

Theme 1: Knowledge, Practices, and Composition (Obj1/RQ1)

1. **Do farmers in your community practice agroforestry (trees with crops)?**
   ☐ Yes ☐ No ☐ Not sure

2. **Which tree species are most commonly grown in your farms?** *(Tick all mentioned)*
   ☐ Grevillea
   ☐ Calliandra
   ☐ Alnus
   ☐ Markhamia
   ☐ Polyscias

☐ Vernonia

☐ Ficus

☐ Other(s): ____________________________

3. **How would you categorize the majority of trees grown on farms?**

   ☐ Mostly exotic ☐ Mostly indigenous ☐ Balanced mix ☐ Not sure

4. **Do you know which species are indigenous and which are exotic?**

   ☐ Yes ☐ No ☐ Partially

5. **(Optional open)**: *How do you define or identify a tree as indigenous or exotic?*

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

Theme 2: Preferences and Perceptions (Obj1/RQ2)

6. **Which type of trees do you personally prefer to plant?**

   ☐ Exotic ☐ Indigenous ☐ Both equally ☐ None

7. **What are your main reasons for this preference?** *(Tick up to 3)*

   ☐ Fast growth

   ☐ High timber/firewood value

   ☐ Soil fertility improvement

   ☐ Cultural or medicinal value

   ☐ Biodiversity or shade

   ☐ Easy to sell in market

   ☐ Easier access to seedlings

   ☐ Other: ____________________________

8. **A) In your experience, how do the following compare between exotic and indigenous trees?**

Function	**Exotic better**	**Indigenous better**	**Same**	**Don’t know**
Soil improvement	☐	☐	☐	☐
Water retention	☐	☐	☐	☐
Timber/firewood	☐	☐	☐	☐
Biodiversity/shade	☐	☐	☐	☐
Crop compatibility	☐	☐	☐	☐

B) Participatory Ranking Activity (GROUP EXERCISE)

“Let’s do a quick ranking activity together. We will compare exotic and indigenous tree species based on some important criteria. Please discuss and then tell us which type you think is better for each function.”

Function	**Exotic trees**	**Indigenous trees**	**About the same**	**Varies / Don’t Know**
Growth speed	☐	☐	☐	☐
Profitability (timber, fuel)	☐	☐	☐	☐
Soil fertility	☐	☐	☐	☐

improvement				
Shade / Biodiversity	☐	☐	☐	☐
Compatibility with crops	☐	☐	☐	☐
Cultural / Medicinal value	☐	☐	☐	☐

9. **Are there any trees you avoid planting?**

   ☐ Yes ☐ No

   If yes, *which ones and why?* ___________________________

Theme 3: Constraints to Indigenous Tree Use (Obj1/RQ3)

10. **What barriers prevent farmers in general from planting indigenous species?** *(Tick all mentioned)*

    ☐ Lack of seedlings

    ☐ Slow growth

    ☐ Poor awareness

    ☐ No market demand

    ☐ Livestock damage

    ☐ Negative beliefs

    ☐ Lack of extension advice

    ☐ Other: _____________________________

11. **Do you think exotic trees are more promoted than indigenous ones?**

    ☐ Yes ☐ No ☐ Same ☐ Don't know

12. **Have you or other farmers tried planting indigenous species in recent years?**

    ☐ Yes ☐ No

    If yes, *was it successful?* ☐ Yes ☐ No ☐ Mixed results

Theme 4: Institutional Influence and Support (Obj2/RQ4)

13. **Have you received tree planting support from government or projects?**

    ☐ Yes ☐ No

    If yes, *which type of trees were provided?*

    ☐ Mostly exotic ☐ Mostly indigenous ☐ Both

14. **Do extension officers promote indigenous trees in your area?**

    ☐ Yes ☐ No ☐ Not sure

    If yes, *what do they say about them?*

    (Open follow-up)

15. **Are there policies or programs in your community that encourage agroforestry?**

    ☐ Yes ☐ No ☐ Not aware

    If yes, *do they include indigenous trees?*

    ☐ Yes ☐ No ☐ Not sure

Theme 5: Recommendations and Opportunities (Obj3)

16. **What would most encourage farmers to plant more indigenous trees?** *(Tick all that apply)*

    ☐ Free seedlings

    ☐ Farmer field schools/demonstration plots

    ☐ Clear market access

    ☐ Cultural awareness programs

    ☐ Livestock control strategies

    ☐ Integration into government programs

    ☐ Other: ____________________________

17. **Do you believe a balance of exotic and indigenous trees is ideal for agroforestry?**

☐ Yes ☐ No ☐ Not sure

If yes, *why?* ____________________________

18. **What advice would you give to projects promoting indigenous tree species?**

(Open). --
----

19. **Do you believe indigenous trees should be promoted in this area? Why or why not?**

☐ Yes ☐ No ☐ Not sure

If yes or no, **why?---**

End. Thank you for your time and openness!!!

