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RESOURCES MANAGEMENT**

**EXPLORING NATIVE TREE SEED GERMINATION AND SEEDLING  
PRODUCTION TO ADDRESS AGROFORESTRY NEEDS IN BUGESERA  
DISTRICT, EASTERN PROVINCE, RWANDA**



Thesis submitted in partial fulfillment of the requirements for the degree of  
Masters in Biodiversity Conservation and Natural Resources Management

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**Kigali, July 2024**

## **DECLARATION**

I declare that this thesis is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institution.

Signed by: .....

Mukaneza Drocelle

## **APPROVAL**

I certify that this research project entitled “**EXPLORING NATIVE TREE SEED GERMINATION AND SEEDLING PRODUCTION TO ADDRESS AGROFORESTRY NEEDS IN BUGESERA DISTRICT, EASTERN PROVINCE, RWANDA**” was done under my supervision and has been submitted for examination with my approval.

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***“It is time to embrace the potential of agroforestry as climate solution”***

Adding native trees to agricultural lands improves biodiversity and farmer livelihoods, and can help address the climate crisis at a global scale

***By Nature conservancy***



Source: Photo of *Blighia unijugata* taken in Ntarama Sector, Bugesera District, Eastern province in Rwanda by Drocelle Mukaneza ( January,2024)

## ABSTRACT

Native tree species (NTS) offer a wide range of ecosystem services that are very crucial to human life and society development. In the past decades, deforestation rates have been high in Rwanda and many native tree species have gradually disappeared due to overharvesting and forest degradation. Bugesera District in eastern Rwanda for example, has been subjected to massive native tree species cutting to satisfy local people's basic needs. Hence, there is a high need to be integrated in agroforestry system and afforestation initiatives. This study aimed to explore the current situation of NTS in community farmland, analyze native tree seed germination, and identify how to produce good quality seedlings for domestication. By conducting household survey to understand local perceptions on NTS and by identifying the most preferred NTS through FGD using a pairwise comparison technique, collected data about four NTS that were selected by farmers as the most preferred were tested namely *Markhamia lutea*, *Garcinia buchananii*, *Acacia sieberiana*, and *Kigelia africana*. Four seeds species were tested in vitro experiment with various pre-germination treatments. In addition, two species were grown in controlled condition in a nursery to assess their growth performance. A statistical analysis about germination rate and key growth parameters were performed such as Germination Percentage (GP), Mean germination Time (MGT), height, collar diameter and number of leaves. Results of this study revealed that farmers are willing to grow NTS; however, there is a problem of good quality seed availability and insufficient knowledge and skills on propagation management. According to the experiment results, there were statistically significant differences in germination rate among pre-germination treatments tested. Comparing the germination of tested NTS, the highest germination percentage (66%) over seven days for seeds soaked in cold water was recorded for *M. lutea* and *G. buchananii* (81.3%) but took long time to germinate (30days). The lowest was observed in *K. africana* (3.3%) under control treatment. Moreover, the growth performance of *M. lutea* was much better than *G. buchananii*. *M. lutea* recorded the highest average mean height of 20.2cm with (SD=5.15) and average mean diameter of 6.65mm with (SD=2.25) after six months. In contrast, *G. Buchananii* had a slow growth; average mean height was 9.2cm with (SD=1.88) and average mean diameter of 1.2mm with (SD=0.17). *M. lutea* performed well in terms of growth performance and germination success. Additionally, *G. buchananii* could be recommended to farmers because it was likely preferred for its edible fruits, even though it takes a relatively longer time to grow in the nursery. According to local farmers 'testimonies, there is visible removal of some NTS in the landscape; there is a need to increase the presence of NTS in restoration projects by adopting scientifically proven germination treatments in conducive growth conditions. To address this challenge, during this study, NTS seedling were availed and planted in Bugesera landscape. Thus, it is recommended that the possible propagation of NTS requires supportive programs and policies that focus on the integration of NTS in forest programs and the creation of private nurseries to provide a sufficient supply of NTS seedlings.

**Keywords:** Germination, growth performance, native tree species, seeds treatment.

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## LIST OF ABBREVIATIONS AND ACRONYMS

ARCOS	: Albertine Rift Conservation Society
BGCI	:Botanic Gardens Conservation International
CR	:Critically Endangered
EN	:Endangered
ETS	:Exotic Tree Species
FAO	:Food and Agriculture Organization
FGD	:Focus Group Discussion
FMNR	:Farmers Managed Natural Regeneration
GDP	:Gross Domestic Product
GOR	:Government of Rwanda
IUCN	:International Union Conservation of Nature
IWC	:International Women Convocation
KOIMIZANYA	:Koperative Imizamukire Nyagihunika
MINIFOM	:Ministry of Forest and Mines
MGT	:Mean Germination Time
MINILAF	:Ministry of Land and Forest
NTS	:Native Tree Species
US	:United State
RAF	:Rwanda Forestry Authority
REDD <sup>+</sup>	:Reducing Emissions from Deforestation and forest Degradation
REMA	:Rwanda Environment Management Authority
SIDA	:Swedish International Development Cooperation Agency
Spp	:More than one specie
TAS	:Treatment with Acid sulfuric
TCW	:Treatment with Cold Water
THW	:Treatment with Hot Water
VU	:Vulnerable

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## **DEDICATION**

To my husband who has inspired me to love trees;

To my children: Blessing and Bright.

# CHAPTER 1. INTRODUCTION

## 1.1 Background

For thousands of years, Native Tree Species (NTS) have been part of the local land use system. The products made from these indigenous trees, such as food, medicine, cooking fuel, animal fodder, and building materials were essential for people's subsistence worldwide. For that, scientists and environmental organizations have argued for the protection of NTS for various reasons such as biodiversity conservation, prevention of extinction of valuable native tree species, the increase of crop yield in rural communities, the limit of land degradation, desertification, and adaptation to climate change (RFA, 2022). These trees also have protective functions at local, landscape, and global levels. More clearly, they prevent soil erosion, storing underground water, maintain soil fertility, and contribute to microclimate moderation. The ecosystem services they provide at the global level in terms of carbon sequestration and biodiversity conservation are also significant (Wawira & Thenya, 2017).

In the last decades, native tree species that are extremely crucial to human life and nature conservation have been given low priority in forest development while Exotic Trees Species (ETS) are accorded all of the attention. Exotic trees with fast growth rates are preferred around the world; there is a commonly held belief that exotic trees are better than indigenous trees and that they grow faster, even though measurements have rarely been made (Rinaudo, 2014). Much is known about the selection, breeding, and management of ETS but there has been less research in the field of NTS (Byabashaija et al., 2004).

In Africa, there were many well adapted native trees in agroforestry system (eg: *Faidherbia albida*, *Acacia albida*, *Acacia abyssinica*, *Millettia ferruginea*, and *Cordia africana*) (Negash, 2021b). Nevertheless, currently, many of these tree species have disappeared from the landscape due to population growth and expansion of agriculture and mining activities. With this lost scenario, in deforested areas, most of the time, ETS are commonly planted rather than NTS. Given this situation, scientific knowledge on native tree propagation, domestication, and cultivation is critical to Africa's environmental restoration, socioeconomic development, and indeed to its survival (Negash, 2021b).

In Rwanda, where the deforestation area was estimated at about 105.713 ha (RFA, 2022); many NTS are slowly being lost due to the deforestation and overharvesting.

In this case, Rwanda has prioritized the conservation of natural forests to preserve those NTS and maximize the biodiversity and ecosystem services provided to the population. According to RFA, in 2020, the forestry sector contributed to 6% of the GDP's country and supported the agriculture sector, which accounted for 26% of the GDP.

At this time, existing forest plantations are dominated by Eucalyptus; however, a few native tree species are represented by very few scattered individuals, found in the agricultural landscape as a part of the traditional practice of agroforestry. Common NTs, that have agroforestry potential and retained on farms include *Ficus thonningii*, *Ephorbia tirucalli*, *Erythrina abyssinica*, *Vernonia amygdalina*, *Draceana afromontana*, *Tetradenia riparia*, *Acacia sieberiana*, and *Markhamia lutea* (Nduwamungu, 2011).

In addition, the situation explained above is observed in different corners of the country specifically Eastern party of the country and in study area in Bugesera District ( Ntarama and Musenyi Sectors), which is affected by very high population density (450 population/km<sup>2</sup>) (NISR, 2023), and high level of poverty which puts intense pressure on land and natural resources. Indeed, the massive deforestation and climate change scenarios observed in this region, has also contributed to lower and irregular rainfall patterns, drought, famine, and soil erosion (Rinaudo, 2014). In this regard, native trees are also more affected by this scenario of massive deforestation and start to be less common in the agricultural landscape. Hence, there is an urgent need to explore the trend and status of those NTS, investigate their seed germination, and propose the suitable seed treatment to produce good seedlings for easy domestication of NTS and for reforestation of degraded land to mitigate climate change effects.

## **1.2 Problem statement and justification**

Tree planting is essential to the development of resilient landscapes at multiple scales. In this case, NTS play a crucial role in landscape restoration for tackling climate change, biodiversity loss, and desertification.

They also provide timber, shelter, food, medicine, climate regulation, spiritual and cultural fulfillment as well as esthetic enjoyment (Thompson et al., 2009). In many areas, ETS have been adopted at the expense of NTS and yet, NTS have been also reported to be more resilient to climate change (Bozzano et al., 2014). ETS tend to reduce native biodiversity and alter ecosystem functioning in undesirable ways (Cardinale et al., 2012). In that line, most exotic trees are considered unsuitable for agroforestry, as they are too competitive or damage the soil (Syampungana et al., 2010). In addition, ETS provide limited goods and services to communities and increase the risks associated with pests and pathogens outbreaks. Furthermore, they may even result in direct negative impacts on human well-being such as depletion of soil nutrients and water reserves (Gaertner et al., 2011).

In Africa, NTS have traditionally provided building materials, crafts, food, medicine, firewood, timber, etc. Apart from adaptability to local climatic and edaphic conditions, many NTS are known to offer a wide range of uses and services as most of them are multipurpose (Byabashaija et al., 2004). Currently, they are slowly disappearing due to deforestation and overharvesting for medicine, wood, charcoal, road construction, and community farm expansion (Rinaudo, 2014).

In Rwanda, the same scenario is also observed where the problem of deforestation remains persistent due to the cutting down of trees, the expansion of cultivation land, the construction of new infrastructure, searching for firewood, cattle grazing, etc. This situation leads to the loss of NTS habitats, their fragmentation, and the extinction of some NTS. In addition to that, NTS on agricultural land have been overexploited without replanting (RFA, 2022).

Currently, few initiatives are using NTS in afforestation and reforestation. However, a limited number of native tree species is represented by very few dispersed individuals, found in the agricultural landscape as part of the traditional practices of agroforestry (RFA, 2022). The same research reported that one of the constraints for the farmers to adopt NTS consists of the availability of seedlings. In addition to that, farmers do not have a wide knowledge of seed germination and related treatments.

Despite many researchers who have conducted numerous studies about ETS, a handful of research have been conducted on native tree species and there are limited studies on suitable seed propagation of those NTS and their growth performance in the nursery level for producing good quality seedlings.

The present study focuses on exploring NTS seed germination and good quality seedling production, as these species are more valuable for the entire community and agroforestry system in terms of climate change mitigation and local people's livelihood. Therefore, there is a need to document appropriate way of native tree species domestication as well as to determine their performance in local nurseries in order to prevent their risk of extinction leading to the degradation and loss of biodiversity in agricultural ecosystem.

## **1.3 Objectives**

### **1.3.1 General objective**

The main objective of this study is to explore native tree seed germination and seedling production in order to address agroforestry needs by availing seedlings in community nurseries and enhancing the use of NTS in the agricultural landscape.

Furthermore, while exploring the germination and growth performance of the seedlings produced in nurseries, they were supposed to be transplanted in community farmland in order to boost the number of NTS that were grown in community farmland, as well as for reducing the risk of extinction of those tree species.

### **1.3.2 Specific objectives**

1. To investigate local perceptions about native tree species in Bugesera District communities;
2. To identify suitable seed treatment for NTS;
3. To conduct seed germination tests of NTS;
4. To assess and compare NTS growth performance in community nurseries.

### **1.3.3 Research questions**

1. What are local perceptions about NTS?
2. What are the possible seed pre-treatments that can be used to accelerate the NTS germination process?
3. Is there any difference between treated and untreated NTS seed germination in a controlled environment?
4. How is NTS growth at the nursery level?

### **1.3.4 Research hypotheses**

During this research, the following hypotheses were tested and verified:

- ✓ Local communities testify that NTS are gradually disappearing in agriculture landscape;
- ✓ Treatments of soaking native tree seeds in cold water increase NTS germination process;
- ✓ Effect of seed treatment on native trees is not significantly different from the germination of untreated seed;
- ✓ Seedling growth of NTS in community nurseries is not significantly different among tested species.

## **1.4 Limitations and scope of this study**

While conducting this study, I assessed the NTS germination and methods to produce the good quality for only preferred species chosen by local communities specifically in Eastern part of the country specifically in Ntarama and Musenyi Sectors in Bugesera District. However, based on differences in tree phenology, time and financial limitations, this study did not consider all NTS found in study area. Indeed, five most preferred NTS have been selected; but during the research experiments, only the first two NTs chosen in each sector were assessed. However,

due to seeds unavailability of some species like *Ficus thonningii*, *Ficus ovata* and other possible NTS, some species are replaced by other selected in the top ten list. For example, while testing the germination, *Ficus thonningii* or *ovata* was replaced by *Acacia sieberiana*.

In addition to that, all pre-treated seeds in this research were germinated under controlled conditions in order to be able to extrapolate the results to nurseries for the production of high quality seedlings. However, it is possible that some species could respond differently under field conditions to those experimented in the laboratory. Various responses should be expected so far.

## **CHAPTER 2. LITERATURE REVIEW**

In this chapter, some highlights underline overview of research done by other scientists in order to identify relevant theories, methods and gaps in similar studies. It also contains some information on the status and some statistics carried out in different research done on a global scale.

### **2.1. Status of native tree species**

NTS all over the world are declining considerably due to the conversion of arable lands coupled with unwise and excessive utilization triggered by increasing population growth (Hundera, 2010). Under below, on this Figure 1 and 2, the scenario states how currently exotic tree species are dominating over indigenous ones and as an example how some US native tree species are being threatened according to the IUCN Red List category.

According to Figure 1, in Africa, Europe, South America and Oceania the introduced species are dominating native tree species whereas on the other side specifically in Asia, North and Central America native trees species are dominating. Even if there is a high domination of introduced species, in previous decade, the world has at least 1.11 billion ha of primary forest composed mainly by NTS that are not disturbed. However, it has decreased by 81 million ha since 1990, but the rate of loss has been more observed in 2010- 2020 compared with to the past (FAO 2020).

