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EVALUATION OF THE LEVEL OF ADOPTION OF NATIVE TREE SPECIES IN LANDSCAPE RESTORATION IN 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

Declaration

I ABIMANA CYUZUYO Henriette hereby declare that this research is my original work and it has never been submitted before to any University or higher learning Institution for the award of a degree or any other qualification.

Student name and signature: ABIMANA CYUZUYO Henriette …….

Supervisor and signature: Prof. Elias BIZURU …….....

Co-supervisor and signature: Dr. Joseph NSENGIMANA …….....

Dedication

I wholeheartedly dedicate this work to my beloved husband, **RUKUNDO Christian**, my dear children **RUKUNDO NEZA Oren Prestone** and **RUKUNDO BEZA Mia Adje**, parents, and friends, whose unwavering support, motivation, encouragement, moral guidance, and financial assistance have been a cornerstone throughout my life.

I also extend this dedication to all those from whom I have gained academic and professional inspiration your contributions have shaped and enriched this journey.

Acknowledgment

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Generally, I am more grateful to all people, and our friends in all ages and institutions that contributed technically or financially to conduct this research project.

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List of acronyms and abbreviations

CBD	Convention on Biological Diversity
DSD	District Support Department
FAO	Food and Agriculture Organization of the United Nations
GoR	Government of Rwanda
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
NISR	National Institute of Statistics of Rwanda
REDD+	Reducing Emissions from Deforestation and Forest Degradation
REMA	Rwanda Environment Management Authority
UK	United Kingdom
UN	United Nations
UNEP	United Nations and Environmental Programme
UNEP-WMC	United Nations Environment Programme World Conservation Monitoring Centre
UNFPA	United Nations Population Fund

Abstract

Studies indicate that forest and land degradation is a serious problem worldwide, developing countries in particular, and to reverse large-scale degradation and deforestation goes beyond what can be achieved by site-level ecological restoration. This study assessed the level of adoption of native tree species for landscape restoration in Rwanda, focusing on Rulindo District. A purposive random sampling approach was employed to interview 95 farmers using face-to-face structured questionnaires. The results highlighted that 84.21% have already planted native species while 15.79% did not. Regarding the adoption level, this study found a significant variation in the adoption of native species being used in landscape restoration. *Markhamia lutea* was found to be the most adopted tree species in the Rulindo (30.8%) followed by *Ficus thoningii* (18.6%), *Erythrina abyssinica* (16.2%), *Mitrygnya rubrostipulata* (9.6%), *Polyscias fulva* (9%), *Afrocarpus falcatus* (8.1%), *Maesopsis eminii* (5.1%), *Tetradenia riparia* (1.2%), *Maesa lanceoalata* (0.6%) and *Sesbania sesban* and *Ficus ovata* (0.3%). For the exotic tree species, of the most adopted species was *Greveilla robusta* (38.9%) followed by *Alnus acuminata* (17.8%), *Persea americana* (16.5%), *Citrus x limon* (13.1%), *Psidium guajava* (7.5%), *Mangifera indica* (4.4 %). *Cedrela serrata* (0.9%), *Calliandra houstoniana var. calothyrsus* (0.6%) and *Citrus* × *aurantiifolia* (0.3%). All respondents acknowledged the importance of growing native trees, with 84% rating their preference as high. Furthermore, 94% recognized ongoing community conservation efforts to conserve native trees in their respective community, 4% are not sure and 2% responded that there are no efforts in place. The adoption was facilitated by community champion groups and cooperatives (39%), the government (18%), the role played from other initiatives (14%), the intervention of NGOs (12%), incentive mechanisms (8%,) among others. Moreover, it revealed that the successes are associated with diverse benefits such as fuelwood (19%), soil enhancement (17%), and timber production, shade (13%), medicine (12%), fencing 10%), food (7%), cultural use (4%) provided by native tree species. However, despite the level of the success, challenges still persist, including limited seed availability (30%), low germination rates (27.6%), poor soil and climate conditions (18.5%), low seedling survival (12.7%), and high seedling costs (9.1%). Thus, this study recommend to increase native species coverage in Rwandan by bridging the highlighted challenges. The findings provide a good source of information to refer to for the landscape restoration using native tree species in similar ecological areas to the District of Rulindo.

Keywords: adoption, landscape restoration, native tree, smallholder farmers

1. INTRODUCTION

1.1. Background information

Landscape restoration recognized as critical global initiative aimed at reversing back the degradation of ecosystems, enhancing biodiversity, and improving human well-being (Brink *et al.*, 2023; Chazdon & Uriarte, 2016; Mansourian *et al.*, 2017; Ockendon *et al.*, 2025; Stanturf & Mansourian, 2020; UNEP, 2024b; Yusof *et al.*, 2024). The initiative increase the resilience of biodiversity, and deliver important ecosystem services (Aronson *et al.*, 2020; Chazdon, 2017; Wortley *et al.*, 2013). Its significance continues to escalate as biodiversity declines and ecosystem services erode globally (Aronson *et al.*, 2020). It has attracted global attention with the recent declaration of the UN Decade on Ecosystem Restoration (UNEP, 2024a) and the Bonn Challenge/New York Declaration on Forests aiming to bring 350 million hectares of deforested and degraded land into restoration by 2030 (Verdone & Seidl, 2017). Likewise, the Convention on Biological Diversity (CBD) calls for the restoration of 15% of the degraded ecosystems and the associated ecosystem services, as stated in Aichi Target No. 14 and 15 (UNEP & CBD, 2011)

However, the translation of these ambitious goals for landscape restoration into reality is a major challenge (Höhl *et al.*, 2020). Given that studies indicate that greenhouse gas emissions have reached unprecedented levels over the last decade, with Africa being one of the most vulnerable continent to the impacts of climate change (IPCC, 2022; Sintayehu, 2018), government's ongoing economic growth highly threatened by climate change (Government of Rwanda, 2020; World Bank Group, 2022), and climate change projections indicate increased precipitation and rising temperatures, exacerbates environmental challenges (Haggag *et al.*, 2016; Kimutai *et al.*, 2024). Successful landscape restoration is viewed as tool for reversing back some issues (Cevallos *et al.*, 2020; Harris *et al.*, 2006).

Landscape restoration is currently viewed as a tool for climate adaptation, with emphasis on increasing ecosystem resilience to future climates (Cevallos *et al.*, 2020; Harris *et al.*, 2006). (Suding, 2011) stipulated that restoration ecology not only recognized for its ecological benefits but also for its contributions to sustainable development, human well-being strategies. However, studies in Denmark indicated that successful restoration efforts must consider the complexity and changing nature of ecosystems and site conditions (Stanturf *et al.*, 2018), to reverse large-scale

degradation and deforestation goes beyond what can be achieved by site-level ecological restoration (Chazdon, 2017), diverse and sometimes unstable sociopolitical systems and stakeholder needs (Mansourian *et al.*, 2005), continued deforestation and forest degradation, and limited technical capacities (Abdel-rahman, 2024; UNEP-WCMC, 2016).

In landscape restoration, researchers highlights that the focus should be on increasing the potential use of native species (Bieng *et al.*, 2021). The self-organizing processes that create naturally regenerating forests and natural regeneration in planted forests promote local genetic adaptation, foster native species with known traditional uses, create spatial and temporal heterogeneity, and sustain local biodiversity and biotic interactions (Chazdon & Guariguata, 2016b). Given that studies indicate that more research is required to improve our knowledge of native species and their dynamics in mixed uneven-aged forest systems, and how these dynamics affect their productivity (Bieng et al., 2021). This context remains unclear in Rwanda.

Literature suggests that the integration of ecological, social, and economic dimensions particularly in crucial regions, where the socio-economic dependency on forest resources complicates restoration efforts (Djenontin *et al.*, 2018). The Rwanda Forest Sector Strategic Plan (2017-2021) outline an increase in the number of scattered trees on cropland and agroforestry areas up to 50 trees/ha by developing and intensifying agroforestry techniques on all suitable lands (Bernard *et al*., 2019). In the same line, Rwanda aimed to double the agroforestry coverage from 6% to 12% up to 2024 (Bernard *et al*., 2019). The Global policy context is to have 100% of the farms implementing agroforestry by 2030 (FAO, 2020). However, studies showed Rwanda as country where the inventory and the assessment of trees outside forests have not been comprehensively carried out (Ndayambaje, 2013). To this end, despite the progress being made, the insights from the communities, assessing its effectiveness and level of native species integration remains unclear to date.