Annex 3: Non-Farmer Informant Interview Guide

NON-FARMER INFORMANT INTERVIEW GUIDE

Study title: *Understanding the Preference for Exotic over Indigenous Tree Species in Agroforestry Systems: A Study across a Gradient of Proximity to Gishwati-Mukura National Park in Ngororero District, Rwanda*

Respondents: Forestry/agriculture officers, cell leaders, NGO/project staff, and nursery managers

☐ Consent obtained

INTERVIEW DETAILS

- **Interview Code:** __________
- **Interviewer Name:** ____________________
- **Date:** ________________
- **Cell:** ☐ Gashubi ☐ Bungwe ☐ Cyahafi
- **Respondent Role (tick one):**

  ☐ Forestry Officer ☐ Agronomist

  ☐ Local Government Leader ☐ NGO Staff

  ☐ Tree Nursery Manager ☐ Other (specify): __________

SECTION A: GENERAL AGROFORESTRY KNOWLEDGE & TREE PREFERENCES

1. In your professional experience, how do you define agroforestry, especially in this region?

   ……………………………………………………………………………………

2. Which types of trees are most promoted or encouraged in agroforestry programs in this area?

   ☐ Exotic species ☐ Indigenous species ☐ Both equally

   If one is preferred, why? _______________________________

3. Which exotic tree species are most commonly found on farms here?

   ☐ Grevillea ☐ Eucalyptus ☐ Calliandra ☐ Others: ___________

4. Which indigenous species are sometimes used or promoted in agroforestry?

   ☐ Markhamia ☐ Ficus spp. ☐ Dombeya spp. ☐ Vernonia spp. ☐ Others: ___________

4.1. Are any of these actively promoted?

☐ Yes ☐ No If yes, which one(s)? ___________________________

4.2. Are any of these species **growing without being planted or managed** (i.e., occurring naturally)?

☐ Yes ☐ No If yes, which one(s)? ___________________________

4.3. In your opinion, what are the advantages and disadvantages of using indigenous species in agroforestry?

…………………………………………………………………………………

5. Are there programs (past or ongoing) promoting indigenous species in agroforestry in your area?

   ☐ Yes ☐ No If yes, specify the project and main interventions:

   …………………………………………………………………………………

SECTION B: FARMER PERCEPTIONS AND BELIEFS (OBJECTIVE 1)

6. Based on your interactions with farmers, how are indigenous trees generally perceived?

   ☐ Useful ☐ Not useful ☐ Culturally important ☐ Problematic (e.g., harmful to crops)

   Explain: ____

7. Do local beliefs, taboos, or traditional practices affect the planting of indigenous tree species?

   ☐ Yes ☐ No ☐ Not sure

If yes, please give an example or commonly cited belief:

………………………………………………………………………………………

8. Have you observed a change in farmer perceptions of indigenous trees over the past 5–10 years?

   ☐ More positive ☐ More negative ☐ No major change

   Explain briefly: ____

SECTION C: CONSTRAINTS TO INDIGENOUS TREE USE (OBJECTIVE 1 & HYPOTHESIS 2)

9. In your opinion, what are the top three challenges limiting farmers from planting indigenous tree species?

   ☐ Lack of seedlings

   ☐ Lack of knowledge or extension

   ☐ Belief that they are slow-growing

   ☐ Low market value

   ☐ Policy neglect

   ☐ Not included in programs/projects

   ☐ Cultural issues

   ☐ Other: ___________

   Explain briefly: ____

10. Are indigenous tree seedlings available in local nurseries or seed centers?

    ☐ Rarely available ☐ Available but in low numbers ☐ Available in sufficient quantity ☐ Not available at all

    Explain the main cause of this situation: _____________________

SECTION D: INSTITUTIONAL AND POLICY ENVIRONMENT (OBJECTIVE 2)

11. Which institutions are most influential in tree species promotion in this region?

    ☐ Government (e.g., RAB, District Agronomists)

☐ NGOs (e.g., ARCOS, LAFREC, FH)

☐ Private tree nurseries

☐ Farmer cooperatives

☐ Other: ____________

12. Do any local policies or regulations encourage the use of indigenous trees in agroforestry?

☐ Yes ☐ No ☐ Not sure

If yes, specify policy or program: ______________________

13. Have you or your institution received training on the value of indigenous species for agroforestry or conservation?

☐ Yes ☐ No

If yes, from where and what was emphasized?