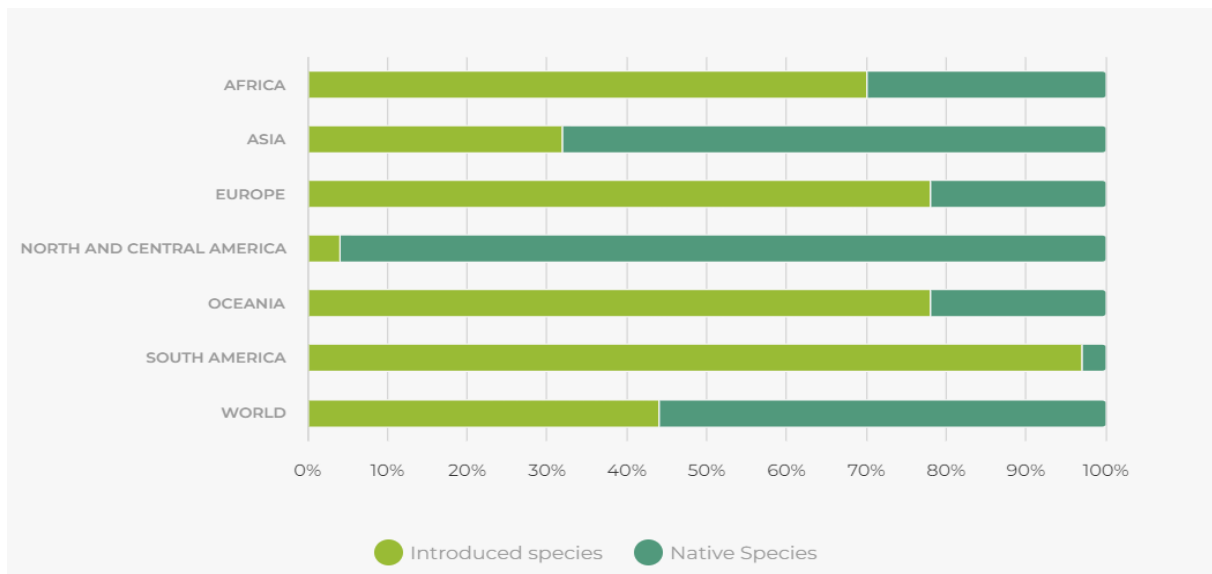


Figure 1: Proportion of introduced and native tree species in plantation forest by region (FAO, 2020)

Figure 2 shows that, according to the IUCN Red List, 94 NTs (11%) are assessed as threatened (those which are in category of critically endangered (CR), endangered (EN) and vulnerable (VU) in the United States. In addition, fifteen percent (132 species) of United State NTS are considered to be of conservation concern where they are assessed as either extinct in the wild, critically endangered, endangered, vulnerable or near threatened (Carrero et al., 2022). More clearly, even if in many countries, the data and statistics about NTs are not easily known and are classified into data defiance species. This scenario found in United State is almost the same in many countries on worldwide.

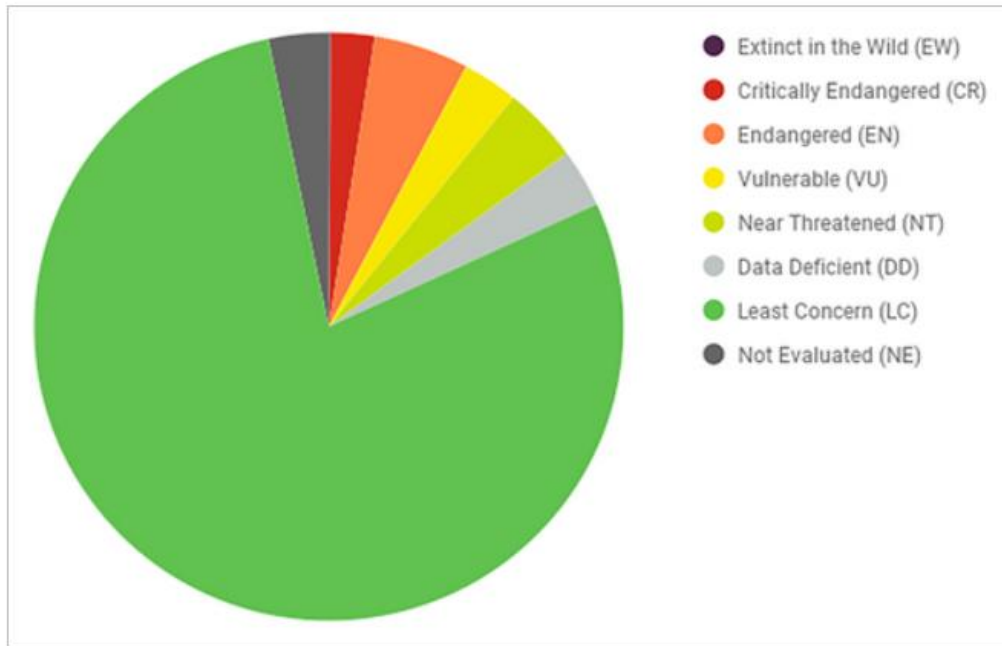


Figure 2: Proportion of native US tree species for conservation of nature (IUCN) red list category (Carrero et al., 2022)

Deeply, the most pressing issue about NTS is deforestation, which was mainly caused by excessive cutting down for fuel, the need for expansion of agricultural lands and cattle grazing, and new infrastructure construction. Different parts of the world experience tree threats at different levels even if the main threats are common and change over time at the global scale. Under below on the following figure, the main threats that affect trees have been identified and assessed by the IUCN Red List (BGCI, 2021):



Figure 3: Main tree threats and percentage of trees affected (BGCI, 2021)

According to Figure 3, more trees are threatened due to land conversion for agriculture. Moreover, land use change is also observed in the case of urban and industrial development (such as road construction, and human settlement) as well as mining activities. Afterward, overexploitation especially for timber trade takes the second place among tree threats. In addition to logging, trees species are used for medicinal and horticultural purpose. On the other hands, trees are also affected by numerous pests and diseases; and most of the time, climate change is the key driver for the survival and the spread of many pests and diseases. Consequently, all those cited threats, have also caused a significant decline in the richness of some NTS from the area (Mascaro et al., 2012), with a high risk of becoming extinct in case there are no possible strategies for replanting them. More clearly, the habitat in which native trees were planted; is currently depleted and changed due to the current climate change scenarios as shown above. Climate change is highly affecting NTS due to the frequency and intensity of extreme weather events such as prolonged droughts or heavy precipitation, which result in flooding (Lima et al., 2022).

Through the global tree assessment, intensive research has been undertaken over the past five years to compile extinction risk information on the 58.497 tree species worldwide; currently, 30 % of them are threatened with extinction including NTS, and at least 142 tree species are recorded as extinct in the wild (BGCI, 2021). Another assessment conducted in the contiguous 48 United States on the conservation status of 881 native tree species reveals that at least one among nine native species is now threatened with extinction.

Indeed, among those NTS, 11% to 16% of them were considered as threatened with extinction due to pest diseases and invasive species. One of the most alarming findings given was that 17 of those threatened tree species are not currently protected in any botanical garden, arboretum, or seed bank (Carrero et al., 2022).

Additionally, based on a review of the conservation status of all European tree species and according to IUCN's regional red list guideline; among 454 native tree species assessed in Europe, 168 (37%) of them are considered threatened in Europe( Rivers et al., 2019).

A similar situation is also observed in Africa. With a vast and diverse geographical landscape, which is predominantly covered by forests mainly composed of various NTS; currently, most of them (NTS) are today under serious threats (Negash, 2021a). As, it was demonstrated above for different continents, NTS play a key role as source of food, medicine, fiber, fodder for cattle, and medicine everywhere in Africa. They are also essential for maintaining biodiversity, replenishing natural resources as well as supporting ecosystem function. As result, these NTs are overexploited during their use and have declining at alarming rates due to illegal logging and agriculture expansion. One very important reason for why Africa's agriculture has remained unsustainable is highly related to the extensive removal of native trees and shrubs from the landscapes (Negash, 2021a).

According to different countries, specifically in Ethiopia, one of the main challenges in Ethiopia is the destruction of its forests. Only, ten decades ago, approximately 40% of Ethiopia was covered by forests that were composed of various indigenous tree species such as *Podocarpus falcatus*, *Acacias spp.*, the African pencil cedar, and wild olive as well as many other tree species. But currently, the cover of real forests is less than 3%, and a substantial proportion of this consists of ETS, including the different types of Eucalyptus species (Negash, 1995).

In Nigeria, according to the quantitative assessment of NTS conducted in Gerei Forest Reserve, the result has revealed that almost 53.3% of the tree species in the reserve are endangered. Indeed, it was also observed that most indigenous trees are rare in the area and this could be the result of the following effects such as bush burning, animal grazing, agriculture expansion, and saw millers (Saka & Olaniyi, 2013).

In Uganda, a research study was carried out among smallholder farmers in the Mt Elgon region of Uganda. It was found that NTS were cultivated in low numbers and dominated by ETS (Graham et al., 2022). The farmers also reported planting 63% of ETS. Furthermore, more clearly, the situation is presented in the following table where NTS accounted for only 33% of all planted tree species, and in contrast, ETS are planted massively compared to NTS (Table 1).

Table 1: Tree species most frequently planted on smallholder farms in Kapchorwa and Bulambali Districts of the Mt Elgon sub region of Eastern Uganda (ETS are marked with an asterisk(Graham et al., 2022)

<b>SPECIES</b>	<b>CASES</b>	<b>% OF TOTAL</b>
Eucalyptus spp.*	101	24.0
Cordia africana	59	14.0
Persea americana	51	12.0
Grevillea robusta*	44	10.0
Ficus spp.	44	10.0
Mangifera indica*	20	4.7
Unknown	19	4.5
Malkhamia lutea	16	3.8
A.heterophyllus*	16	3.8
Cupressus lusitanica	9	2.1
Ricinus communis*	7	1.6
Maesopsis eminii	7	1.6
Citrus sinensis*	5	1.2
Pinus spp*	5	1.2

In Rwanda, forests cover a total area of 330.576 ha which 215.739 ha are natural and 114.837 ha are forest plantations. In addition, small wood plots and agroforestry trees represent approximately 222.520 ha. Thus, the total area of national forest cover is 553.098 ha or 21% of the total country area with only 11,9% of natural forest (MINIFOM, 2010).

In addition to that, compared with previous scenarios explained, in Rwanda, there is also a risk of forest overexploitation, which has led to forest degradation and forest cover reduction, and this affect highly the natural forest. According to MINILAF (2017) in their forest investment plan, natural forest cover has changed over time as reported in the following table:

Table 2: Change over time (1984- 2015) of key natural forest in Rwanda. Source:  
(MINIFOM, 2010)

Name of the forest	Area (ha) 1984	Area (ha) 2015	%loss
Buhanda natural forest	1,116	18	98.4%
Gishwati natural forest	21,213	1,440	93.2%
Mashyuza natural forest	85	6	92.7%
Ibanda-Makera natural forest	1,425	169	88.1%
Karama natural forest	3,235	1,061	67.2%
Dutake natural forest	31	11	65.7%
Karehe- Gatuntu natural forest complex	48	19	60.3%
Nyagasenyi natural forest	45	19	58.2%
Akagera national park	267,741	112,185	58.1%
Mukura national forest	4,376	1,988	54.6%
Sanza natural forest	49	24	51%
Mashoza natural forest	36	18	51%
Muvumba natural forest	1,286	688	46.5%
Ndoha natural forest	39	29	26%
Kibirizi- Muyira natural forest	454	352	22.4%
Busaga natural forest	191	159	16.9%
Nyungwe national park	112,230	101,005	10%
Volcanoes national park	16,128	16,004	0.8%
<b>Total</b>	<b>429,728.47</b>	<b>235,192.27</b>	<b>45.27%</b>

Forest cover reduction varies between 0.8%- 98.4% which is very high (Table 2). The main roots for this intense reduction are mainly forest overexploitation due to deforestation, and inefficient wood conversion methods, which cause forest degradation.

Indeed, because of FMNR's project interventions, rural communities testify that they are aware and have started to fill the impacts of the disappearance of their NTS. In detail, the loss of traditional medicines, lack of fodder, and firewood, and high impacts of climate change are now seen as being directly related to the loss of indigenous tree species (Rinaudo, 2014).

In the project intervention area specifically in Bugesera District, the two main issues identified by the FMNR project are that local population did not provide enough value to these NTS and as result, it remains only a low number of trees stumps in the landscape.

Within this situation explained in this review, on one hand, if the deforestation continues at the current rate without conservative measures and NTS plantations programs and management, no natural forest or NTS will be remaining in the coming future. Moreover, this will have devastating long-term effects, including accelerating pest disease, increasing soil erosion and soil infertility, alarming climate change disasters, and reducing food security. On the other hand, the majority of forests worldwide are made up of non-native trees and eucalyptus has been a particularly popular one in Africa. However, eucalyptus sucks up water and tends to seek nutrients from the soil; making it not easier for other plantations including NTS to compete with them (Amazonas et al., 2018).

As a solution, NTS plantations are a perfect solution to those above challenges. Consequently, all the nations worldwide have a large mission to push for the sustainable conservation of NTS, which have now disappearing considerably. There is also a need to change people's mindset of thinking that exotic trees are more productive than native trees. In the short time, the argument seems to be true but in the long term when you balance the use and the value of these NTS for the preservation of the environment; the argument could be false. As for exotic trees, there are some NTS, which are very productive considering the cost of their wood, and other nutritive and medicinal values attributed to them.

On this point, having a look at the status of NTS provides some basic information showing how these species are disappearing considerably if there is nothing done. In this case, there is an urgency to conserve them and accelerate their domestication. On the following point, let us resume a review of the use of these valuable tree species in order to raise awareness and increase our understanding of why we need to domesticate them and integrate them into our agroforestry systems.

## **2.2 Importance of native tree species in community livelihoods and climate resilience**

### **2.2.1 Native trees values in community livelihoods**

Several literatures highlight the importance of using diversified NTS in ecological restoration. According to the FAO, the use of diversified NTS supports local communities in traditional medicine; they help them sustain their livelihoods as well as control the spread of invasive alien species (FAO, 2012). Indeed, it was found that NTS provide more benefits than ETS in terms of ecosystem services (Arcos-LeBert et al., 2021). Different scientists and environmental organizations raise various convincing reasons towards NTS protection. The main reasons include the preservation of biodiversity, preventing the extinction of important native trees, increasing of crop yields in rural communities, avoiding and preventing land degradation as well as for climate change adaptation and riverbanks protection (RFA, 2022).

Despite the wide variety of trees present everywhere in the landscape, only a small number of NTS are known to be used. In order to safeguard these species, their habitats, the countless communities they support, and the ecosystem services they offer, it is essential to understand the current usefulness of NTS. In addition to that, NTS provide timber, food, fiber, and medicine to humans and cattle and also holds a great cultural and spiritual value (Carrero et al., 2022).

NTS can be also utilized as feed since they can provide very good animal fodder (for instance *Acacia abyssinica*). Others have cultural values such as *Ficus thonningii* that were used as sacred sites. Community members have historically avoided cutting it, preferring to wait for itself to fall down (Byabashaija et al., 2004).

Regardless of the significant importance of NTS to life on earth, many fundamental knowledge gaps urgently need to be addressed (Negash, 2021a). According to the author Legesse Negash (2021) in his study conducted in Ethiopia, he highlights, the importance of these NTS; not only for the numerous products that can be derived from them but also for the ecological role they play for being wombs of biodiversity, for conserving water, regenerating soils, minimizing erosion, sequestering CO<sub>2</sub> and for moderating the climate.

In detail, NTS are also profitable because they regulate nutrients, build organic matter of topsoil, fix nitrogen, and create habitats for beneficial soil micro-organisms (Wawira & Thenya, 2017).

In addition to that, the wood from NTS is also used as a source of energy; it helps in house construction, making furniture and paper as well as many utilities. Moreover, many of these native trees play a key role in medicinal use. For instance, a medicinal tree known as *Prunus africana* is well known for its property to treat prostate problems (Negash, 2021a). Furthermore, according to different testimonials during this research, the populations in Bugesera testify that *Mitragyna rubrostipulata* is also known as kidney and liver remedy.