1.2. Problem statement

Rwanda is already densely populated and dependent on agriculture and its population is projected to reach 16.3 million by 2032 (UNFPA Rwanda, 2017) . It has the second-highest population density in Africa (Imasiku & Ntagwirumugara, 2020; Mukanyandwi *et al.*, 2018), and is ranked to be most densely populated country in East Africa (Karamage *et al*., 2016). Due to the fact of small land, this growth of population will have adverse effects on the environment, food security, and

well-being of the population. On other hand, environment and biodiversity have to be conserved in a sustainable manner.

Given that Landscape restoration recognized as critical global initiative aimed at reversing back the degradation of ecosystems, enhancing biodiversity, and improving human well-being (Aronson *et al.*, 2020; Brink *et al.*, 2023; Chazdon & Uriarte, 2016; Mansourian *et al.*, 2017; Stanturf & Mansourian, 2020; Wortley *et al.*, 2013; Yusof *et al.*, 2024). Studies indicate that forest and land degradation is a serious problem worldwide, developing countries in particular (Sabogal *et al.*, 2015), and to reverse large-scale degradation and deforestation goes beyond what can be achieved by site-level ecological restoration (Chazdon, 2017). Rwanda has taken environmental conservation at the forefront as seen in Government planning priorities (Government of Rwanda, 2023; REMA, 2006, 2023). Given the advancement, studies highlights that even though the government is making a huge effort every year in landscape restoration through tree planting campaigns, not all planted trees survive their first years (Mutagoma, 2022).

To date, the driving factors remains unclear, there are still limited research that have been conducted to determine the extent of native species being promoted in several sites of landscape restoration in Rwanda while fulfilling government plans and strategies. A recent study conducted by Ntabakirabose *et al*. (2024) in Kirehe showcased some threats for native species such as the firewood, animal grazing, medicine, building, others, and food, and the study calls for the native species integration in landscape restoration. Even though the mentioned threats not clear for some, there are other parameters needs to be thoroughly analyzed to really understand success and challenges of native species in landscape restoration. Thus, there is a need for more studies/ research on the exploration of challenges in the adoption of native tree species.

1.3. General objectives

The present study assesses the success and challenges of landscape restoration using native tree species in Rulindo District in Rwanda.

1.4. Specific objectives

1. Identify the existing trees being promoted in landscape restoration in Rulindo District

2. Assess the people's perception about growing the native trees

3. Determine the uses of native trees in the study area

4. To determine the factors affecting native tree species use in landscape restoration

1.5. Scope of the study

The study conducted in Rulindo District of Rwanda, through investigating the success and challenges of landscape restoration using native tree species. The sample size during the survey is determined in the section 3.2.

1.6. Significance of the study

The study provides the empirical factual evidence for the success and present challenges of using native species in landscape restoration to inform decision making

1.7. Research questions

The study was guided by the following questions:

i. What are native tree species being integrated in landscape restoration in Rulindo District?
ii. What are people's perception in growing native tree species?
iii. What are the current uses of native trees in the study area?
iv. What are driving factors affecting native tree species use in Rulindo District?

1.8. Hypotheses

1. Different native species have been integrated in landscape restoration and their adoption differs from one to another.
2. Native tree species with multiple benefits and tolerates a wide range of environmental conditions than others, will perform well in landscape restoration.
3. Lack of access to seeds, germination rate, costs, low survival rate are the major driving factors for using native species in landscape restoration in Rwanda.

2. LITERATURE REVIEW

2.1. Role of native species

Studies highlight importance of native species in landscape restoration (Geddes *et al.*, 2011; Shackleton, 2016), they are very important because of impacts on ecological properties and native biodiversity (Chazdon *et al.*, 2016; Shackleton, 2016). However, despite the high diversity of trees in the tropics, very few native species have been used in tropic ecosystems (Amazonas *et al*., 2018). Study in Panama showed native species to have more positive impacts on the environment than exotics (Wishnie *et al*., 2007). Other showed exotic species to provide limited goods and services to local landholders (Lamb *et al*., 2005; Wishnie *et al*., 2007). In Panama, people showed to be interested in planting more native trees than exotic species in restoration activities (Garen *et al*., 2009).

Studies in Pakistan showed that the local community still relies on indigenous plants as important medicines for solving local health problems (Saqib *et al*., 2014). This is in the same line with the (Gahamanyi *et al*., 2021) showed the value of native species as well. A recent study on native trees species resources use in the USA, showed native to be more conservative in water use than exotic ones (Cavaleri *et al*., 2014). A recent study conducted in Kirehe Distrct supports that native tree species often require less water (Ntabakirabose *et al.*, 2024). Equally important, Narango *et al.* (2017, 2018) stipulated clear positive benefit of native plants to wildlife than non-native ones. In the same vein, native species support more biodiversity than non-native ones (H. E. Hoyle, 2021). In paradoxical side, a recent study in the UK showed that knowledge and practices of indigenous and local people are quickly disappearing (Balvanera *et al*., 2020). Again, Elias & Fabien (2024) study conducted in Gasabo District showed that indigenous trees were used in ecosystem restoration despite the lack of seedling and cuttings.

2.2. Challenges in landscape restoration

Forest and land degradation is a serious problem worldwide, particularly in developing countries (Sabogal *et al.*, 2015). Studies indicates that approximately one billion people live in degraded areas, and one third of the world's population is considered to be affected by land degradation (Sabogal *et al.*, 2015). Restoration agencies are hindered by policy incoherence, as well as the challenges of navigating competing interests at the landscape scale (Sayer *et al.*, 2021). Riggs et

al. (2018) study in Indonesia stipulated that broad social and economic challenges continue to hinder implementation of the scheme, including the extreme poverty of the people, harsh environmental conditions and lack of clarity over tenure.

Chazdon *et al*. (2019) study highlighted three cross-cutting challenges in landscape restoration like (i) poor alignment across levels and sectors of government; (ii) Environmental and social heterogeneity; and iii) Lack of enabling conditions and implementation capacity. In complementarity, studies indicate that these challenges considered as obstacles to implementing REDD+ initiatives *(Angelsen et al., 2018; Gritten et al.*, 2019; Kane *et al*., 2018). Restoration initiatives can be hampered by sectorial management silos (e.g., forestry, agriculture, water, conservation), unaligned policies, and power and information imbalances between and within levels of government (Buckingham *et al.*, 2020; Sapkota *et al.*, 2021; Schweizer *et al.*, 2021; von Kleist *et al.*, 2021).

A recent studies indicates instances where diversity impedes restoration initiatives good progress and leading to conflicts (Chazdon *et al.*, 2019). Equally important, studies indicates that the most successful community forest projects tend to be those involving homogeneous populations, which share strong customary institutions and can negotiate more easily on rules and norms, goal setting, and benefit distribution (Baynes *et al.*, 2017; Chang & Andersson, 2021). Yet, the disparity remains in Rwanda context due to limited researches.

2.3. People perception of growing native species

Studies suggests that people had more positive perceptions about the appearance of the restoration initiatives and to prefer to live in restored area (Dou *et al.*, 2019; Gobster *et al.*, 2022; Nowak *et al.*, 2014; Ntabakirabose *et al.*, 2024; Stange *et al.*, 2022). H. Hoyle *et al.* (2017) study conducted in UK identified four key factors driving acceptance and rejection of non-native planting such as: aesthetics; locational context; historic factors and inevitability; and perceptions of invasiveness and incompatibility with native wildlife. A recent studies highlights that monitoring and assessing how local public perceptions evolve as an important part of tailoring restoration activities to meet societal expectations as ecological restoration assumes its more prominent role in land management policy (Stange *et al.*, 2022).

3. MATERIAL AND METHODS

This chapter provides details about the research site description, data collection procedures, data processing, analysis and reporting. The research site section covers the geographical area in which the study will be carried out, and the section on data collection describes instruments used in data collection. Lastly, this chapter also contains methods used in data analysis and reporting.

3.1. Study area description

The study conducted in Rulindo District of Rwanda (Figure 1). Rulindo district spreads over 567 km^2 and it lies roughly halfway between Kigali City and Musanze town. Rulindo is mostly characterized by hills with their altitude rising to 2,438 m, it has a Tropical climate, characterized by a succession of rainy seasons and droughts with average annual temperature is 19 degrees celicius and vegetation is largely composed of food crops with woodland eucalyptus, Grevillea and Cyprus (Rulindo DSD, 2018).