……………………………………………………………………………………

14. Are there guidelines or incentives given to nurseries to produce indigenous species?

☐ Yes ☐ No ☐ Not known

If yes, please describe them briefly: ____________________

SECTION E: OBSERVED OUTCOMES AND RECOMMENDATIONS (OBJECTIVE 3)

15. In your observation, how do exotic and indigenous trees differ in performance within farms?

Aspect	**Exotic Trees ☐ Better**	**Indigenous Trees ☐ Better**
Growth rate	☐	☐
Crop compatibility	☐	☐
Soil fertility	☐	☐

Shade provision	☐	☐
Farmer interest	☐	☐

Add explanation or examples: ___________________________

16. What actions do you recommend to **encourage the integration of indigenous species into agroforestry** (assuming that increasing their use is desirable)?

    ☐ Establish local indigenous nurseries

    ☐ Train extension officers and farmers

    ☐ Integrate indigenous species into national subsidy programs

    ☐ Include them in demonstration plots

    ☐ Provide market/value-chain incentives

    ☐ Other (specify): _______________________

17. Is there anything else you'd like to share that could improve agroforestry policy or practice?

    ………………………………………………………………………………………

END OF QUESTIONNAIRE

Thank you for your time and valuable insights!

Annex 4: Ecological Inventory Sheet (Surveyed Plot Form)

ECOLOGICAL INVENTORY SHEET (Surveyed Plot Form)

Project title: Understanding the Preference for Exotic over Indigenous Tree Species in Agroforestry Systems: A Study across a Gradient of Proximity to Gishwati-Mukura National Park in Ngororero District, Rwanda.

☐ Consent obtained

SECTION A: IDENTIFICATION DETAILS

Field	**Information**
Plot Code	________________________
Date of Survey	________________________
Cell	☐ Gashubi ☐ Bungwe ☐ Cyahafi
GPS Coordinates	Latitude: ___________ Longitude: ___________
Elevation (m)	________________________
Slope (%)	☐ 0–5 ☐ 6–15 ☐ 16–30 ☐ >30
Farm Size (ha)	________________________
Overall Agroforestry System	☐ Scattered trees on cropland ☐ Boundary planting ☐ Woodlot ☐ Homegarden ☐ Other: ____________

Field	Information
Associated interview code	____________________

SECTION B: TREE INVENTORY

No	Local Name	Scientific Name (if known)	Indigenous or Exotic	DBH (cm)	Height (m)	Distribution Type	Associated Crop(s)	Soil erosion sign (Yes/No)	Negative Crop Effect (Yes/No)	If Yes, Tree Name	Effect Description	Management practices	Tree origin	Propagation method	Est. Survival rate (%)

No	**Local Name**	**Scientific Name (if known)**	**Indigenous or Exotic**	**DBH (cm)**	**Height (m)**	**Distribution Type**	**Associated Crop(s)**	**Soil erosion sign (Yes/No)**	**Negative Crop Effect (Yes/No)**	**If Yes, Tree Name**	**Effect Description**	**Management practices**	**Tree origin**	**Propagation method**	**Est. Survival rate (%)**

Notes:

- Measure DBH at 1.3 m height using a tape or caliper.
- Estimate height using clinometer or visual estimate.

- Record erosion signs, crop effects, and interactions per tree in columns.
- Tree spacing and overall density (trees/ha) will be computed later during analysis using GIS.
- Distribution type to choose: **Scattered, Boundary, Clustered, Block, and Homegarden**
- Tree management practices to look at are: **Pruning, Coppicing, Pollarding, Mulching, Protection from livestock, weeding around trees, and seedlings replacement**
- Tree origin to choose: **Government nursery, NGO/project, Private nursery, Natural regeneration, Own nursery and Friends/neighbors**
- Propagation method to choose: **Direct sowing, Seedling transplant and Wild transplant**
- Estimated survival rate is for recent planting

SECTION C: OBSERVED TREE BENEFITS AND ECOSYSTEM SERVICES

Ecosystem Function	**Observed**	**Description (if yes)**
Soil fertility improvement	☐ Yes ☐ No	____________________________
Shade provision	☐ Yes ☐ No	____________________________
Biodiversity habitat (birds, insects)	☐ Yes ☐ No	____________________________

Slope/erosion control	☐ Yes ☐ No	____________________________
Fuelwood source	☐ Yes ☐ No	____________________________
Timber or pole production	☐ Yes ☐ No	____________________________
Fruit/nut/food production	☐ Yes ☐ No	____________________________
Cultural/spiritual use	☐ Yes ☐ No	____________________________

SECTION D: ENUMERATOR NOTES

- Observations on plot health or degradation signs:
- Farmer comments shared during plot walk:
- Any photos taken? ☐ Yes ☐ No   If yes, file name(s): ____________