In Kenya during the assessment of indigenous trees done in Kiambu County, there were also other numerous uses of NTs shown in this region. They highlighted some NTS that play a key role in medicinal therapy including *Ficus thonningii*, *Acacia abyssinica*, *Allophylus abyssinicus*, *Prunus africana*, and *Croton megalocarpus*. These trees are very useful to treat diarrhea, hemorrhage, jaundice, headache, burns, and venereal disease. Besides that, others are specifically used as insect repellants or as acaricides such as *Acacia abyssinica*, *Podocarpus milanjanus*, and *Vitex keniensis* (Wawira & Thenya, 2017).

In Rwanda according to the research done by RFA in 2022 on 42 NTS in order to enhance their propagation, they specify how these NTS are the main source of medicines for both humans and animals. More clearly, different medicines are extracted from leaves, bark, roots, and other parts of NTS. For example, extracts from barks of *Prunus africana* are used to treat prostate cancer, and barks from *Syzygium Ssp.* treat amoeba while the leaves of *Vernonia amygdalina* and *Mitragyna rubrostipulata* are used to cure flu and intestinal parasites.

On the other hand, some native trees such as *Syzygium spp.*, and *Polyscias Fulva* provide good quality honey extracted from their flowers while others are considered to be native fruit tree species such as *Myrianthus holstii*, *Syzygium spp.*, *Annona senegalensis*, *Garcinia b Buchananii*, *Ximenia caffra*, *Clausena anisata* and *Parinari excelsa* (RFA, 2022).

Considering the shown utility of NTS, there is a need to sensitize the usefulness of those NTS and to promote alternative uses of NTS as well as to reinforce the tree cover that includes a significant number of indigenous trees in the agricultural landscape.

### **2.2.2 Native Tree Species for climate change resilience**

In the last years, climate change has negatively affected forest ecosystems and the communities that depend on them. Changes in the global temperature and precipitation regime have been significantly driving species responses including plant development processes and tree growth (Gray & Brady, 2016). Indeed, climatic conditions will not only affect plant development and tree growth but will probably cause numerous disturbances such as drought, heavy rain, and wildfire, which will affect considerably trees in some regions. Nowadays, scientists are increasingly worried about the threats that climate change poses to the forest in general including NTS. Studies have shown that ongoing changes in climate parameters may result in vegetation shifts leading to significant changes in species composition and biomass production including tree decline (Gauli et al., 2022). Currently, climate change is also altering the habitat in which trees species including NTS are being planted, and hence the composition of forest is shifting. While certain species will thrive with climate change, others may not even survive (Zhong et al., 2022).

In our changing climate, trees are crucial both in climate change mitigation and greenhouse gas reduction as well as for supporting and enhancing the quality of life in our natural and living space. In addition, trees are mainly considered as key drivers through afforestation, reforestation, and conservation programs such as Reducing Emissions from Deforestation and forest Degradation (REDD+) initiatives. However, forests and trees are already being impacted by climate change, posing a threat to their ability to adapt and overcome additional effects of climate change (Meybeck & Licona Manzur, Clemancia, 2021).

NTS are normally ones that have grown naturally in their habitat. Hence, they are successfully adapted to their local soil and climate conditions.

On this point, we highlight their adaptability to the current climate change problem. In addition to that, with this relevant characteristic and function, NTS support well human beings from the ecosystem services they provide and life of other living species such as pollinators, insects, birds, and small mammals (Hall et al., 2011).

Native trees are therefore crucial to the normal function of an ecosystem. As a sustainable conservative measure, they are the better choices for maintaining the safety of our planet and building a resilient ecosystem in the future years. As we know, non-native trees provide numerous benefits too in a short time compared to NTS; but according to the people's testimonials during this research, ETS are no longer resistant to climate change in the same way as NTS. In addition, they argued that those ETS are also easily attacked by pest disease. However, NTS evolve in response to the changing climate, allowing them to maintain or even expand their natural range. In this case, instead of planting many non-native trees, they should be reduced and prioritize NTS which are more resilient and have more adaptability to face the climate change scenarios.

More clearly, NTS are highly adapted to their surrounding environment and have a positive impact on the neighborhood ecosystem. Because, they have adapted to the environment where they naturally develop, they have a better chance of survival for growing easily without any obstacles. Additionally, they can cope with weather variations of their native region's climate and they are very familiar with the soil conditions so they will not need any fertilizers in case the surrounding soil is healthy. NTS require less water because they can withstand the weather conditions where they naturally grow as explained above. Thus, they are suitable in dry areas because they are considered as drought-resistant (Gray & Brady, 2016).

Furthermore, it is consequently needed to assess more in detail the NTS adaptability and their effectiveness for adaptation strategies to mitigate climate change. In addition to that, we need also to restore our forestland with NTS integration, building strong tree genetic diversity, boosting our landscape resilience to climate change and mitigate existing impacts as well as diversifying the forest by planting NTS that are more suitable to thrive with a future climate.

From the future perspective, one of the most things, communities or policy decision-makers can consider for limiting the impact of climate change; is to plant trees, preferably native ones, and to care for them properly.

## **2.3 Native tree seed germination and good quality seedling production**

### **2.3.1 Native tree species propagation**

In previous years, deforestation and forest degradation have led to widespread biodiversity loss and environmental destruction (FAO, 2020). Within this situation, afforestation initiatives have been undertaken to overcome this global challenge.

Selection and successful propagation of NTS are important for improving the ecological restoration of these forests (Lu et al., 2016). More clearly, NTS propagation is commonly referred to as an appropriate technique to reproduce and establish NTS for conservation, reforestation purposes, and landscape restoration. In addition to that, in agroforestry, tree species need to be diversified with an emphasis on NTS for increasing crop yield, fighting against erosion, and restoring degraded land. With the rising concern of indigenous tree species, it is also essential to preserve the NTS genetic diversity (MINILAF, 2018).

Therefore, in order to move beyond the situation explained above, scientists propose the study of more appropriate native tree species by region and always considering biodiversity based restoration approach as the NTS propagation can vary depending on each species. Since most interest has been focused on exotic tree species up to now, there is a limited knowledge about indigenous tree species, particularly in phonological behavior, seed physiology, extraction, drying, storage and pre-sowing treatment of NTS seeds. Furthermore, restoration with NTS require first their identification with their seeds' availability and the possible propagation technologies that are appropriate to the local context (Lu et al., 2016).

Like other plants, many NTS can be simply grown from seeds; but to ensure their seed availability, it is important to understand well the specific requirement for effective propagation.

In wild plants, seed germination is often variable. Some seeds germinate immediately while others germinate irregularly over a period of weeks, months, or even years. A key benefit of growing NTS from good quality of seeds is the best way to preserve the genetic diversity within a species (Hooper et al., 2009).

Here, seed quality refers to the physical and physiological state, but also encompasses the genetic pathological and entomological attributes that affect seed performance. More clearly, good quality tree seeds must be generally collected from mature or healthy trees, which fulfill the established relevant standards for their phenotypes depending on each species. The most widely used methods by Tree seed centers in Rwanda for assessing seed vigor are measurement of germinating rate, seedling growth rate, and also considering physiological and physical qualities of tree seed (MINILAF, 2018).

One of the greatest limiting factors and challenges for reforestation efforts in recent years has been the shortage of suitable young NTS plants and the key problem was poor germination of collected seed (Burg et al., 2014). With this challenge, Wageningen University has conducted research about relevant seed treatment for NTS, and interesting findings were observed. This can be more useful for foresters, farmers, and decision-makers who want to propagate NTS.

It has described the main seed biology issues of NTS, the safe way of harvesting and storage, how to break dormancy particularly observed in most of NTS and the appropriate method to be used for the seed germination to achieve a successful NTS propagation (Burg et al., 2014).

Normally, a seed is considered as the basic sexual reproductive unit of the plant. In addition, seeds cover all kind of different structures and vary depending on phenology and physiology of each species. These structures are mainly tree seeds from fruit, flowers with fruits inside, florets, etc. (Leadem, 2002), (Burg et al., 2014). For a successful germination test or experiment, it is very crucial to consider the seed's storage behavior. On one hand, it is necessary to take care of seeds in case they are collected in a way that does not compromise their ability to germinate. Roughly, seeds can be grouped into types such as orthodox seeds, which can be easily dried and stored and recalcitrant seeds, which must be planted immediately after their harvesting.

All those types of seeds have unique characteristics and their germination method and dormancy-breaking techniques required, that vary for every NTS depending on various factors. For all these methods, seed disinfection by water or other chemical products is required to treat fungi. (Burg et al., 2014).

According to numerous researchers, Negash (2021), Díaz-Páez et al. (2022), Burg et al. (2014), (and Lu et al. (2016), some techniques used in NTS propagation done in different countries are similar: firstly, in the seed collection, a key parameter to consider in NTS propagation is the appropriate way and time of seed selection. Seeds need to be harvested while they should be enough mature. The maturity can be observed from the fruit color (normally white or green and frequently yellow, and red depending on different species) and when they fall off trees. While collecting seeds, it is very important to consider genetic variation, which can increase by collecting seeds from different trees at different sites (Leadem, 2002).

After collection, some NTS do not germinate so easily without any other treatments. Most of them become unable to germinate in case they are directly sown, this phenomenon is called dormancy. To overcome this dormancy, some seeds need treatments such as seed stratification (Burg et al., 2014). More clearly, many native tree seeds require a period of cold stratification to break dormancy before they germinate. This cold stratification is done by putting seeds in a cool or moist environment for a given period (Díaz-Páez et al., 2022).

As explained above, some seeds have a hardseededness character with a hard seed coat that needs to be scarified and scratched to facilitate the moisture to enter into the interior of the seed and promote rapid germination. This process is called seed scarification. For example, for orthodox seeds with large seed, which has the hardseededness character (i.e.: *Acacia albizia*) seeds need to be cracked manually and soaked in water for 3 hours (mechanical scarification). Moreover, for another method, the seeds can be soaked in H<sub>2</sub>SO<sub>4</sub> for up to 1 hour until the seeds are pitted, and then after rinse them in water (chemical scarification) to get clean seeds (Burg et al., 2014).

Another common technique is the direct seeding where, seeds are sown directly into the soil. This method is suitable for native tree seeds that are easily germinated. Direct seeding requires a proper site preparation to protect the seed against pest and other invasive plants (Lu et al., 2016). In case, there is a problem of seed availability, a technique of vegetative propagation could be used. Some NTS can be propagated in such way through techniques such as cuttings, layering, or grafting.

Cuttings involve taking a section of a tree, usually a stem or branch, and encouraging it to form roots. Layering involves encouraging a branch or a stem to produce roots while it is still attached to the mother tree. Grafting involves joining a section from the desired tree to a compatible rootstock (Díaz-Páez et al., 2022).

Finally, to grow seed to mature seedling, it is better to design a nursery, where optimal conditions can be provided for germination and growth. This method allows seeds to germinate easily in controlled environments and better management of growth factors such as light, temperature, and moisture. In this area, one seedling or propagated tree that, has reached an appropriate size, can be transplanted into its desired location. Proper handling, seed transportation, and planting techniques are crucial for ensuring the successful establishment of NTS nurseries (Dumroese et al., 2021).

Apart from these methods of NTS propagation and considering the study conducted in Rwanda about the native tree seed germination, there is a great recommendation for all foresters and tree farmers that for ensuring a successful germination; they must consider the type of seeds and the limiting environmental factor. Some of these factors are edaphic such as soil depth, fertility, texture, and structure, others depend on climatic conditions like temperature, aridity, and humidity and it is very crucial to prevent pest disease (MINILAF 2018). Indeed, it is very crucial to prioritize the use of locally sources seeds in order to preserve genetic diversity and adaptability to the regional and ecological conditions. In addition, it is also very important to take into account the uniqueness and characteristics of each NTS in order to be able to determine well the most suitable technique of propagation.

### **2.3.2 Quality seedling production of NTS**

The success of NTS propagation and forest restoration programme is largely depend on the quality of the planting stock. In this case, the quality of seedling has a significant impact on the field survival of trees, growth performance and the quality of produced timber. More clearly, the quality of seedling is defined by its genetic composition and physical characteristics of the mother tree, while physical quality considers the morphological and physiological condition of the seedling when it is grown in the nursery (Nestor Gregorio, Arturo Pasa, Steve Harrison, 2020).

According to Nestor et al. (2020), they describe a high-quality seedling as a seedling with no bent stem or having two stems, not too small with few leaves or extremely small leaves. Shortly, a good seedling must be free from any deformities. In detail, a low-quality seedling is not profitable because it will always produce a low quality of tree even if it will be provided all needed treatment; and planted in the appropriate location. However, a high quality seedling should guarantee low seedling mortality, the less intensive management needed, which provides a minimal cost plantation (Moreira et al., 2016). Preferably, improving the physical quality of NTS seedlings must be done from the step of seed collection and must be also reinforced until the seedling grows at the nursery level. Normally, under all circumstances, 20-30% of seedlings raised in the nursery will be of poor physical quality. Unfortunately, those with low quality must be discarded and should not be considered for field planting (Nestor et al., 2020).

According to the insight given by a few researchers, producing high quality Native Tree seedlings requires careful attention for successful NTS propagation and restoration (Moreira et al., 2016). However, based on constant while we were in Bugesera District, there is a lack of knowledge according to all given information related to NTs propagation and good quality seedling production. Consequently, the number of NTS planted was constantly reduced due to the reasons that the community gave in terms of seed availability and the lack of knowledge for establishing NTS nurseries. Within this situation, on one hand, awareness campaigns should be prioritized for the communities to understand well how to propagate the NTS and how to produce a good quality seedling; and start to do on their own NTS nurseries at the community level. On the other hand, there is an urgent need to promote private sector interest, which must viewed as a crucial component in the successful growth of a tree seed business.

## **CHAPTER 3. METHODS AND MATERIALS**

This chapter discusses the methodology adopted to explore NTS situation in the study area, to identify the most preferred NTS and to assess their growth and germination performance. This chapter also describes the site location of this study, explores the process used to select the study population, and demonstrates different steps undertaken as well as different tools used to collect data during this research.