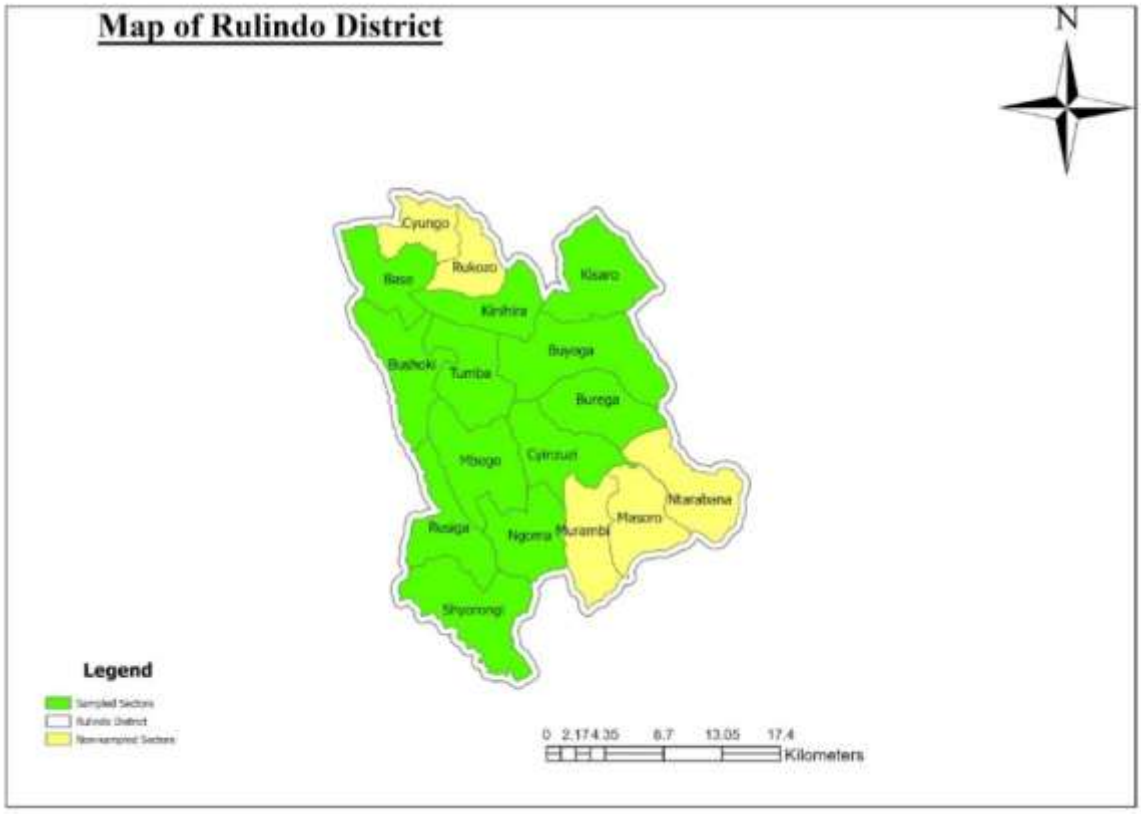

Figure 1: Study area in Rulindo District. *Source*: Primary data

3.2. Targeted population

This study targeted 248,431 populations in 12 Sectors in Rulindo District (Table 1).

Table 1: Targeted population during investigating challenges of landscape restoration using native tree species in Rulindo District in Rwanda.

#	District	Sector Name	Fifth Rwanda Population and Housing Census, 2022		Total
			Male	Female	
1	Rulindo	Base	9,574	10,954	20,528
2	Rulindo	Burega	6,571	7,322	13,893
3	Rulindo	Bushoki	11,102	12,468	23,570
4	Rulindo	Buyoga	11,743	12,978	24,721
5	Rulindo	Cyinzuzi	7,543	8,225	15,768
6	Rulindo	Kinihira	8,082	9,063	17,145
7	Rulindo	Kisaro	11,054	12,059	23,113
8	Rulindo	Mbogo	9,070	10,031	19,101
9	Rulindo	Ngoma	6,061	6,642	12,703
10	Rulindo	Rusiga	6,416	7,036	13,452
11	Rulindo	Shyorongi	21,182	22,562	43,744
12	Rulindo	Tumba	9,710	10,983	20,693
Grand Total			**118,108**	**130,323**	**248,431**

Source: Fifth Rwanda Population and Housing Census, 2022 (NISR)

3.3. Sample size

The required sample from population was selected among household members in Rulindo District. The sample size (n) was obtained using Alain Bouchard-formula (Uwimpuhwe, 2018)applied when the population of origin is less than 1 million.

$$\text{Nc} = \frac{Nn}{\text{N+n}} = \frac{248{,}431 \times 95}{248{,}431 + 95} = 95$$

N= Size of the population, n: level of confidence at 95%, Nc= sample size.

3.4. Data collection procedures

Firstly, this starts with the highlights for the tools that were used in the data collection. Questionnaire survey instrument developed in both English and Kinyarwanda to gather information from the respondents, Kobo Toolbox, note books, pencils and pens was used to record the obtained data.

Through data collection, the survey was conducted using Kobo Toolbox**,** a digital data collection tool that allows offline survey administration with an android mobile device. The Kobo Toolbox recognized as smarter data collection tool being easier to access, less expensive and more efficient

in data collection (Lakshminarasimhappa, 2021). Initially, a structured questionnaire was designed (appendix 1), and deployed using Kobo Toolbox**,** ensuring a structured and standardized data entry.

The survey primarily employed open-ended questions to capture a precise range of attributes reflecting participants' attitudes. This approach is valuable for understanding the reasons behind people's beliefs and for collecting detailed information about their perceptions. Open-ended questions promote richness and more in-depth in answering (Kriger, 1990; Özgüner *et al.*, 2012) Purposive random sampling technique was used for the 95 farmers sample size. Interviews and structured questionnaires was used to gain data as per the respondent's skills and intentions. The questionnaire survey was designed in both English and Kinyarwanda language to facilitate the respondents to answer the questions. Through this initiative, we reached on informants' place (household-to-household) to respond to the questions and people were interviewed face-to-face. Visiting household-to-household will allow us to make direct observations in the farmers' and the surrounding fields.

Field observations was made in the informants' field and record the native species present. Responses were directly recorded in the Kobo Toolbox form, reducing the risk of data entry errors and ensuring real-time data synchronization. Informed consent were obtained from all participants, ensuring that they understood the purpose of the research. All data collected was treated with high confidentiality.

3.5. Data processing, analysis and reporting

Following the data collection and entry with in the Kobo Toolbox, informant's responses were downloaded from Kobo Toolbox in an Excel format. During data cleaning, the dataset was checked for completeness and consistency, addressing issues such as missing values, duplicate entries, and inconsistent responses.

The cleaned dataset was analysed using Microsoft Excel Software**,** by applying several techniques. Pivot tables were used to summarize and aggregate data across different informant dimensions. Finally, data visualization using bar charts results was used for clear illustrations of the success and challenges of landscape restoration using native tree species in Rwanda.

4. RESULTS

4.1. Existing tree species in Rulindo District

4.1.1. Native tree species in Rulindo landscape

Of the 95 informants, 84.21% have personally planted native tree species before while 15.79% did not personally planted native tree species (Figure 2 b). Adoption of *Markhamia lutea* found to be highest (30.8%) followed by *Ficus thoningii* (18.6%), *Erythrina abyssinica* (16.2%), *Mitrygnya rubrostipulata* (9.6%), *Polycias fulva* (9%), *Afrocarpus falcatus* (8.1%), *Maesopsis eminii* (5.1%), *Tetradenia riparia* (1.2%), *Maesa lanceoalata* (0.6%) and the lowest were *Sesbania sesban* and *Ficus ovata* (0.3% each) (Figure 2 a).