### **3.1 Study area description**

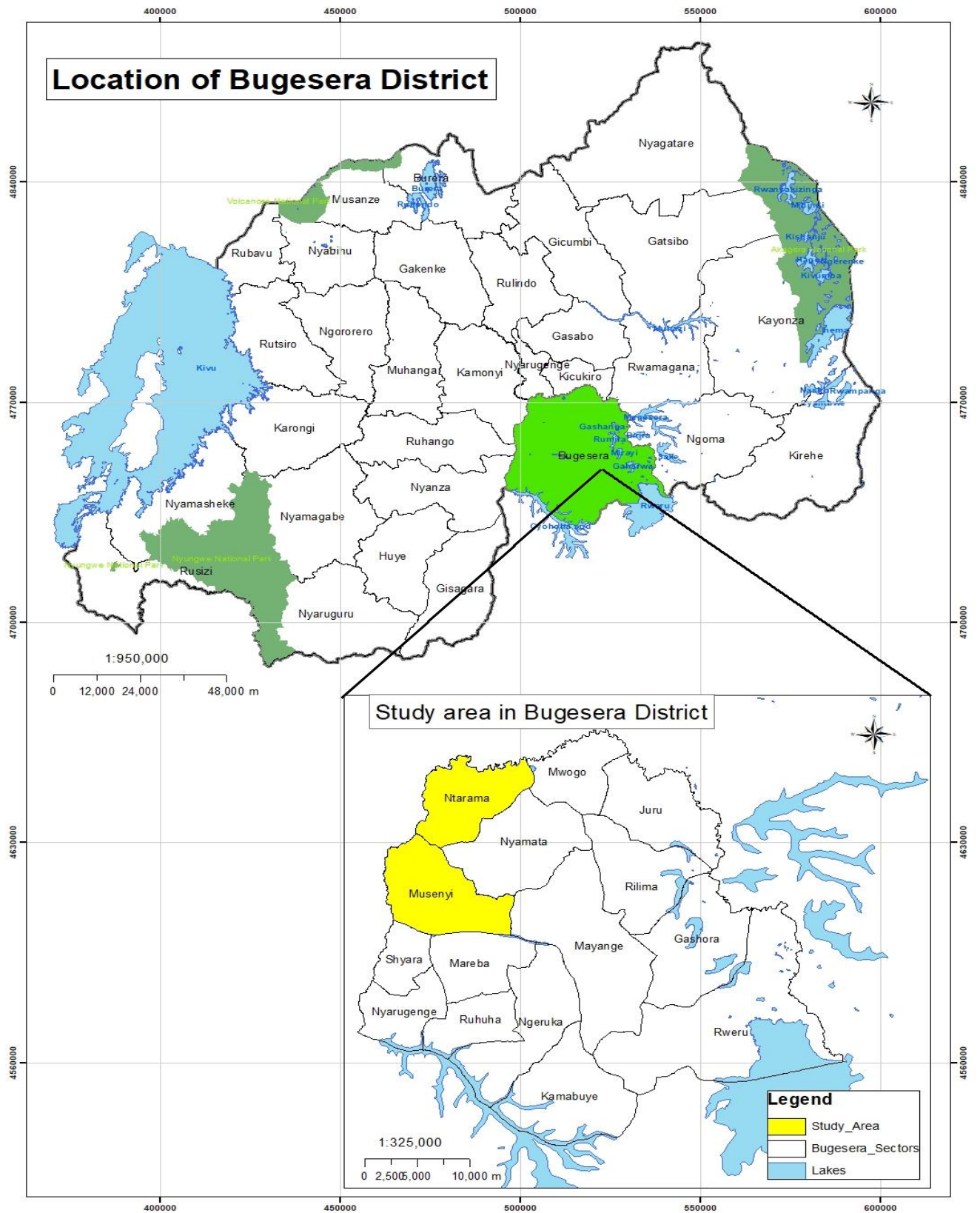
This study was carried out in the Bugesera District. It is located in the southwest of the eastern province, ranges between  $-2^{\circ} 14'4.42''$  S  $30^{\circ} 08'53.70''$  E. In addition to that, Bugesera District covers a surface of 1337 km<sup>2</sup>, and is bordered by Rwamagana District to its Northeast. Nyarugenge and Kicukiro Districts of Kigali city are located to its North whereas Kamonyi District of Southern province is to its North-West. Ngoma District of Eastern Province is located to its East, Ruhango, and Nyanza Districts of Southern Province to its West, and finally, the Republic of Burundi, which is positioned to its South where they are largely surrounded by Lake Rweru and Lake Cyohoha in the South. Bugesera District is one of the seven districts that constitute the Eastern Province in Rwanda. It is also composed of 15 administrative sectors, 72 cells, and 581 villages (GOR, 2019).

According to the population and housing census of 2022, the population of Bugesera District was estimated to be 551,103 people with 271,468 males and 279,635 females. The population density was 450 population/km<sup>2</sup> and is counted among the highest density in Rwanda (NISR, 2023). In comparison to other parts of the country, Bugesera District is considered one of Rwanda's drought-prone regions due to its regular rainfall deficit and substantial frequency of dry periods. The maximum temperature varies between 26 and 29°C and the minimum temperature ranges between 13-15°C. This area is known for being among the hottest and driest regions at the country level (Wali et al., 2015).

The soil of the District is typically sandy, very permeable and contains insufficient humus. The hydrological network of Bugesera District is mainly defined by 3 rivers (Nyabarongo, Akanyaru & Akagera) and 9 lakes (Rweru, Cyohoha North, Cyohoha South, Gashanga, Kidogo, Rumira, Mirayi, Kirimbi & Gaharwa) (GOR, 2019).

The vegetation is mainly dominated by drought resistant plant such as *Asparagus falcatus*, *Aloe dawei*, *Acacia spp*, *Ephorbia turicalli*, *Cactus saguaro*, *Papyrus cypperus*, *Grevillea robusta* and *Pinus spp*. (Mikwa et al., 2014). These plants have negatively affected by climatic effects, especially the dryness of the hills and the flooding of marshes. Hence, they are depleted over the years and the region experienced several scenarios of food insecurity. Within this situation, wild animals that used to inhabitant in this region were forced to move toward Akagera National Park. However, some species remain such as ante eaters, mice, and various species of birds, hippos, crocodiles, turtles, ducks, wild geese, and different species of fish especially in lakes (GOR, 2019).

The site location of this research was based in eastern part of Rwanda, in Bugesera District specifically in Musenyi and Ntarama sectors (Figure 4). For each sector, one cell has been selected with their two villages. The selected ones are Nyagihunika cells with Nyakajuri and Rwankeri villages and Cyugaro cells with Kidudu and Rugunga villages. In addition to that, there was the establishment of tree nurseries in each sector. The site of nurseries was determined based on various factors such as water and road accessibility.



**Figure 4: Location of Bugesera District, Rwanda**

## 3.2. Household survey

A qualitative mixed with quantitative methodology was adopted for this research. Qualitative research methodology requires talking to people about their thoughts and experience in order to understand well how a phenomenon or something else is viewed within a specific group (Tukahabwa, 2018). In this case, different methods used in household survey are highlighted in the following points.

### 3.2.1 Sample design

In this survey, a simple random sampling was used where each person in the target population has an equal chance of being included in the sample. For more clearly, the direct target population was the farmers located in research area. As this targeted population has the different characteristics: some know well and grow NTS in their farm, others are considered to know NTS or not. The first categories are the farmers, who was gathered in association, and accompanied by ARCOS to grow NTS. Others are simply farmers, which located in the research area. Within these two categories, a stratified random sampling is used and hence, the entire population was stratified into subpopulation or strata. Consequently, two strata have been made including farmers in associations, which have some knowledge on native tree and for others, which have ideas or not about those trees. Those famers were located from two sectors, two cells and four villages as described above in study area description. In addition to that, Yamane's formula (Uakarn, 2021) has been used to determine the sample size to use during the survey. The formula is presented under below:

**Yamane's formula:**

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

Where:

n: sample size

N: Population size

e: Level of precision or sampling of Error

In this study N= 1.001 (The total population of targeted villages according to statistics given by villages chairman and e= 5%.

Within this situation, the sample size distribution was allocated as shown in Table 3.

Table 3: Sample size distribution of population in study area

Villages	Total population	Population Sample size distribution by villages	Household In Arcos	Sample size	Farmers household targeted	
				n	N	n
1. Nyakajuri	187	53	36	10	151	43
2. Rwankeri	190	54	100	28	90	26
3. Kidudu	320	92	55	16	265	76
4. Rugunga	304	87	80	23	224	64
<b>Total</b>	<b>1.001</b>	<b>286</b>	<b>271</b>	<b>77</b>	<b>730</b>	<b>209</b>

### 3.2.2 Questionnaire administration

An online questionnaire pre-loaded in the Kobo toolbox is used to guide the personal interview and lasts around 35 min per interviewee. More clearly, Kobo Toolbox is a free open-source tool used to facilitate the collection of data using digital tools such as mobile devices, computers, and tablets as well. The researcher interviews the respondent using the questions from the pre-established questionnaire and then records the answers on the mobile devices. Both open-ended questions and closed questions; have been used. The respondents were allowed to add any further information that seems pertinent to this study. In addition to that, the questionnaire was anonymous; the data provided and the identity of the respondent was kept confidential. For each respondent, a field observation was done in order to identify different native trees, which was grown on their farm, and to investigate their preference and other considerations related to NTS domestication and use. The respondents were found in their home, and most of the time in their farm. 305 questionnaires were completed during the household's survey including 286 questionnaires with others, which were used as trial to verify the conformity of the Kobo toolbox and others found with errors, and which were excluded from the data analysis

### 3.3 Focus group discussion using pairwise ranking matrix

After analyzing and investigating the list of NTS commonly found in two Sectors, Musenyi and Ntarama of Bugesera District developed during the survey, a Focus Group Discussion (FGD) was organized to explore the most important and preferred NTS in the region. Surveys are good for collecting information about people's attributes and attitudes but to understand things at a deeper level, it's better to use a Focus Group Discussion (Eliot, 2005).

Sometimes, it is required to listen to the opinions and thoughts of a small group who know well the situation; FGDs are well suited for those situations. In addition, it also reveals deeply the farmers' preferences in terms of the most usable NTS with all detailed information.

In this case, in order to determine the most preferred NTS, a FGD session was organized with a small number of farmers who represent the whole community targeted. Twenty farmers who grow NTS (10 farmers in each Sector), were selected purposively by local authorities, based on the land size stratifications (NTS growers with  $\geq 0.59$  ha, the minimum land size on average of a population in Bugesera District (GOR, 2019) and the highest number of NTS that they grow into their land. They were invited and gathered in the two sessions of FGD ( each one per Sector) to discuss the top five lists related to the most preferred tree species from the top ten NTS identified during the previous survey conducted. In that case, the most common and preferred NTS were identified after the consultation in the FGD using a pairwise ranking matrix. The pairwise ranking matrix is a common tool used to set the stakeholders' priorities. It also allows for easy comparison of different people's priorities (IWC, 2017).

For more details, among ten NTS identified during the survey, the farmers in FGD have provided details information for each species, split out the five most preferred using a pairwise ranking matrix, based on their role, the way of germination, and their economic and touristic value. Among the five NTS identified, it was planned to grow available species in nurseries in order to assess their performance in local conditions and to avail the seedlings for easy propagation and domestication.

### **3.4 Testing germination and growth of NTS**

In this research, an exploration about growth performance and various seed treatments was made to facilitate the germination of the most common and preferred native tree species in the region. Indeed, in this step, a quantitative methodology was used in order to count regular germinated seeds and to measure quantitatively different aspects related to the growth performance of the NTS tested.

### **3.4.1 Tree species selection**

As explained in previous points, different methods were used to identify the most preferred NTS at each study area; the five most preferred species were identified and ranked based on farmers' testimonials. In this case, this study focuses directly on those chosen NTS. However, due to timeline limitations, not all the species could be part of the research experiment. Consequently, the first two NTS highlighted during the FGD in each sector were selected to be assessed in order to understand well their growth performance and to analyze different possible treatments that could be used to improve their germinate rate.

### **3.4.2 Seeds collection**

Seeds were collected in different areas depending on their availability. Some seeds were collected in natural forests close to the study area and others were collected in community farms according to the population testimony about the NTS location. In case, seeds are not available for the more preferred NTs, cuttings could be another option for exploration. However, during this study, we have preferred to explore the species that could be germinated easily by seeds.

Furthermore, in order to improve tree genetic diversity, seeds were collected from different parent trees, and the distance among them must be almost more than 200m. Additionally, mature fruits were promptly collected on branches or the ground depending on fruit and seed types. Then after, seeds were well stored and treated (extraction, cleaning, grading, and drying) depending on seed type. All necessary data were recorded and documented.

### **3.4.3 Seed treatment and NTS germination experiment**

For all selected NTS, the collected fresh seeds were directly used for germination experiments after some treatments where applied. To understand the effect of different seed treatments on germination rate, seeds were treated and tested in order to analyze the most appropriate treatment to use to accelerate NTS germination. The selected seeds were placed in a controlled nursery environment to monitor their growth performance and germination success.

More clearly, the growth were recorded four times within two months of intervals along six months. Data for diameter, height, and number of leaves were compiled in Excel sheets and analyzed in R software before making some trends graphs.

In order to perform the seed germination test, 10ml of tap water was spilled into glass petri dishes containing seeds that were layered on filter paper above the sand layer. A hundred seedlings per petri dish, in 3 replications for every treatment were randomly placed in a controlled environment in a seed lab. A seed germination was supposed to begin while there was an imbibition of water by the dry seed, followed closely by embryo expansion and the radicle emergence. Seeds with any radicle emergence were considered as germinated seeds (Lu et al., 2016). Every day, the number of seeds that sprouted out, was counted until no more seeds germinated. The experiment monitoring were done during 60 days.

#### **3.4.4 Nursery design and layout**

A good nursery must be well designed to protect the seedlings and to provide them the optimum circumstances for survival and growth. A good nursery practice is the foundation of any successful planting programme (Dumroese et al., 2021). More in detail, a good nursery must be designed in the right way with the space and facilities needed to grow the targeted number of seedlings, size and good quality of seeds to be planted. For selecting the nursery's locations, environmental factors were also considered such as water availability, light, temperature, moisture, mineral nutrients, etc. During this study, these nurseries have been positioned near Lake Cyohoha (one in Musenyi sector) and near Gasave wetland (another in Ntarama sector). In addition, they were positioned in a flat, sheltered, and well drain area.

During this study, two nurseries were established in Ntarama and Musenyi Sectors. As soils in Bugesera region are generally dominated by sandy clay (Mikwa et al., 2014). Suitable soil has been considered and hence the organic manure is used to improve the soil structure. Thus, a raised seedbed of 1 m wide and 10 m in length was designed (Nestor, Pasa & Harrison, 2020), to hold the germinated seedling before being transplanted in the nursery. As said above, there was also a shade cover typically formed from local and simple materials to protect the seedlings from the harsh sun. After, the seeds sowing, each experiment was labeled with the species nouns, date of sowing, and other necessary parameters.

On one hand, while growing seedlings, different steps and practices are carried out; and shared by the local people based on their previous experience and indigenous knowledge. Indeed, while installing these nurseries, we focus on local people who have basic knowledge related to tree nursery. Normally, in Musenyi the members of KOIMEZANYA Cooperatives and in Ntarama, some volunteers are involved in nurseries activities. This approach of Community Based Forest, which integrates the community in forest restoration and increase community participation in forest management (FAO, 2017); is very successful and induce the local people ownership and provide some benefits from the trees species planted and well managed.

Under below, the different steps and techniques used at the nursery level, in search of producing good quality seedlings are:

- 1) Seedling watering: As the study area is located in dry regions, in order to maintain a healthy seedling; they are watered regularly twice per day as shown above;
- 2) Nursery shading: in order to protect young seedlings from high temperatures or wind, local grasses are used to shade the nurseries. Here, instead of using the net, we use local grasses that can be found by local people without other expenses;
- 3) Thinning: Regularly, while monitoring the seedling growth performance, we used to remove weak plants to allow healthy seedlings to grow well;
- 4) Insect pest and disease control: Attacked plants are removed within the thinning process and insect pests are removed physically. During this research, the insects found, are mostly caterpillars.
- 5) Weeding: This process was done physically in case weeds emerge;
- 6) Hardening: Before transplantation ( 2 weeks before); seedlings are removed from a relatively sheltered and protected environment to be familiar with a possible future harsh situation such as drought, heavy rain, wind, etc.;
- 7) Transplanting: This process was done after 6 months of nursery installation. The seedlings were lifted from nurseries, transferred to the field where they supposed to grow and be mature.

### 3.5 Data analysis

In data analysis, on one hand, qualitative and quantitative data from the survey were interpreted, by adjusting preliminary results given by kobo toolbox. These data were completed by data collected from FGD. The stem diameter and total height of seedlings, the main basic parameters considered as the best predictor of seedling survival and growth (Hooper et al., 2009), were measured. Furthermore, the preferred species selected for each site were classified according to their taxonomic identity, and growth performance. After collecting all these quantitative data related to different native tree performances in a controlled environment, data were recorded using different tables and make some trend graphs. After, some data were exported into R, others in SPSS software. A paired sample t-test was computed to determine the effect of seed treatment on germination rate and differences among the species selected according to their growth performance.

For results interpretation, a kind of comprehensive review of the current situation and status of NTS in the target area, the challenges accounted for and given from the survey and experiments were communicated. In addition, according to the results of this research done, appropriate seed treatment of the most common and preferred native tree species and the way of producing the seedlings of good quality in the region were also interpreted.

. According to the germination experiments, to find the results, the following formula were used:

- Germination percentage (GP) was calculated as the following:

$$GP = \frac{n}{N} * 100$$

Where n is the number of germinated seed at the end of experiment, N is total seeds tested (Fetouh, M. and Hassan, 2014)

- Mean germination time (MGT) was calculated by using the following formula :

$$MGT = \frac{\sum (n * d)}{N}$$

Where n is number of seeds germinated each day, d is number of days from the beginning of the test, and N equals to the number of seeds germinated at the termination of the experiment (Kulkarni et al., 2007).

A regular record of germination rate and key parameters were measured (germination percentage, mean germination time, growth parameters such as height, diameters, and number of leaves) in the controlled environment. In the end, to communicate the findings, some tests were performed to assess the effect of the used treatment on seed germination rate.

## CHAPTER 4. RESULTS AND DISCUSSIONS

This chapter presents the research findings and discusses the results found during this study.

### 4.1 Presentation of results

#### 4.1.1 Respondents demographic characteristics from the survey

Almost 49.4 % of the respondents were female while 50.6% were male. The majority (54.9%) were above 55 years old. This was significant because this age represents the most ones who had sufficient knowledge about NTS. However, few respondents were of the young generation (between 25- 35 yrs) with only 6 %; could be problematic. Additionally, the majority of respondents are married (76.9%) and the principal profession practiced by most respondents is agriculture with 96.7%; the other with a small percentage do the construction works and trade. At the household level, on average, there are five members in each family. According to the respondent's education level, over 78.2% of research respondents have completed at least a basic primary education. Only 4.4% had completed secondary education, and 16.4% had no formal education.

#### 4.1.2 Tracking the status and local knowledge about Native tree species in study area

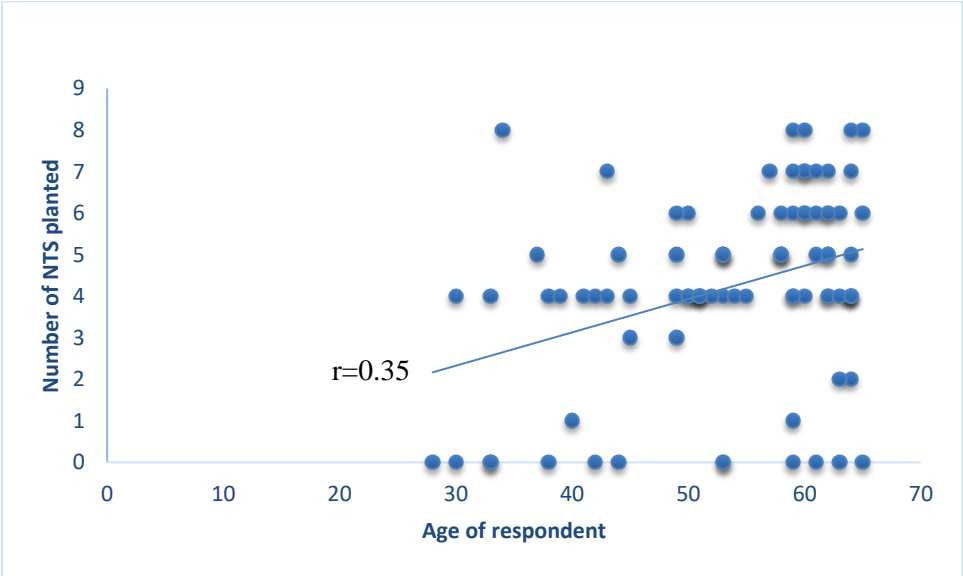
##### 4.1.2.1 NTS status in the study area

In Bugesera District, 40 NTS were found in respondent's land specifically in Ntarama and Musenyi Sectors. Indeed, the most abundant species were *Markhamia lutea* (60.14%), *Euphorbia tirucalli* (58.2%), *Erythrina abyssinica* (54.9%), *Ficus thonningii* (46.2%), *Acacia polyacantha* (22%), *Acacia sieberiana* (20.9%), *Vernonia amygdalina* (22%), *Combretum molle* (15.4%). Survey results from this study show that 60.4% of respondents preferred exotic trees instead of native tree species ( Table 4).

Table 4: Reason of respondents' preference between NTS & ETS

ETS	NTS
ETS grow faster than NTS.	NTS provide fodder and litter of good quality.
ETS seeds are more easily available compared to NTS.	NTS are more resilient to climate change, they are not attacked by pest disease and they are no longer affected by drought and heavy rain.
ETS are more sensitized by agronomists and forest extensionists	NTS are considered as a sign of historical identity. They are sacred trees.
ETS are quickly productive and market-oriented.	NTS are very useful in traditional medicine compared to ETS
NTS take more space than ETS	NTS have a hard tree while ETS have a soft tree

The most common reasons of selecting ETS, were that the farmers believe them to grow fast and are market oriented. However, for those who have selected NTS, they liked their medicine properties. Apart from the preference, the study tested further if there is some factors that could influence local people to adopt these NTS. Here, the study analyzed if there was any relationship between age and the adoption of NTS (Figure 5).



As result, there was a weak correlation between age and number of NTS planted into the farm (Pearson correlation coefficient( $r$ ) =0.35) (Figure 5). In addition, There was no relationship between the education level and number of NTS planted into the farm ( $r$ =0.06). According to the loss of NTS, 80.2% of respondents testified that there are some NTS, which were grown previously in the study area and are no longer present, demonstrating that native tree species are on the brink of extinction in the study site and there is an urgent need to restore them as endangered species and revive such valuable species.

#### **4.1.2.2 Community knowledge of common NTS**

The study also explored Bugesera communities' knowledge of common NTS grown in that location. This study found that 98.9% of the respondents agree that they know what NTS is and have some knowledge about it. However, only 64.8% of them are the only ones who own some NTS growing on their farm whether naturally or by planting them. More in detail, a large number (59.3%) of these NTs are grown naturally on the respondents' farms; only 32.9% are those who have planted NTS in their farms. Specifically for the NTS domestication, the majority (62.6%) reported that they do not have any idea about how to grow these NTS, while only 13% of respondents confirm to have sufficient knowledge and skills to grow and to plant native trees.

Assessing Bugesera communities' knowledge of NTS is very important and provides deep understanding of their traditional knowledge about the use of these NTS, their practices, and what they do with NTS. In addition, it is also very helpful to assess if they have the basic knowledge necessary to support conservative measures of indigenous tree species.

#### **4.1.2.3 Location of NTS in farmland**

According to the location of NTS on the farm, the study examined where these NTS grew most based on their placement. There were three categories: There are some trees, which are scattered on the farm. These refer to trees that were not close to the homestead area but that grew almost anywhere inside the farm. Additionally, other trees can be found at the boundary of the farm. These trees are those that were grown intentionally to serve as fences separating one farm from another.

Lastly, some trees grew close to the homestead area but not on agricultural land used by farmers. Within this situation, most of the trees in Bugesera communities were scattered on the farm (54.9%), while others (32.9%) were located at the boundary of the farm. The remaining (6.5%) are in the homestead.

#### **4.1.3 Native tree seeds availability**

Finding tree species with easily accessible seeds and advanced propagation techniques that are suitable to the local environment is very essential to restore and domesticate NTS. A seed has a significant role in predicting the success of any plant production system. According to the testimonies from respondents, they reported that there is a problem of availability and inadequate seeds or seedlings; that meet their demand. During the survey, 54.9% of respondents obtain rarely their NTS seedlings from tree nurseries installed by the central government and projects, while others (42.9%) use cutting taken from remnant native trees. Indeed, a small number (19.8%) pick seedlings from natural forests, and 23.1% collect seeds from scattered NTS in the farmland. In addition to that, the low production of seeds linked to the low germination rate was more especially observed for NTS.

In addition to that, farmers' respondents testify about some main challenges encountered for producing NTS species such as seed sources, that are very few and most of the time, that are not known. Indeed, the lack of sufficient knowledge about NTS seed collection, storage, planting, and the problem of the people's awareness, which is low, have also raised. In study area, where NTS need to be restored, a reliable supply of seeds is critical to the successful restoration (Bozzano et al., 2014).

While emphasizing and searching about seed availability, we found the situation as shown in the table below. More clearly, the table highlights also the supposed germination time for each species and the number of seedlings that can be produced per 1 kg of seeds sown. The information related to the number of seeds produced in 1 kg was found in the agroforestry database published by the World Agroforestry Center (Orwa et al,2009).

Table 5: Seed availability of most preferred NTS in Musenyi and Ntarama Sectors

N <sup>o</sup>	NTs (vernacular nouns)	Scientific name	Family	Seeds availability	Germination time ( other related information)	Number of seeds per kg ( estimation)
1.	Umusave	<i>Markhamia lutea</i>	Bignoniaceae	Seeds easily available	20-30 days	75,000
2.	Umuvumu	<i>Ficus thonningii</i>	Moraceae	seeds/ cutting ( flowering and fruiting in October)	Unkown ( fast growing from cuttings are better than seeds	90,000
3.	Umunyinya ( w'ingara) without thorns	<i>Acacia sieberiana</i>	Leguminosae	Seeds are available	4 months	75,000
4.	Umurama	<i>Combretum molle</i>	Combretaceae	Seeds/ suckers	5-20 days (3-6 weeks)	10,000
5.	Umunazi ( with edible fruits)	<i>Parinari curatellifolia</i>	chrysobalanaceae	Seeds	6 months	250- 350
6.	Umuzo	<i>Teclea nobilis</i>	Rutaceae	Is not a prolific seeder	Non identified .Germination rate and seed viability are very low	20,000
7.	Umusarasi (with edible fruits)	<i>Garcinia buchananii</i>	Clusiaceae	Seeds/ seedlings/ cuttings	2 months ( 3- 8 weeks)	2,000- 2,500
8.	Umuvungavungo	<i>Kigelia africana</i>	bignoniaceae	Seeds ( roasted seeds can be eaten but raw seeds are poisonous).	4-6 weeks	3,400- 6,000
9.	Umumuna	<i>Lannea schimperi</i>	Anacardiaceae	Seedlings/ cuttings of stem an root	30-45 days	Not found
10	Umunzenze	<i>Olea africana</i>	Oleaceae	Seeds	20- 45 days	13,800
11	Umukore	<i>Dombeya torrida</i>	Sterculiaceae	Seeds/ cuttings	3 weeks	35,000- 40,000
12	Umuzibaziba	<i>Mitragyna rubrostipulata</i>	Rubiaceae	Seeds are often difficult to collect/ cutting/ The seeds are very tiny difficult to find/ Stem/ branch/ and root cutting	the germination rate of seeds is very low or non-existent 2 weeks	Not specified
13	Umurehe	<i>Ficus ovata</i>	Moraceae	seeds/ cutting quickest method of propagation	Not specified	Not specified
14	Umumena	<i>Pappea capensis</i>	sapindaceae	Seeds	6-10 weeks	Not specified

According to Table 5, only four species (*Markhamia lutea*, *Combretum molle*, *Garcinia buchananii* and *Kigelia africana*) among 14 NTS preferred have seeds that are easily found in the study area. This represents a seed availability rate of only 28.5%, which is very low. Regardless of the situation shown above, illustrating how local people found the NTS seed, *Markhamia* seeds are ones that are found easily because this tree species is the most preferred in the region and is compared to eucalyptus in terms of providing good quality of timber.

#### 4.1.4 Most preferred and used native tree species

In order to determine the community perceptions of NTS and to identify the most preferred NTS in Bugesera District; two sessions of FGD were conducted with a small number of farmers who represent the whole targeted community.

Twenty farmers (ten farmers in each sector) were selected purposively. In this case, those farmers were chosen by the local authorities based on the land size stratification ( $\geq$  to 0.59 ha, the minimum land size on average of a population in Bugesera District (GOR, 2019). It means that the participants in FGD must have sufficient land to grow NTS. In addition, the farmers must be NTS growers and lovers, indeed, they must have at least five NTS on their farm and a good willing to propagate and domesticate the NTS.

The findings from the FGD show that a large number of NTS are currently utilized and well known by the local population; to satisfy their socio-economic needs, ethno-veterinary medicine, energy as well as cultural requirements. Regardless of providing firewood, medicine, fruits, and charcoal; according to the respondents during the survey, the most used indigenous trees are presented in Table 6 with the main usage of each NTS.

Table 6: The most used indigenous tree species

Tree species	Frequency	%	Role
1. <i>Markhamia lutea</i>	248	86.9	Wood processing for construction and carpentry, commercial purpose, leaves become fertilizer on its surroundings.
2. <i>Ficus thonningii</i>	238	83.4	Wood production, cords from their bark, house identity.
3. <i>Erythrina abyssinica</i>	147	51.6	Traditional cults, medicine, beekeeping.
4. <i>Ephorbia tirucalli</i>	166	58.02	Fences, fighting against termites, used to taste poisonous, and pest control
5. <i>Acacia polycantha</i>	122	42.7	Cow shelter, fodder and litter.
6. <i>Acacia sieberiana</i>	115	40.4	Inflammation healing, beautification, traditional belief, very useful in cattle farm
7. <i>Croton megalocarpus</i>	91	31.8	Not specified
8. <i>Iboza riparia</i>	78	27.4	Medicine
9. <i>Polyscias fulva</i>	46	16.2	Solid wood
10. <i>Vernonia amygdalina</i>	44	15.3	Medicine for human and cattle
11. <i>Olea africana</i>	44	15.3	Traditional cane, boat construction, charcoal production, and wooden statue
12. <i>Mitragyna rubrostipulata</i>	40	14.07	Traditional medicine
13. <i>Blighia unijugata</i>	34	12.09	Provide a good fertilizer
14. <i>Entada abyssinica</i>	31	10.8	A good shelter

Furthermore, other NTS that play a key role in people livelihood are also identified during FGD. According to FGD participants, they testify that in the previous year, the flowers of *Rhus natalensis* and *Acokanthera schimperi* were very used in apiculture to produce good quality of bee honey, but currently, those species are rarely found in the farm. Indeed, the fruit of *Garcinia buchananii* and *Parinari curatellifolia* were likely eaten by children, prevent them from the flu, and cough. The *Teclea nobilis* were also used for making the traditional cane.

As Ntarama Sector is a little far from Musenyi Sector, there are many similarities in terms of various types of NTS found there and how they are used. However, there are some variations in species that could be caused by biophysical variation: For instance, Ntarama Sector is primarily made up of hills and wetland whereas Musenyi Sector is located close to Lake Cyohoha. There are particular NTS in those two distinct geographical areas that are more easily adapted in the vicinity of the lake or in wetland area. For instance, *Mitragyna rubrostipulata* are well adapted near the wetland or in cold region, whereas *Garcinia buchananii* is only found in forest area. In addition, historically in pre-colonial period in Rwanda, *Ficus thonningii* was considered as sacred tree (Umuhoza et al., 2023), and the majority of people made sure that *Ficus thonningii* tree were planted in the compound to serve as a marker and indicator of home family's presence. Even, currently, those sacred trees exist and aged with more than a century, and called them "Ibisigaratongo"

In study area, to determine the appropriate way in which, farmers in study area could easily domesticate the NTS, we start by searching in deep the most preferred and loved ones. So far, a pairwise ranking matrix is used as a tool that allows us to compare the different people's priorities in terms of NTS. In this case, the participants of FGD were asked about the most preferred native tree species starting with top ten list. They were also asked other pertinent question in order to complete the information given during the household survey conducted during this research.