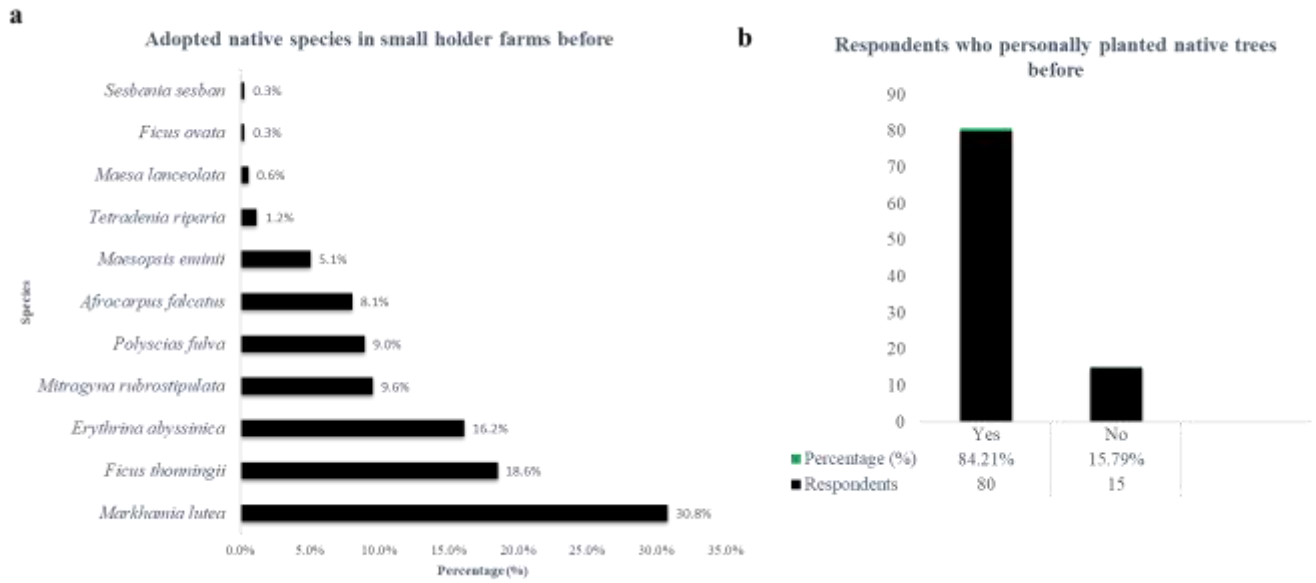

Figure 2: Adopted native trees species by small holder in Rulindo (fig. a), respondents who personally planted native trees in Rulindo (fig.b),

4.1.2. Exotic tree species adoption in Rulindo landscape

90 % have personally planted exotic tree species before while 10 % did not personally exotic tree species (Figure 3 a). Adoption of *Greveilla robusta* shown to be the highest (38.9%) followed by *Alnus acuminata* (17.8%), *Persea americana* (16.5%), *Citrus x limon* (13.1%), *Psidium guajava* (7.5%), *Mangifera indica* (4.4 %), *Cedrela serrata* (0.9%) and the lowest were *Calliandra houstoniana var. calothyrsus* (0.6%) followed by *Citrus* × *aurantiifolia* (0.3%) (Figure 3 b).

Figure 3: Respondents who personally planted exotic trees species before (fig.a), and adopted exotic tree species in farms in Rulindo (fig. c).

4.2. People's perception on growing the native tree species across Rulindo landscape

100% of the respondents think growing native tree species has a lot of benefits and are willing to plant them. 84.21% of the respondents have already planted native tree species in their farms against 15.79% with no single native tree species planted in the farm (Figure 4. a). Of the reasons behind the interest of growing native tree species, 80% of the interviewees are motivated by their goods and services, 15% by NGOs, 3% by cultural and 2 % by Government (Figure 4. b).

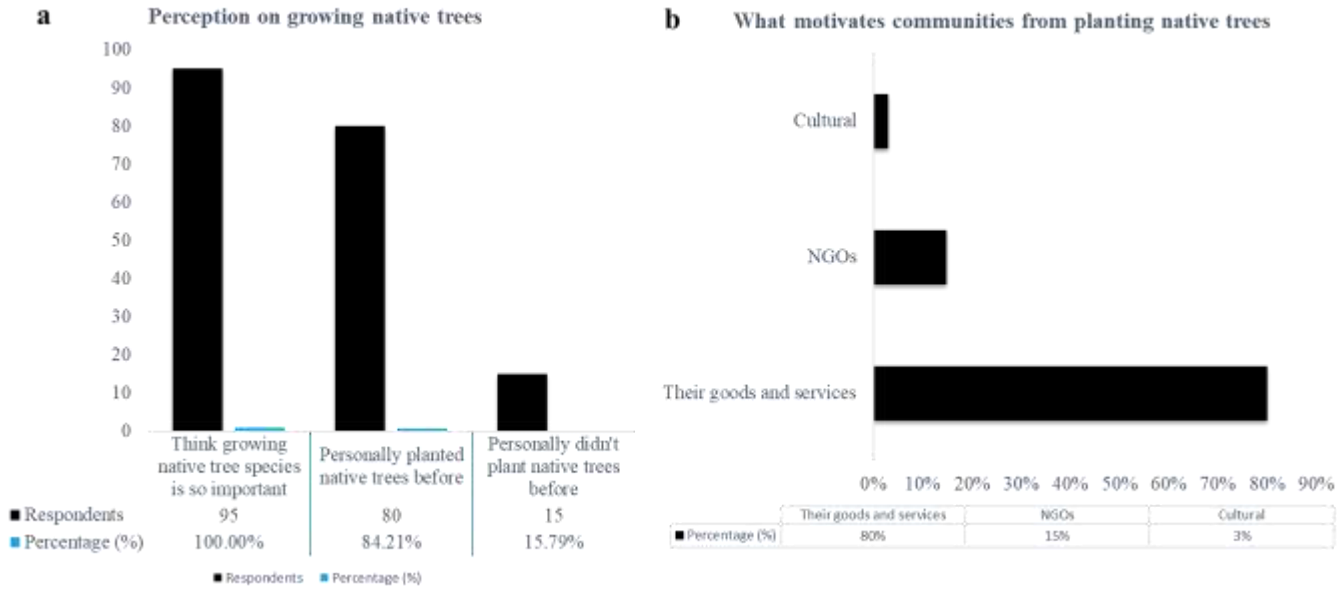

Figure 4: Perception of local communities on growing of native plant species a) Status of native tree growth as per the responses of interviewees b) The reasons behind the interest of growing native tree species.

Moreover, 84% of the respondents estimate that growing native tree species is important while 14% estimate it very important and 2% not really important (Figure 5). When farmers harvest the planted trees, 100% of them responded that they automatically replace them.

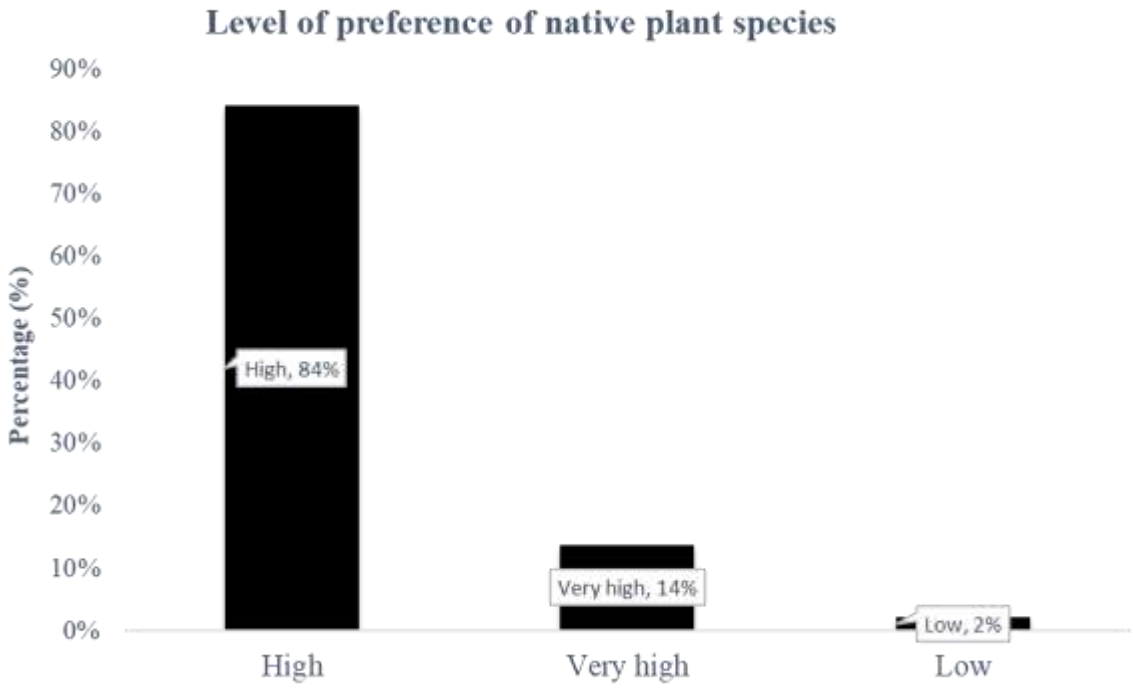

Figure 5: Level of preference of native species

With regard to native tree species conservation in the communities, 94% responded that there are efforts in place to do it in their respective community, 4% are not sure and 2% responded that there are no efforts in place (Figure 6.a). Those efforts include to the planting and protection of the species by the communities themselves. 39% of the respondents highlighted the intervention of community champion groups and cooperatives, 18% by Government, 14% the role played from other initiates, 12% explained the intervention of NGOs, 8% incentive mechanisms for the farmers, 4% traditional ecological knowledge, 3% native tree species value chain development and 1% education and awareness campaign (Figure 6.b).