Starting with top ten list, in Musenyi Sector, there are: *Markhamia lutea*, *Ficus thonningii*, *Acacia sieberiana*, *Combretum molle*, *Parinari curatellifolia*, *Teclea nobilis*, *Garcinia buchananii*, *Kigelia africana*, *Lannea schimperi*, *Olea africana*.

In Ntarama sector, there are *Markhamia lutea*, *Ficus thonningii*, *Dombeya torrida*, *Mitragyna rubrostipulata*, *Ficus ovata*, *Garcinia buchananii*, *Parinari curatellifolia*, *Olea africana*, *Pappea capensis*, and *Acacia sieberiana*.

According to this list the most preferred in Ntarama and Musenyi are almost similar except *Dombeya torrida*, *Mitragyna rubrostipulata*, *Ficus ovata* and *Pappea capensis*, that are mostly found in Ntarama Sector and *Combretum molle*, *Teclea nobilis*, *Kigelia africana* and *Lannea schimperi*, that are specific in Musenyi Sector.

For shortening the list, the pairwise ranking matrix is used to identify the top five NTS most preferred in study area. The matrix is attached in Appendix 3 and 4. More in detail, the top five NTS preferred in Musenyi Sector are: (1) *Markhamia lutea* (2) *Ficus thonningii* (3) *Olea africana* (4) *Teclea nobilis*, (4) *Garcinia buchananii* (5) *Kigelia africana*. Whereas, the top five NTS preferred in Ntarama Sector are: (1) *Markhamia lutea* (2) *Mitragyna rubrostipulata* (3) *Ficus thonningii* (4) *Ficus ovate* (5) *Garcinia buchananii* (5) *Dombea torrida* (Figure 6).

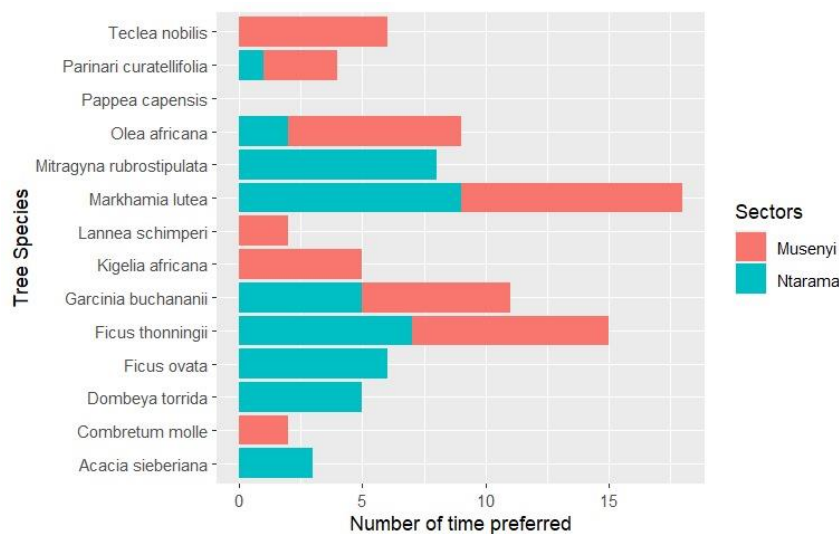


Figure 6: The most preferred NTS in Bugesera community

Figure 6 shows the high rating of preference recorded for three common species namely *Markhamia lutea*, *Ficus thonningii* and *Garcinia buchananii*. The determination of the preferred species in the agroforestry system is very crucial in order to accomplish the local people's needs and to facilitate short, medium and long-term practices for their livelihoods.

#### 4.1.5 Assessment of native tree seed germination

The germination is a critical stage in life of a tree (Kindt et al., 2006). The germination rate of a particular seed lot is a key indicator to how that seed will perform at the field (Negash, 2021a). In order to analyze attentively the germination of NTS during this study, we undertake different steps in following points.

##### a. NTS seed collection

Seeds of only two NTS (*Kigelia africana* & *Garcinia buchananii*) were available, others were missed due to seeds unavailability except *Markhamia lutea* which was not in fruiting period. To complete the list of 4 NTS to be tested, seeds for *Acacia sieberiana* were added on the list. Under below are native tree seeds selected to be tested:

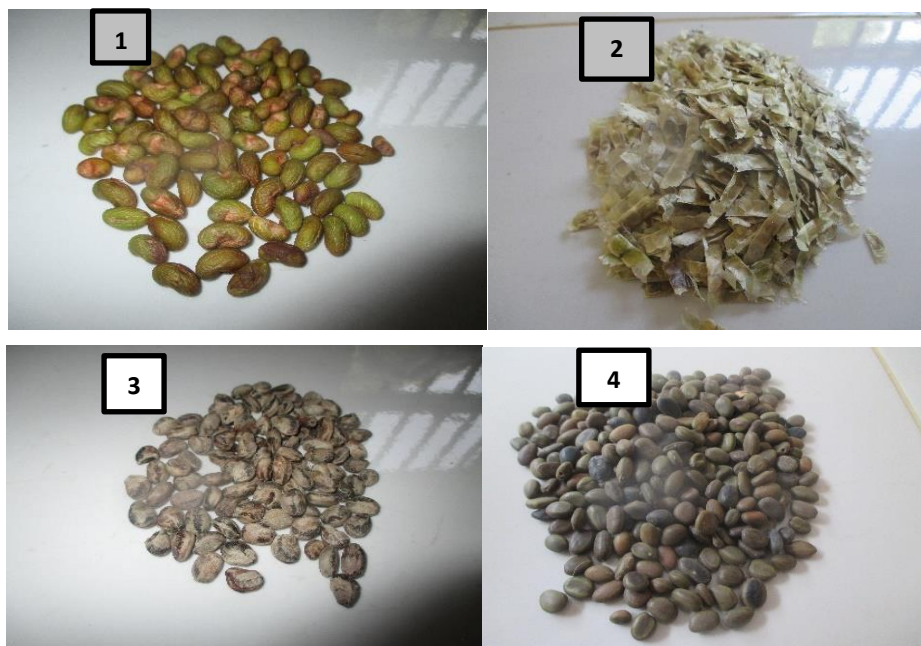


Figure 7: Seeds of NTS identified to be analyzed in germination test: (1) seeds of *Garcinia buchananii* (2) seeds of *Markhamia lutea* (3) seeds of *Kigelia africana* (4) seeds of *Acacia sieberiana*

Clearly, the two seeds collected in Bugesera were both collected in farmland ranging between a succession of trays whose altitudes vary between 1.300 & 1.667m (Wali et al., 2015). *Kigelia africana* was closely harvested in Musenyi Sector and *Garcinia buchananii* so far in Ririma Sector.

Subsequently, seeds from *Kigelia africana* and *Garcinia buchananii* were extracted from mature fruits, then after cleaned and moderately dried. For the two species collected from Bugesera, fresh seeds were stored for two days in a dry package and were directly used for germination experiments without special storage or processing. The other two remaining were taken from RFA where they were processed and stored in the seed bank.

## b. Native Tree Seeds Treatment

During this study, the effect of pre-sowing treatments was investigated in order to determine the best treatments for increasing NTS germination and speeding up early seedling growth. In addition to that, many seeds from native trees are long-term dormant due to hard seed coats or other characteristics. Consequently, even in the best growing conditions, seeds cannot germinate during this natural state of dormancy. Furthermore, the main factor that contributes to poor or erratic germination is seed dormancy (Burg et al., 2014).

Normally, most seeds typically require special treatment in order to germinate easily, particularly those from native trees. For some hard seeds, soaking them in hot or cold water and sulfuric acid allow more moisture to get through and to soften the seed coat in order to accelerate the germination. During this study, the principal treatments used are listed in Table 7.

Table 7: Native trees experiment design for NTS germination done at RFA laboratory

N <sup>0</sup>	Native tree species	Number of treatment	Treatment specification	Replication number	Number of seeds	Sowing date
1	<i>Markhamia lutea</i>	2	T <sub>0</sub> : control treatment	3	100 seeds	25.1.2024
			T <sub>1</sub> : Soaking seeds in cold water for 24 hrs	3	100 seeds	26.1.2024
2	<i>Garcinia buchananii</i>	2	T <sub>0</sub> : control treatment	3	100 seeds	25.1.2024

			T <sub>1</sub> : putting seeds in cold water for 24hrs	3	100 seeds	26.1.2026
3	<i>Kigelia africana</i>	3	T <sub>0</sub> : control treatment	3	100 seeds	31.1.2024
			T <sub>1</sub> :soaking seeds in hot water for 24 hrs	3	100 seeds	31.1.2024
			T <sub>2</sub> : soaking seeds in sulfuric acid for 5 min	3	100 seeds	31.1.2024
4	<i>Acacia sieberiana</i>	3	T <sub>0</sub> : control treatment	3	100 seeds	31.1.2024
			T <sub>1</sub> : soaking seeds in hot water for 24 hrs	3	100 seeds	31.1.2024
			T <sub>2</sub> : soaking seeds in sulfuric acid for 5 min	3	100 seeds	31.1.2024

From the practical perspective, the present experiment indicates that for all four tested species, germination in the control was generally low in all species except *Markhamia lutea* and *Garcinia buchananii*. More clearly, the germination rate was higher for treated seeds compared to untreated seeds. However, for *Markhamia lutea*, there is no significant effect between untreated and treated seeds. Pre-germination treatment was the most suitable option to use in NTS propagation and restoration. Cold treatment increases the germination for *Garcinia buchananii* while for *Kigelia africana*, *Acacia sieberiana*, seeds germinate more effectively when seeds are treated either by soaking them in hot water or sulfuric acid.

#### 4.1.6 Native Tree germination test

Tree species and populations vary in the rate and percentage of germination (Baskin, 2003). Aspects including the mean germination time, germination rate, and germination percentage can be used to quantify this variability. More clearly, information about seed germination and seedling establishment is very essential for successful restoration (Broadhurst et al., 2008).

That is why it is very crucial to conduct a seed germination test when you want to know the future possible propagation and to plan for plant species restoration. To perform native tree germination test, the experiment was designed in this manner (Figure 8).



Figure 8: Seeds of *Markhamia lutea* and *Garcinia buchananii* in experiments for NTS germination test



Figure 9: (Left) *Markhamia lutea* seeds with radicle emergence (Germination starter) (right) *Markhamia lutea* seeds with first leaves

According to the Figure 8 and 9, some seeds are waiting to germinate while others already started to germinate. Differences in germination response to different treatment were evident in each experiment (Figure 10).

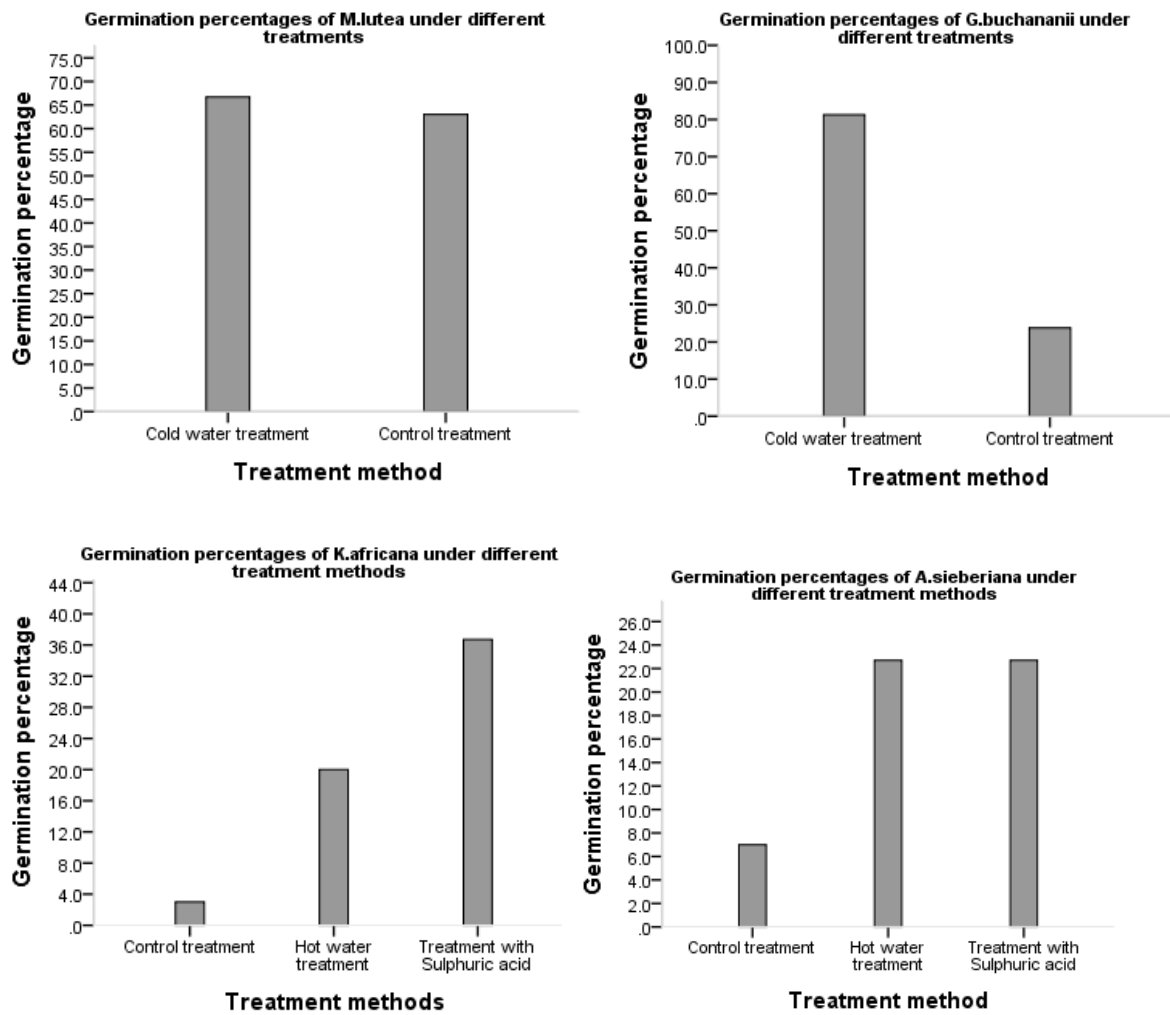


Figure 10: Effect of pre-germination treatment used for four NTS tested

Based on Figure 10, for four NTS species tested in the seed lab at RFA, *Markhamia lutea* always performs well in case of germinating very quickly, and there are less significant differences between treated seeds or not. More in detail, while soaking *Markhamia lutea* in cold water, the germination rate was 66.6%, and under control treatment, it was 63%. However, in *Garcinia buchananii*, there were significant differences: under control, *Garcinia buchananii* germination rate was 23.7%, and when treated by soaking in cold water, the germination increased up to 81.3% and required almost the same time to germinate (29 days) compared to control (30 days). For all tested NTS, the pre-treatment of soaking seeds in cold or hot water increase their germination rate.

*Kigelia africana* demonstrated the same performance as *Acacia sieberiana* of growing hardly. *Kigelia africana* germinated without treatment at the rate of 3.3%, and treated, the germination increased to 20% (THW) and 36.6% (TAS) within 10 days. However, for *Acacia sieberiana*, applying treatment, the germination increased with hot water (22.6% in 13 days) or with sulfuric acid (22.6% in 15 days) (Appendix 5).

Based on statistical analysis in order to test research hypotheses, a paired sample test (T-test) was performed comparing two methods used for each tree species. By comparing the mean percentages of germination for *Garcinia buchananii* under treatment conditions (T<sub>0</sub>- TCW), the results show that there is a high significance difference between two conditions ((p-value=0.001 < than 0.05). Therefore, it is very important to treat the seeds *Garcinia buchananii* with cold water before sowing in the seedbeds in order to increase the germination rate.