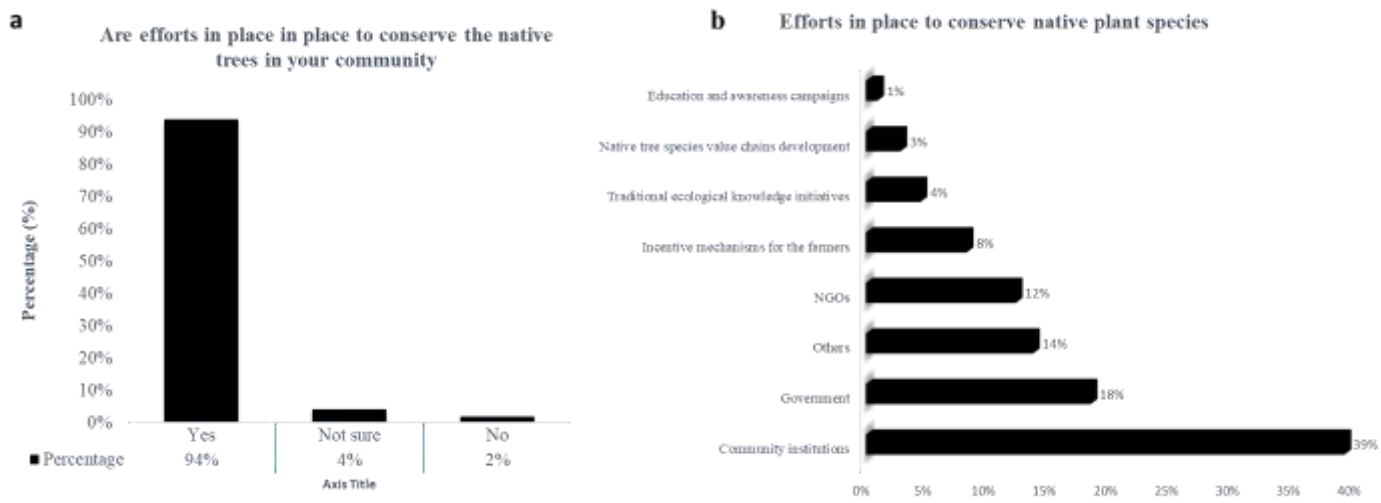

Figure 6: Efforts in place for conservation of native plant species in landscape restoration

4.3. Uses of adopted native tree species across Rulindo landscape

Of the 95 respondents, 19% rely on native trees as source for firewood, 17 % for soil improvement and timber,13% for shade, 12% for medicine, 10% for fencing, 7% for food, 4% for cultural use and the least for shade and others (Figure 7). Table 2 shows multiple uses for each native species with *Markamia lutea* ranks on the first place followed by *Ficus thoningii*, *Erythrina abyssinica*, *Mitragyna rubrostipulata*, *Polycias fulva*, *Afrocarpus falcatus*.

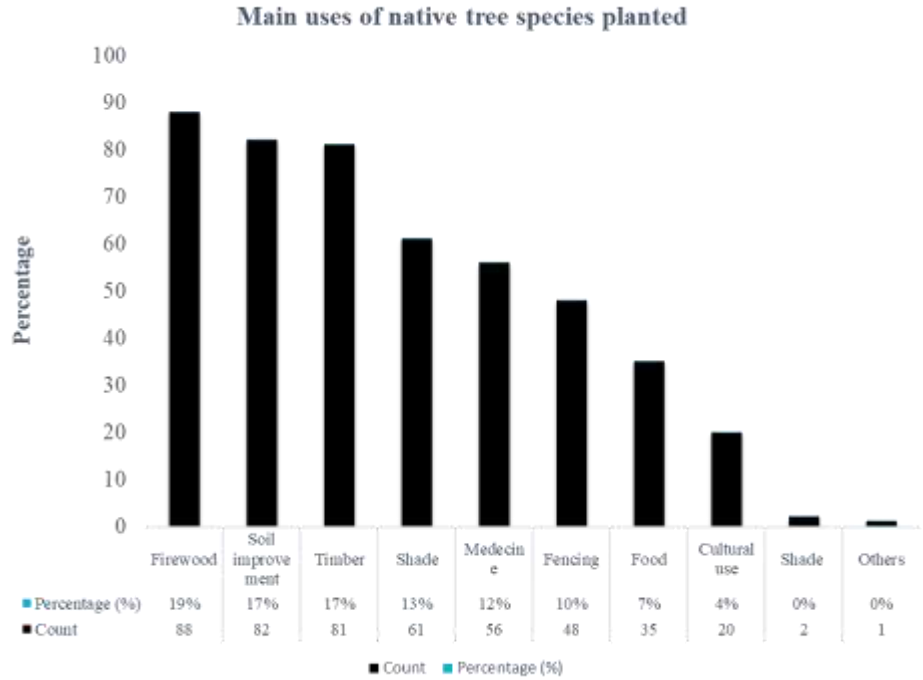

Figure 7: Possible use of native species

Table 2: Multiple uses for each native tree species adopted in the Rulindo landscape

	Use								
Species	**Timber**	**Firewood**	**Food**	**Medecine**	**Shade**	**Cultural use**	**Soil improvement**	**Fencing**	**Others**
Afrocarpus falcatus	x	x	x	x	x	x	x	x	
Erythrina abyssinica	x	x	x	x	x	x	x	x	
Ficus ovata	x	x	x	x	x	x	x	x	
Ficus thonningii	x	x	x	x	x	x	x	x	
Maesa lanceolata	x	x	x	x	x	x	x	x	
Maesopsis eminii	x	x	x	x	x		x	x	
Markhamia lutea	x	x	x	x	x	x	x	x	
Mitragyna rubrostipulata	x	x	x	x	x	x	x	x	
Polyscias fulva	x	x	x	x	x		x	x	

Average years of harvesting native tree species and the price in Rwandan Francs (RWF) of timber planck at the local market is shown on Figure 8. The adopted species showed a significant variation of average years for harvesting native tree species for timber planck and the price of the timber planck at the local market. *Ficus ovata* showed to have many average years (18) and high average price for native tree species timber planck (5,000 RWF), *Erythrina abyssinica*, *Ficus thoningii*, and *Markhamia lutea* showed 8 average years for harvesting timber planck each with 3,118 RWF, 3,370 RWF, and 2,340 RWF average price for timber planck at the local market, respectively. *Mitragyna rubrostipulata*, *Maesopsis eminii*, and *Polycias* fulva showed 7 average years for timber planck harvesting followed with 2,000 RWF average price for the timber planck at the market for each (Figure 8).

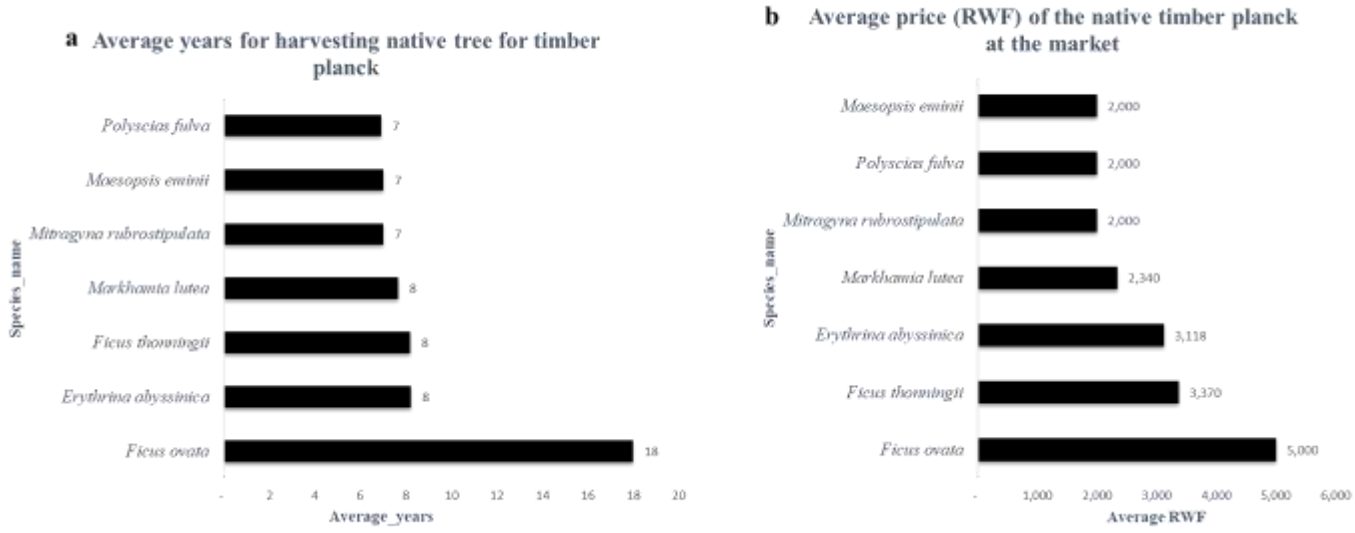

Figure 8: Average years before harvesting native tree species for timber (fig.a) and average price of a one timber planck at the local market in the Rulindo (fig.b).