For *Markhamia lutea*, there was no significance effect between two conditions (T<sub>0</sub>- TCW) (p-value=0.82). Therefore, there is no need to treat *Markhamia lutea* seeds before sowing them. For *Kigelia africana* on one side, with THW and T<sub>0</sub> treatment conditions, the findings indicate that there is indeed significant difference between two conditions (p-value=0.02). On the other side, with TAS and T<sub>0</sub> treatment condition, There is also a high significant difference between untreated seeds and treated seeds (p-value=0.007). Similarly, for *Acacia sieberiana* between T<sub>0</sub> and THW, the results indicate that there is also significance level between these two conditions (p-value=0.013). However, under T<sub>0</sub> and TAS (p-value=0.03) .Thus, *Acacia sieberiana* and *Kigelia africana* seeds need to be treated either by hot water or by soaking them in sulfuric acid (Table 8).

Table 8: Summary of paired sample test analysis of NTS under different treatments

Species/ Treatment	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Garcinia T <sub>0</sub> – TCW	7.76471	8.19702	1.98807	-11.97923	-3.55019	-3.906	16	.001
Markhamia T <sub>0</sub> – TCW	-.6471	11.5214	2.7943	-6.5708	5.2767	-.232	16	.820
Kigelia T <sub>0</sub> - THW	-.29412	.46967	.11391	-.53560	-.05264	-2.582	16	.020
Kigelia T <sub>0</sub> - TAS	-.64706	.86177	.20901	-1.09014	-.20398	-3.096	16	.007
Acacia T <sub>0</sub> - THW	-2.64706	3.88814	.94301	-4.64616	-.64796	-2.807	16	.013
Acacia T <sub>0</sub> - TAS	-2.64706	4.56811	1.10793	-4.99577	-.29835	-2.389	16	.030

#### 4.1.7 Assessment of Native Tree Species growth performance at nursery level

During this study, the measurement of NTS growth performance is done at the nursery level. During this study, two nurseries were established precisely in Ntarama and Musenyi Sectors. Only the two most preferred species namely *Markhamia lutea* and *Garcinia buchananii* were planted in nurseries for further assessment. The seedlings are raised in a nursery within 6 months before transplantation into local people’s farmland

According to local people's testimonies, the main challenge encountered in getting NTS planting materials is that there is a lack of NTS in an existing nursery in Bugesera. In this case, while conducting a survey, 60.4% of respondents affirmed that there is a lack of nurseries, that hold native tree species and 78.02% affirmed that they would like to own it locally.

During this experiment, a regular recording of data about growth performance has been done. More clearly, 30 *Markhamia lutea* seedlings were examined randomly and marked; to be able to recognize them for the following monitoring session.

For *Garcinia buchananii*, all 51 seedlings were monitored. Seedling height was measured in centimeters from the base of the stem (soil surface) up to the top of the stem (highest part of the plant) using a ruler. While for root collar diameter, was measured apart from where the roots join the main stem in millimeters using a caliper (some photos in Appendix 6). As results, the related data are presented in Figure 11 and Figure 12.

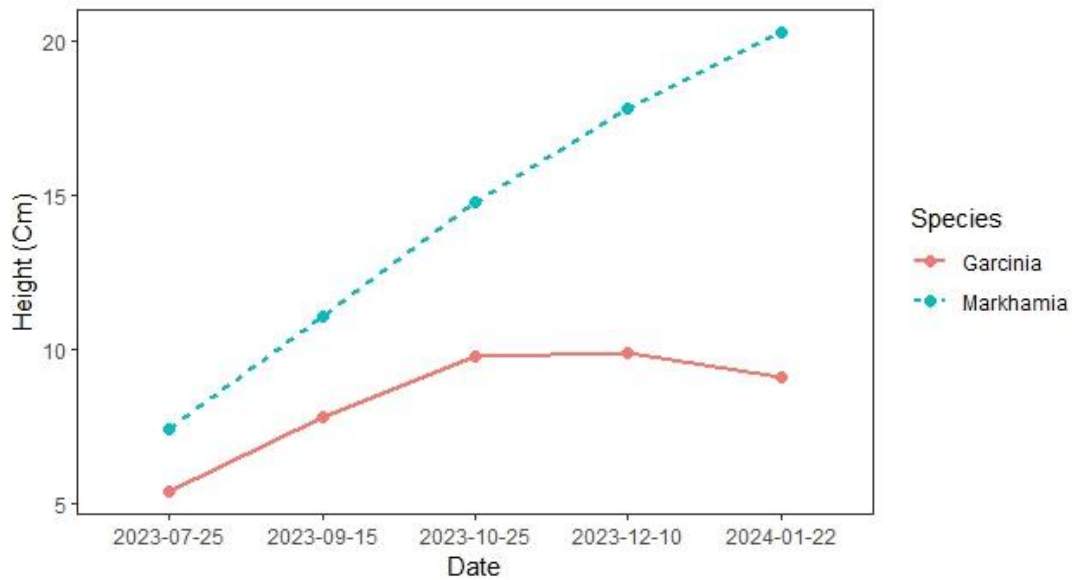


Figure 11: Seedling height evolution of *Markhamia lutea* and *Garcinia buchananii* in tree nursery

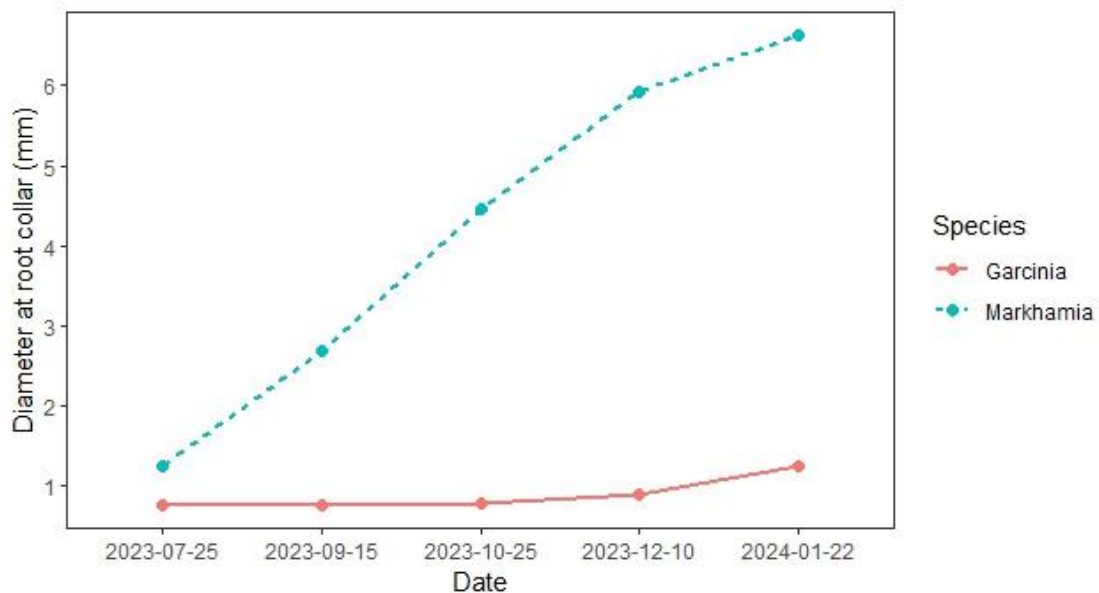


Figure 12: Seedling diameter evolution of *Markhamia lutea* and *Garcinia buchananii* in tree nursery

Figure 11 and Figure 12 show that the growth performance of *Markhamia lutea* was much better than *Garcinia buchananii*. The results show that *Markhamia lutea* had the highest average mean height of 20.2cm and maximum height of 23 cm with (SD= 5.15) and average mean diameter of 6.65 mm with the maximum diameter of 9.2 mm with (SD= 2.25) after 6 months. According to the observation done on the field, *Markhamia lutea* perform well in dry regions specifically in eastern party of Rwanda including Bugesera landscape as compared with other species planted in nurseries.

Indeed *Markhamia* seedlings produced in nurseries were found to be uniform. However, *Garcinia buchananii* grew slowly and seedling mortality was very high. The average mean height of *Garcinia buchananii* was valued at mean height of 9.2cm with a maximum height of 14 cm (SD= 1.88) while for average diameter; it was 1.2mm with a maximum diameter of 1.6mm (SD=0.17). For the first two months, *Garcinia buchananii* used to grow normally by then the growth performance started to be reduced due to the high mortality of some individuals. More clearly, there were 51 seedlings that was raised in nursery and after 6 months, it remained only 14 seedlings. In search of the seedling survival rate of *Garcinia buchananii*, the following formula (Repác et al., 2011) was used:

$$\% \text{ Seedling survival rate} = (\text{SN} / \text{TN}) * 100$$

Where SN: Number of survived seedlings

TN: Total number of planted seedlings

Therefore, the seedling survival rate of *Garcinia buchananii* is valued at only 27%, which is very low and predict the high mortality rate while transplanted out into the field. In addition to that, the number of leaves was also assessed. One of the main visible characteristic that describe a plant's growth and development is the number of leaves it has (Dobrescu et al., 2017). That growth performance was presented on Figure 13.

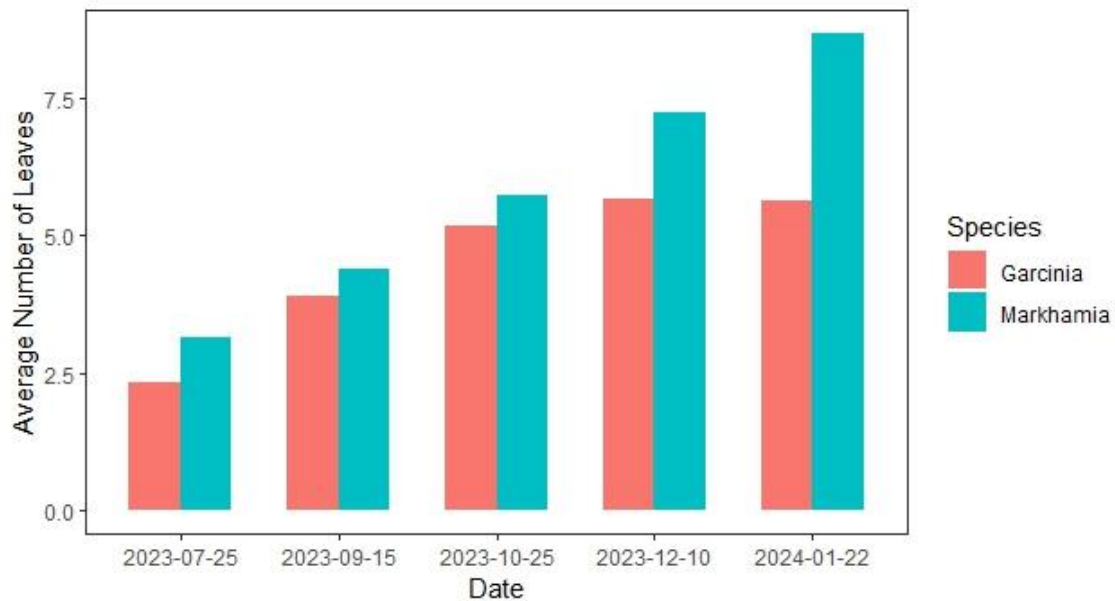


Figure 13: Number of leaves for *Markhamia lutea* and *Garcinia buchananii* seedlings

According to Figure 13, the average number of leaves per seedling of *Markhamia lutea* is eight leaves while for *Garcinia buchananii*, is only four leaves. Moreover, the maximum number of leaves for *Markhamia lutea* was 21 while it was 11 leaves for *Garcinia buchananii*.

According to statistical analysis, t-tests as a comparison test (Zimmermann, 1997) were used to check the difference between the growth performance of two independent variables (*Malkhamia lutea* & *Garcinia buchananii* species). The results generally indicate that the growth performance of *Malkhamia lutea* and *Garcinia buchananii* is significantly differ (P-value= (0.04 or 0.012) <0.05) in terms of height and stem diameter. But according to the number of leaves, there is no difference between species (P-value (0.38) >0, 05) (Table 9).

Table 9: Results for independent sample test for NTS growth performance

NTS growth performance	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t-value	df	p-value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
<b><u>Height (cm)</u></b>									
Equal variances assumed	4.549	0.066	2.387	8	0.044	5.8600	2.4552	0.1984	11.5216
Equal variances not assumed			2.387	5.050	0.062	5.8600	2.4552	-0.4324	12.1524
<b><u>Stem diameter</u></b>									
Equal variances assumed	12.137	0.008	3.236	8	0.012	3.2800	1.0136	0.9426	5.6174
Equal variances not assumed			3.236	4.047	0.031	3.2800	1.0136	0.4786	6.0814
<b><u>Number of leaves</u></b>									
Equal variance assumed	0.706	0.425	0.920	8	0.384	1.2000	1.3038	-1.8067	4.2067
Equal of variance not assumed			0.920	7.166	0.387	1.2000	1.3038	-1.8687	4.2687

Based on these findings, while verifying the null hypothesis, which states that, “*The seedlings growth performance in community nurseries is not significantly different among NTS*, the null hypothesis was rejected as the growth performance of *Markhamia lutea* and *Garcinia buchananii* were significantly differ in term of height, collar diameter and number of leaves. However, the null hypothesis was also accepted only in terms of the number of leaves, as there are no significant differences between the two tested species.

## 4.2 Discussions

### 4.2.1 Local perceptions about NTS

The majority of respondents preferred exotic trees instead of native trees. This is similar to the finding from a study of a Farmers Managed Natural Regeneration project in his study, where they have found that indigenous trees are not valued in Bugesera communities (Rinaudo, 2014). Ndayambaje (2013) in his research about trees and woodlots in Rwanda, reported that agroforestry systems are dominated by a wide range of exotic trees.

In the study area, the adoption of NTS is related to respondents' preferences. A number of planted species in farmer's land are ETS with their belief that ETS are grown very fast and, are very productive compared to NTS. But, some respondents do not agree with this statement; some respondents testified that even if the growth rate of NTS are moderate compared to ETS, some of these tree have a high value more than ETS. For example, the timber and woods from *Markhamia lutea* are very expensive in Bugesera compared to the wood of *Eucalyptus* or *Grevillea robusta*. According to this situation, the lack of scientific knowledge regarding their propagation biology combined with the physiological response of these NTS under field conditions had been one of the obstacles in their adoption (Negash, 2021b).

On the other hand, while analyzing if there are some factors that influence the adoption of these NTS in their agriculture practices using correlation test, we found that there is a small influence between the age and adoption of NTS (Figure 5); and no influence related to education level for farmers who grow NTS. In addition to that, from 30 years, the number of respondents who have planted almost two NTS started to increase; and are highly remarkable in eldest age specifically in the range of 50 and 70 years (Figure 5). This confirms the concept that the young generation are not very involved in NTS. Alternatively, you cannot conserve anything that you do not know or value. From a future perspective, it is very important to raise awareness for the value and the conservation of NTS, specifically in the young generation considered as the future conservationists of these valuable native tree species.

The results found on community knowledge of common NTS show that, local farmers in study area commonly have little information about how they grow, how they are being propagated, where they can easily find the seed, etc. Hence, their knowledge is generally at a low level. As a result, NTS have been negatively criticized using three sentences: “Difficult to propagate”, “difficult to cultivate” and “slow growing”. In addition, most of farmers confuse ETS & NTS; they attest that knowing the difference between them can sometimes be tricky, and difficult to discover the real nuance between those tree species.