On other side, average years of harvesting exotic tree species and the price of timber planck at the local market is shown on Figure 9. *Alnus acuminata* showed high average years of tree harvesting for timber planck and price of the timber planck at the local market (8 years and 3,095 RWF), *Psidium guajava, Cedrella serrata, Persea americana, Mangifera indica, Citrus limon* showed equal average years for tree harvesting exotic tree and average price for timber at the market (7 years and 2,000 RWF for each). *Greveilla robusta* showed 6 average years of tree harvesting tree for timber Planck and 2,594 RWF price of the timber Planck at the local market.

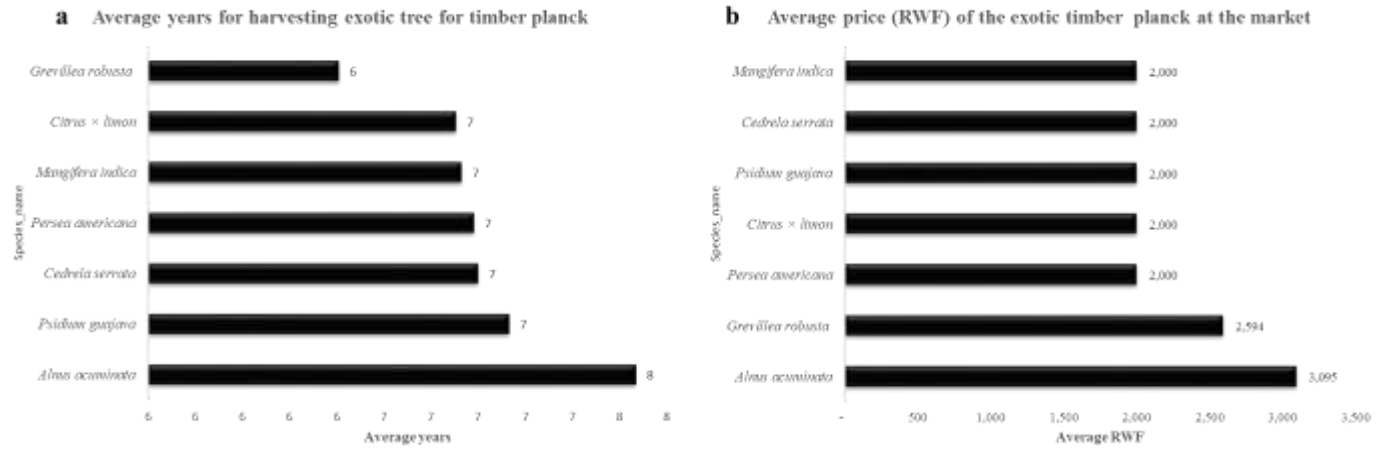

Figure 9: Average years for harvesting exotic trees for timber planck (fig.a) and average price of the timber Planck at the local market in the Rulindo (fig.b).

Adopted native plant species have many medicinal uses associated with their organ use in treatment of several ailments, and results provides mode of preparation for each species in the treatment of the ailments (Table 3).

Table 3: Type of ailments treated by native tree species, organ use and how to use it (mode of preparation) from the respondents.

1. Erythrina abyssinica		
Ailment for treatment	**Organ use**	**How to you use it (mode of preparation)**
Skin disease	Leaves, Roots and Fruits	Mixed with water And draying

Wound, tooth disease and cough	Leaves and Roots	Boiled water and drying
2. Ficus thonningii		
Cough and problem of internal organ	Leaves	Drinking water
Cough and worms	Leaves	Drinking water
Skin disease	Leaves	Mixed with water And draying
Wound, tooth disease and cough	Leaves and Roots	Boiled water and drying
3. Markhamia lutea		
Cough and worms	Leaves	Drinking water
Stomach ache	Leaves	boiled in water drying
Wound, tooth disease and cough	Leaves	Boiled water and drying
Skin disease	Leaves	Mixed with water
4. Mitragyna rubrostipulata		
Stomach ache	Leaves	boiled in water draying
Wound, tooth disease and cough	Leaves	Boiled water and drying
Wound	Roots	Drying
Skin disease	Roots, leaves and fruit	Mixed with water
5. Afrocarpus falcatus		
Wound, tooth disease and cough	Leaves	Boiled water and drying
Skin disease	Roots, leaves and fruit	Mixed with water
6. Polyscias fulva		
Wound, tooth disease and cough	Leaves	Boiled with water and drying
Skin disease	Leaves	Mixed with water
Wound	Roots	Drying
7. Tetradenia riparia		
Cough and problem of internal organ	Leaves	Molting the leaves and Drinkwater from them
Cough and worms	Leaves	Molting the leaves and Drinkwater from them

Adopted native tree species found to be beneficial for soil improvement. The species and associated crop (s) with is shown below (Table 4).

Table 4: Native tree species and associated crops in the Rulindo landscape

	Associated crops							
Species name	**Beans**	**Maize**	**Cassava**	**Potatoes**	**Sorghum**	**Cabbage**	**Banana**	**Soya bean**
Erythrina abyssinica	x	x	X	x	x	x		
Ficus ovata	x	x	x	x				
Ficus thonningii	x							
Ficus thonningii	x	x	x	x	x	x	x	x
Maesa lanceolata	x	x	x	x				
Maesopsis eminii	x	x			x	x		
Markhamia lutea	x	x	x	x	x	x		x
Mitragyna rubrostipulata	x	x	x	x	x	x		
Afrocarpus falcatus	x	x			x	x		
Polyscias fulva	x	x			x	x		

4.4. Factors affecting native tree species growth in landscape restoration.

Of the 95 respondents, 30% reported lack of seeds as the main challenge for native tree species use in landscape restoration followed by low germination rate (27.6%), poor soil/climate (18,5%), low survival rate (12.7%), High cost of seedlings showed 9.1%, the lowest was lack of knowledge (1.8%) followed by other (0.3%) (Figure 10).

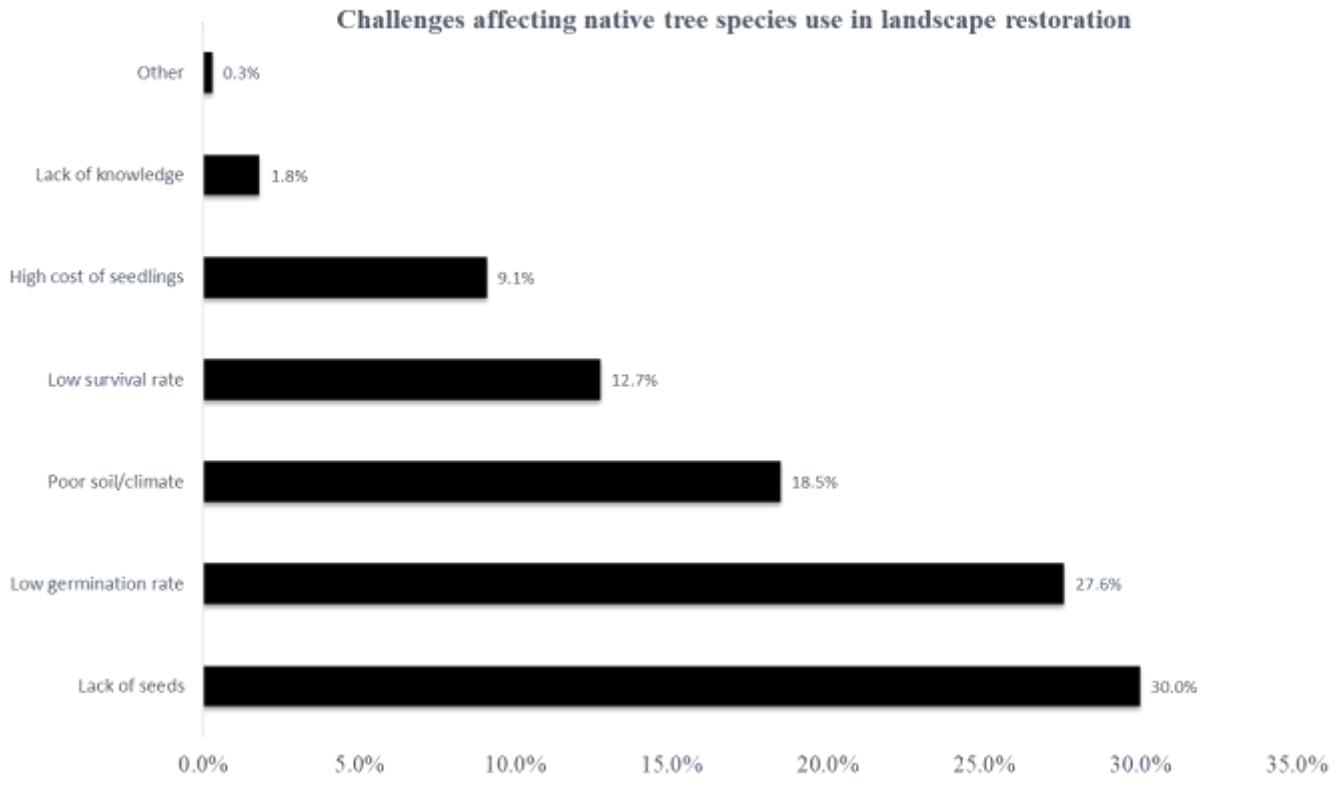

Figure 10: Factors affecting native tree species use in landscape restoration

5. DISCUSSION

In this section we illustrate the reasons behind of our findings showed in the result section, the comments and suggestions while relating to existing empirical studies and other literatures.

5.1. Existing trees being promoted in landscape restoration in Rulindo District

Of the 95 informants, 84.21% have personally planted native tree species before while 15.79% did not personally planted native tree species (Figure 2 b). Adoption of the native species particularly *Markhamia lutea* is closely associated with multiple ecological and socioeconomic benefits, including soil fertility enhancement, provision of timber and traditional medicinal resources (Figure 7). This matches with what was found by Elias & Fabien (2024) and Ibrahim *et al.* (2016)studies. Some studies suggest rapid growth for *Markhamia lutea* as a pioneer species makes it valuable for land rehabilitation and sustainable agricultural intensification (Ibrahim *et al.*, 2016). Moreover, adoption of native tree species in the Rulindo District should be associated with their multiple benefits as well (Elias & Fabien, 2024; Irakiza *et al.*, 2016). The Leakey *et al.* (2022) study indicates that, the native tree species in Rwanda encompass a variety of taxonomic groups, including hardwoods; softwoods, fruit-bearing, medicinal, and ornamental tree species, each adapted to specific environmental conditions.

The integration of exotic species, particularly high preference of *Grevillea robusta* is associated with its fast growth and production of timber, firewood as well as sticks for climbing beans (Bucagu *et al.*, 2013; Cyamweshi *et al.*, 2023). It is also associated with their improvement of crop production (Ndayambaje & Mohren, 2011; Niyomfura *et al.*, 2022). Moreover, Den Biggelaar & Gold (1996). Study highlighted that tree species with multiple utilities and high locational adaptation were highly appreciated by Rwandese farmers. Thus, the aforementioned species highly adopted by farmers coincides with this finding.

5.2. People's perception of growing the native trees

100% of the respondents think growing native tree species has a lot of benefits and are willing to plant them. In this line, regarding preference, 84% prefer them at high, 14% at very high and 2% at low level. This coincides with the studies highlighted that agroforestry has been part of agricultural practices for hundreds of years in Rwanda, and people managed to adopt native species in their farms (Iiyama *et al.*, 2018).

The present study revealed that 80% of the interviewees are motivated by their goods and services. This match with other studies highlights importance of native species in landscape restoration (Cavaleri *et al.*, 2014; Chazdon, 2017; Chazdon & Guariguata, 2016a; Geddes *et al.*, 2011; Narango *et al.*, 2017, 2018; Ntabakirabose *et al.*, 2024; Shackleton, 2016), the findings for these supported by NGOs match with Corson (2010) study highlighted the role of environmental NGOs in working tirelessly to champion conservation and promote sustainable practices..

With regard to native tree species conservation in the communities, 94% responded that there are efforts in place to do it in their respective community, 4% are not sure and 2% responded that there are no efforts in place (Figure 6.a). Those efforts include to the planting and protection of the species by the communities themselves. The efforts in place to conservation of native plant species in landscape restoration shown on figure 6 match with other studies. For instance, studies highlighted that capacity building through training and field demonstrations as an important initiative to increase the adoption rate of agroforestry species (Iiyama *et al.*, 2018; Kiyani *et al.*, 2017). The study supports the crucial role for Government effort in conservation of native tree species. This is in line with the government initiatives, taking environmental restoration at the forefront. For instance, the Rwanda Forest Sector Strategic Plan (2017-2021) outline an increase in the number of scattered trees on cropland and agroforestry areas up to 50 trees/ha by developing and intensifying agroforestry techniques (Bernard *et al*., 2019). Also, Rwanda aimed to double the agroforestry coverage from 6% to 12% up to 2024 (Bernard *et al*., 2019) and the Global policy context is to have 100% of the farms implementing agroforestry by 2030 (FAO, 2020).

Further, other studies highlighted crucial role of incentives for the success of restoration activities (Polyakov *et al.*, 2024; Tedesco *et al.*, 2023). The finding for 4% who reported that traditional ecological knowledge as an effort in place to conserve native plant species demonstrates that local people are knowledgeable about the plant species to use for habitat restoration in a diverse habitat. This finding is in line with Haq *et al.* (2023); Irakiza *et al.* (2016), and Tuyizere *et al*. (2025) studies. Despite the efforts in place, the present survey highlights that when they harvest trees they automatically replace them. However, the seed source for healthy seedlings they plant need to be well understood. Thus, this underscores the need to capacitate the local communities for producing the seedlings of their preference.

5.3. Possible uses of adopted tree species in landscape restoration across the Rulindo landscape

Of the 95 respondents, 19% relay on native trees as source of firewood, 17 % for soil improvement and timber, and the least for shade and others (Figure 7). Table 2 shows multiple uses for each native species with *Markamia lutea* ranks on the first place followed by *Ficus thoningii*, *Erythrina abyssinica, Mitragyna rubrostipulata, Polycias fulva, Afrocarpus falcatus*. The possible use of the native species particularly is medicinal, timber, firewood, charcoal, cultural, soil improvement, shade, fencing, and others (Figure 6). The multiple benefits of *Markhamia lutea* such as ecological and socioeconomic benefits, including soil fertility enhancement, provision of timber and traditional medicinal resources (Figure 7) matches with (Elias & Fabien, 2024; Ibrahim *et al.*, 2016) studies.

The multiple benefits of *Ficus thoningii* reported by informants are supported by (Bala *et al.*, 2021; Balehegn & Hintsa, 2015; Cottee-jones *et al.*, 2016; Dangarembizi et al., 2014; Iiyama et al., 2018; Irakiza *et al.*, 2016). For instance, Bala *et al*. (2021) and Dangarembizi *et al*. (2014) studies highlights that *Ficus thonningii* widely used to treat conditions such as diarrhea, respiratory infections, wounds, and urinary tract infections, due to its rich content of bioactive compounds such as alkaloids, flavonoids, and tannins. Other highlights its antimicrobial, antioxidant, anti-inflammatory, and anti-ulcer properties (Balehegn & Hintsa, 2015). Least but not the last, studies indicates that *Ficus spp*. plays an important and sometimes critical role in the ecology of many tropical frugivorous (Bleher *et al.*, 2003; Felton *et al.*, 2008, 2013; Kinnaird & O'Brien, 2005; Shanahan *et al.*, 2001).

Erythrina abyssinica showed to have more medicinal uses through treating ailments such as wound, tooth disease, and cough and so forth. This matches with Gahamanyi *et al*. (2021) study highlighted that the bark and leaves of *Erythrina abyssinica* have been traditionally used in folk medicine to manage a large number of ailments, such as sleeping sickness, coughs, rheumatic fever, abdominal pain, and diarrhea diseases. Medicinal values of *Mitragyna rubrostipulata* shows complementarity with (Ramathal & Ngassapa, 2001; Wishnie *et al*., 2007) study which highlighted that were used to treat several ailment such as diarrhea, dysentery, cholera, or gastroenteritis. Informants reported value of *Polycias fulva* for soil improvement. This coincides with the studies highlights great contribution of *Polycias fulva* to soil fertility through its high rate for leaf loss as crucial in the natural environment because it provide good mulch, make the soil under the tree

quite fertile, this, together with open crown make it a potentially excellent agroforestry species (Kinyamario *et al*., 2008). The values for *Afrocarpus falcatus* such as anti-inflammatory, antioxidant, antibacterial, and anti-cancer activities, linked to bioactive compounds that can treat asthma, fevers, and venereal diseases (Abdillahi *et al.*, 2011) match with local knowledge from our findings.

The present study showed a significant variation for average years for harvesting native tree species for timber planck and the price of the timber at the local market. *Ficus ovata* showed to have many average years (18) and high average price for timber Planck at the local market (5,000 RWF), *Erythrina abyssinica, Ficus thoningii,* and *Markhamia lutea* showed 8 average years for harvesting timber planck for each with 3,118, 3,370, and 2,340 RWF average price for timber planck at the local market, respectively. *Mitragyna rubrostipulata, Maesopsis eminii*, and *Polycias* fulva showed 7 average years for timber planck harvesting with 2,000 RWF average price for the timber planck at the market for each (Figure 8).

The present study contributes to the limited knowledge for the price of timber planck at the local market in Rwanda. GIZ (2019) reported that about 95% of the supply of sawn wood in Rwanda consists of four species, namely *Eucalyptus*, *Pinus*, *Grevillea* and *Cypresss*. Imports from neighboring countries are more concerned with hardwood such as Libuyu (*Entandrophragma excelsum*) and Muvula (*Milicia excelsa*) (GIZ, 2019). This study highlights the need for conducting a thoroughly research for many tree species in different regions of Rwanda. In this line, studies indicates that barriers to the development and implementation of sustainable timber value chains in Rwanda still remain namely insufficient capital and difficulty to access formal credit, low quality of sawn wood and outdated technology, and poor timber drying (GIZ, 2019).

5.4. Challenges affecting native tree species use in landscape restoration.

Of the 95 respondents, 30% reported lack of seeds as the main challenge for native tree species use in landscape restoration followed by low germination rate (27.6%), poor soil/climate (18,5%), low survival rate (12.7%), high cost of seedlings showed 9.1%, the lowest was lack of knowledge (1.8%) followed by other (0.3%) (Figure 10). A challenge of lack seeds match with studies supports a significant barrier for insufficient access to high-quality seeds for native species (Lu *et al.*, 2017). In this line, literatures supports that seed markets often fail to meet project needs regarding species diversity, provenance, and quality, forcing practitioners to rely on limited seeds

that may not guarantee adaptive capacity under changing climates (Busbridge, 2020; Lu *et al.*, 2017). A challenge of low germination rate match with studies highlights that many native species exhibit low seed viability and germination rates, which hampers both direct seeding and nursery propagation efforts (Busbridge, 2020).

A challenge of high costs of native species match with studies highlights that the raising native tree seedlings is costlier than for commonly planted exotics due to longer production cycles, specialized propagation needs, and high mortality rates (Haq *et al.*, 2023; Hau & Corlett, 2003). A challenge of low survival rate of native species match with studies highlighted low early survival and establishment rates for native seedlings which are frequently observed (Gebirehiwot, 2023). Given the challenges, the present study highlights the need to reverse back them for the successful ecosystem restoration. This is in line with the most recent studies highlights key recommendations including community participation, quality seed provision, research, market accessibility, and cross-sectoral collaboration, as essential to forest landscape restoration success (Tuyizere *et al.*, 2025).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This research surveyed 95 respondents to evaluate the level of the adoption of native tree species in landscape restoration in Rulindo District of Rwanda. The study revealed a strong preference and positive attitude toward the adoption of native tree species in landscape restoration, demonstrating their recognized benefits and the community's willingness to plant and conserve them. While native species like *Markamia lutea* is mostly adopted among other native species while *Greveilla robusta* was mostly adopted species than other exotic species, this present study highlights the collaborative efforts of community champions groups and groups, Government, NGOs, incentives in promoting conservation. Despite these encouraging findings, challenges such as limited seed availability, low germination and survival rates, and environmental constraints continue to hinder wider integration of native tree species. Addressing these obstacles is essential to enhance the sustainability and success of landscape restoration initiatives in the region.

6.2. Recommendations

Based on our findings and observations the following recommendations are suggested:

In landscape restoration, we recommend to use different native plant species for favoring biodiversity conservation and community wellbeing. We recommend to increase native species coverage in Rwandan landscapes starting from having good inputs, many potential nurseries sites and preferably look at adopters' preferences.

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8. APPENDICES

Appendix 1: Questionnaire survey in data collection

RESEARCH TOPIC: CHALLENGES OF LANDSCAPE RESTORATION USING NATIVE TREE SPECIES IN RWANDA: RULINDO DISTRICTS AS A CASE STUDY.					
#/Part	Questionnaire survey for native tree assessment and landscape restoration in Rulindo District of Rwanda				
I	General information				
1	Name of respondent (Optional):				
2	Age:				
3	Gender:	Male	Female	Other	
		' '	' '	' '	
4	Education level	None	Primary	Secondary	Tertiary
		' '	' '	' '	' '
5	Administrative location	District	Sector	Cell	Village
		.....	.....	.....	.....
II	Native tree species and conservation status				
7	What native tree species are commonly found in the area?	.....			
8	Are there any efforts in place to conserve native trees in the community?	Yes	No	Not sure	
		' '	' '	' '	
		If yes, please describe:			
III	Perception toward growing native tree species				
9	Do you think growing native trees is important?	Yes	No	Not sure	
		' '	' '	' '	
10	Have you personally planted native trees before?	Yes	No		
		' '	' '		
		If yes, specify their names?			
11	Have you personally planted exotic trees before?	Yes	No		
		' '	' '		
		If yes, specify their names?			
12	What motivates you from planting native trees?	.....			
IV	Use of native and exotic tree species in landscape restoration				
13	What are the main uses of native tree species you have adopted? (tick all that apply). For all native species mentioned on question 10 above.	Firewood	Timber	Food	Medicine
		' '	' '	' '	' '
		Shade	Cultural uses	Soil improvement	Fencing
		' '	' '	' '	' '
		Other			
		' '			
		Specify:			
	a. If for timber, how many years before you harvest the tree?	.....			
	b. If for timber, what is the price at the market of the timber?	.....			
	c. If medicinal, which organ do you use? To treat which ailment? How do you use it (mode of preparation)?	Organ use	.....		
		Ailment for treatment	.....		
		Details on how it is used	.....		
	d. If used for soil improvement, what are the crops associated with the tree? How is the production since the trees have been planted?	Crops associated	.....		
		Rank on how the production since the trees have been planted			
		Very high (4)	High (3)	Moderate (2)	Low (1)
		' '	' '	' '	' '
	e. What do you do to grow and conserve species no1	.....			
	f. When you completely use the tree, what do you do to replace it?	.....			
	g. What is the level of preference of species no 1?	Very high (4)	High (3)	Moderate (2)	Low
		' '	' '	' '	' '
14		Firewood	Timber	Food	Medicine
		' '	' '	' '	' '
		Shade	Cultural uses	Soil improvement	Fencing
		' '	' '	' '	' '
		Other			
		' '			
		Specify:			
	a. If for timber, how many years before you harvest the tree?	.....			
	b. If for timber, what is the price at the market of the timber?	.....			
	c. If medicinal, which organ do you use? To treat which ailment? How do you use it (mode of preparation)?	Organ use	.....		
		Ailment for treatment	.....		
		Details on how it is used	.....		
	d. If used for soil improvement, what are the crops associated with the tree? How is the production since the trees have been planted?	Crops associated	.....		
		Rank on how the production since the trees have been planted			
		Very high (4)	High (3)	Moderate (2)	Low (1)
		' '	' '	' '	' '
	e. What do you do to grow and conserve species no1	.....			
	f. When you completely use the tree, what do you do to replace it?	.....			
	g. What is the level of preference of species no 1?	Very high (4)	High (3)	Moderate (2)	Low
		' '	' '	' '	' '
V	Challenges affecting native tree species use				
15	Are seeds or seedlings of native trees easily accessible/obtained?	Yes	No	Sometimes	
		' '	' '	' '	
16	What challenges do you face in planting or production of native trees? (tick all that apply)	Lack of seeds	Low germination rate	High cost of seedlings	Low survival rate
		' '	' '	' '	' '
		Lack of knowledge	Poor soil/climate	Other	
		' '	' '	' '	
		Specify:			
17	Have you received any training or support on native tree planting?	Yes	No		
		' '	' '		
		If yes, by whom?			
18	What can be done to improve the use of native trees in landscape restoration?	.....			

Source: Primary data