However, for old people, it becomes much easier because they mostly used NTS from an earlier age. With this constant, it is very relevant to understand the distinction between NTS and ETS as well as the respective effects they have on our ecosystems. It is crucial to raise our level of awareness and responsibility for our native tree species in order to prevent their future extinction.

Other studies have also found that residents’ knowledge of native species is lacking and that there is a general societal knowledge deficiency regarding to the local ecology (Brzuszek et al., 2007). Similarly, in research conducted by REMA about the status of the environment, the findings show that the knowledge base about national biodiversity is limited and give a warning that there is a need to close the gap. This will require much effort in capacity building in fields such as taxonomy, ethnobiology, and ecology (REMA, 2009). Such obstacles, including insufficient knowledge and skills in propagation management and protection; prevent smallholders from raising NTS. In addition to that, in most areas, there are few nurseries producing tree seedlings (Mangaoang & Pasa, 2003), and sometimes, the seedling price is high.

Thus, it is very crucial to gather such kind of information on NTS knowledge and is highly beneficial to consider all these challenges as well as be informed in order to make rational decision making about the management of these NTS. Indeed, local knowledge about NTS must be always considered to offer helpful information, which can be used in the planning and research studies as well as for policy formulation and project development.

Furthermore, according to the status of NTS, the local people have testified that there is a visible disappearing of some NTS. For instance, these three NTS (*Olea africana*, *Teclea nobilis*, *Parinari curatellifolia*) are no longer available but in last year, they used to grow in Eastern Province specifically in Bugesera communities). This statement approves the first hypothesis of this study that said that: “local community testify that NTS are gradually disappearing in agriculture landscape.”

Considering different ideas and thoughts, local people testify that 40 or 50 years ago, the region had a sufficient forest cover, mostly made up of native trees. However, now, deforestation is occurring because of overexploitation and people cutting trees in search of agricultural land. The production of firewood and charcoal together with construction also led to a decrease in this tree cover.

In addition, the introduction of non-native trees has caused the reduction of NTS cover. More clearly, non-native trees hold the potential to become invasive and outcompete native tree species for resources, which can result in a significant reduction in local biodiversity (Gemetchu et al., 2021). The overplanting of these non-native trees has disrupted the NTS to their local ecosystem leading to the alteration of their habitat and food source for local wildlife and humans as testified by the local population in Bugesera District. These effects can lead to reduced biodiversity, destabilizing the very foundation of the natural ecosystem (Taylor et al., 2016).

Similarly, according to the study carried out in Bugesera and Gishwati, local knowledge revealed evidence of declining tree cover and tree species diversity especially native species, which has led to the loss of initial regulating and livelihood function of trees in the farming system (WFC, 2016). This shows how the consideration and integration of NTS in community landscape is highly needed.

#### **4.2.2 Accessibility of native tree seeds**

Currently, NTS are being utilized more and more to restore disturbed and degraded areas. However, one important factor limiting NTS selection and diversification is the availability of quality planting materials (Lu et al., 2016).

The lack of tree seeds, seedlings, and other planting materials (tree germplasm) is a major constraint to the scaling up of agroforestry innovations (Kindt et al., 2006). Tree planting materials depends on a ready supply of germplasm (seeds or vegetative material) of the chosen species (Bozzano et al., 2014). According to the findings, the main challenge encountered in NTS propagation and domestication is the availability of seeds and seedlings. Normally, the domestication process of NTS involves three stages, which are the identification of commonly used tree species, capturing of germ plasma through seeds or vegetative propagation, and incorporating the potential and preferred tree species into existing farming systems.

According to the situation above, there is a need to think about the best or most suitable seed source. More clearly, choice of seed source, both in term of its location and its composition can have an important consequences for the immediate success and for the long-term viability of NTS planting (Bozzano et al., 2014). Therefore, planting a productive, viable and resilient NTS require the utilization of genetically diverse germplasm. Only a seed is not sufficient to grow a NTS, it is required to consider its quality; which affect highly the seed's performance. More clearly, seed quality reflects the appropriate character that will determine the performance of seeds when sown or stored.

Another important constraint in the restoration of these indigenous trees consist of an inadequate, inconsistent and uncoordinated seed supply. Locally, these factors such as the lack of biological and technical knowledge required for appropriate collection, storage, processing to break the seed dormancy and the availability of seed contribute to seed supply deficiency.

Based on findings, only few of local farmers collect seeds from scattered NTS in the farmlands. The remaining found rarely seedlings from nurseries of projects or local foresters; which is more problematic. More clearly, the similar study related to the seed availability has carried out in Kew's Millennium Seed bank in United Kingdom. This center has contacted 30 seed suppliers listed and among them only seven suppliers have been able to respond positively, representing only 24% of success rate for supplier responses. After, the Kew seed center requested seeds of 2000 indigenous species; accompanied by data on seed origin and storage condition. Within this situation, Kew Seed Center was able to secure the collection of only 218 unique species.

This represents an overall seed supply success rate of 13% of the total number of species theoretically available (Bozzano et al., 2014). This case study proves clearly how seed availability is the main constraint all over the world.

According to Table 5, only four species (*Markhamia lutea*, *Combretum molle*, *Garcinia buchananii* and *Kigelia africana*) among 14 NTS preferred have seeds that are easily found in the study area. This represents a very low seed availability rate (28.5%). In addition, during FGD among the farmers' preferred species, like *Olea africana*, *Teclea nobilis*, *Ficus ovata* and *Mitragyna rubrostipulata* were locally missing seeds.

#### **4.2.3 The most preferred and used native tree species**

Farmers regularly plant trees to obtain provisioning and other ecosystem services. Based on finding, 14 NTS are considered as the most used indigenous tree species for providing firewood, medicine, fruits, shelter, timber, beekeeping, etc. According to the information given during the FGD, the majority plant more ETS than NTS because they argued that ETS are sensitized by local authorities and are easily found locally. Even if, they prefer ETS at the expense of NTS, the farmers are aware of the multipurpose utility of NTS according to their testimonies. In contrast, NTS are only domesticated by some who know their value from their childhood and who are now elders and others who are gathered in associations working with NGOs like ARCOS and FMNR projects.

In addition to that, according to the farmers' testimonials, the most preferred NTS, which have existed before in their landscape; however, with agricultural expansion and excessive tree cuttings, most of them, are no longer existed on their farms as shown above. Indeed, they testify that even if they profit from the quick production of exotic tree species, as eldest, they start to remark the great importance of these NTS specifically for their resistance, their wood quality, and the key role they play in terms of fertilizer, erosion control, and climate change adaptation and against pest outbreak.

Normally, native plants naturally grow and evolve with the climate and soils where they are found. This has allowed them to adapt to the weather patterns and moisture conditions of their native range (Lu et al., 2016). As a result, they are healthier, hardier plants that can withstand easily to drought and coldness. This implies that nonnative trees have zero cold tolerance on one hand and no drought resistance in other circumstances.

For successful domestication, there is a need to select those NTS, that are relevant to their communities in terms of utilization or that truly satisfy the needs of the users. Using pairwise ranking tool, farmers made a top ten list of the most preferred NTS in their communities. Then after, among that list, top five list was determined. In both sectors, farmers are willing to restore the NTS specifically for the preferred ones. The commonest indigenous tree species used in Ntarama and Musenyi Sectors are *Markhamia lutea* and *Ficus thonningii* (Figure 6). These species are mostly preferred because they have a big potential of being commercialized, they also provide poles, firewood and timber of a good quality. Moreover, high rating in preference were also recorded for three common species namely *Markhamia lutea*, *Ficus thonningii*, and *Garcinia buchananii* (Figure 6). More clearly, farmers strongly prefer NTS that have a wide range of uses (both economically and ecologically) and high quality products. The determination of the preferred species in the agroforestry system is very crucial in order to accomplish the local people's needs and to facilitate short, medium and long-term practices for their livelihoods.

#### 4.2.4 Identifying pre-germination treatments of NTS

NTS are easily growing from seeds, but understanding the particular requirements for effective propagation is essential to achieve the success. A key benefit of growing native plants from seeds is the best way to preserve the genetic diversity within a species (Burg et al., 2014). Every individual generated from seeds, has a genetic uniqueness, while it is impossible with grafting or cutting. Most trees and shrubs are propagated using seeds but seed germination information is limited to inadequate research (Hirwa & Maniragaba, 2017). During this study, there was an investigation of seed germination of four tested NTS.

During this investigation, a seed selection was the first step to perform in the germination analysis. Considering their NTS seed availability, four NTS were selected including *Markhamia lutea*, *Garcinia buchananii*, *Kigelia africana* and *Acacia sieberiana*.

For analyzing the seed germination, it is very important to consider the storage behavior in order to preserve seed quality. More clearly, as *Garcinia buchananii* and *Markhamia lutea* seeds are recalcitrant, they need to be sown immediately after their collection; or need to be stored at cold room to ensure their viability. Nevertheless, *Acacia sieberiana* and *Kigelia africana* seeds are orthodox because they can be stored for a long time without being depleted.

Among the selected NTS, the type of dormancy varies for each species. Most *acacia* species produce seeds that have physical dormancy (Hussein M. Daffalla, Kauther S. Ali, Magdoleen G. Osman, 2022). More clearly, in order to promote germination, their mature seeds which have a water-impermeable seed coat; need to be cracked or treated. For *Markhamia lutea*, normally, seeds germinate quickly after being sown; nevertheless, many closely related species seem to display a moderate dormancy (Hussein M. Daffalla, Kauther S. Ali, Magdoleen G. Osman, 2022). According to *Kigelia africana*, there is no specific information given by other authors about their seed dormancy properties. However, based on results found by Namah et al., 2019; he found that *Kigelia africana* is relatively a slow growing tree in warm conditions. For *Garcinia buchananii*, Jayant et al., (2018) have reported a prolonged dormancy in many *Garcinia* seeds and it is a constraint on this NTS's ability to successfully germinate and produce seedlings.

Furthermore, within key factors such as soil moisture, temperature conditions, and light availability, NTS seed germination varies. While some seeds germinate immediately, others take a long period of months or even years. According to local people's testimonies, seeds of *Teclea nobilis* and *Olea africana* take more than six months to germinate. Therefore, growing native tree seeds requires a little more perseverance and some special techniques are needed to break seed dormancy.

Within the situation above, to break the dormancy was very important to increase the maximum germination potential and viability of seed in order to achieve the success of young seedling production. In addition to that, there are various methods for breaking dormancy, which accelerate native tree seed germination by treating them before sowing.

However, not all NTS seeds require treatment, some species like *Acokanthera schimperi*, *Blighia unijugata*, *Croton megalocarpus*, *Dombeya torrida*, *Erthryna abyssinica*, *Ficus capensis*, *Kigelia africana*, *Lannea schimperi*, *Markhamia lutea*, *Vernonia amygdalina* can be sown without any treatment (RFA, 2022). Lastly, based on seed experiments conducted in this thesis, identifying suitable seed treatments to facilitate the germination process is crucial. This pre-germination treatment alleviate some seed condition such as dormancy, seeds fungi, etc.

During this study, at least one treatment was used to evaluate the germination status of each species tested. The appropriate treatments were selected according to available information from the previous experiments (Cartes-Rodríguez et al., 2022), (Bacca et al., 2020) and the local people testimony. While doing this research and searching the information related to native trees treatment to break out the dormancy, we found that there is a deficiency in knowledge on the precise dormancy and the best pre-germination treatments to enhance germination ( Neidel, Consunji, Labozzetta and Calle, 2012).

In addition to that, researchers show that many natural tree species experience physical dormancy caused by an impermeable hard seed coat (Bozzano et al., 2014). These plants typically need mechanical or acid scarification. The three most common ways to scarify seeds include soaking seeds in hot, cold water, sulfuric acid and scratching the seed surface.

Although the best method for breaking physical dormancy in all selected species varies (Talonía, 2016), it is necessary to determine a standard treatment or a small number of treatments that can promote germination in order to be able to project their survival and necessary growth development into the future. Based on finding, *Markhamia lutea* do not need to be treated, it can be sown immediately without any treatment. For *Garcinia buchananii*, the germination rate increase when it is soaked in cold water. For *Kigelia africana* and *Acacia sieberiana*, the suitable treatment could be soaking seeds in hot water and sulfuric acid. Briefly, more information regarding the reaction of different NTS to a specific pre-germination treatment could be helpful to improve the NTS restoration. For all tested NTS, the pre-germination of soaking seeds in hot or cold water; increase the germination success.

In line with this statement, the second hypothesis that states, “*The treatment of soaking native tree seeds in cold and hot water increase NTS germination rate.*” Is approved and supported by results obtained from experimental test of native tree seeds.

#### **4.2.5 Germination of native tree species**

Controlling dormancy and germination moment in native tree species will allow more efficient seed management, both for direct seeding and for native plant cultivation in nurseries (Lacoretz et al., 2022). Normally, germination tests indicate the potential germination percentage, which with appropriate management should reflect the germination expected in the field (Schmidt, 2007). Ideally, a seed’s germination rate would always be high if it meets all environmental requirements. However, this is not the case with native tree seeds, they germinate hardly and most of the time, they require standards protocols to germinate effectively as shown in previous points. This statements are also highlighted by others researchers, according to Lacoretz et al; exotics tree species germinate on average ten times more than native tree species (Lacoretz et al., 2022).

In this study, germination testing was done through experiment and, was conducted at the RFA seed laboratory. Due to time and financial limitations, it was preferable to conduct those experiments at RFA in order to get easily the expertise and material facilitation.

In addition to that, *Markhamia* and acacia seeds were provided by RFA because, in the study area, those tree species were not in the flowering period. Others, were collected in the study area.

For four NTS species tested in the seed lab at RFA, *Markhamia lutea* always performs well in case of germinating very quickly, but there are less significant differences between treated seeds or not. Similarly, *Garcinia buchananii* has performed well in terms of germination while soaked in cold water but within 29 days. However, *Kigelia africana* has demonstrated the same performance as *Acacia sieberiana* of germinating hardly. Nevertheless, both increase their germination while treated even if the germination rate is too low compared to two others. This findings was also supported by other researchers where they confirm the poor germination of *Acacia sieberiana* due to their dormancy (Hussein M. Daffalla, Kauther S.Ali, Magdoleen G. Osman, 2022).

Based on statistical analysis in order to test research hypotheses, a paired sample test (T-test) was performed comparing methods used for each tree species. This helps to verify whether there is a significant difference or not between germination percentages for each species under the two different treatment methods used. This paired sample test also provides the t-value and the p-value, which was used for testing the hypothesis (Zimmerman DW, 1997)

With this statistical test , while verifying the null hypothesis, which states that the effects of pre-germination treatment on native tree seeds is not significantly different from the germination of untreated seeds; as result, the null hypothesis is rejected specifically for 3 species (*Garcinia buchananii*, *Kigelia africana* and *Acacia sieberiana*). However, the null hypothesis was accepted for the case of *Markhamia lutea*.

#### **4.2.6 Native tree species growth performance**

Before, it was planned that any seeds supposed to be sown in a nursery should always be subjected to an appropriate germinated test (Nestor Gregorio, Arturo Pasa, Steve Harrison, 2020). However, due to the climate constraints and time limitations, the germination test was conducted after planting the selected species in the nursery.

Only, the assessment of the growth performance of planted species is done at the nursery level and other parameters to evaluate are carried out in the laboratory at RFA center. The seedlings are raised in a nursery within 6 months before transplantation into local people's farmland.

For producing a good quality seedling, the nursery environment should be planned before to support the propagation processes efficiently while offering the best condition (Nestor Gregorio, Pasa Arturo, Harrison Steve, 2020). For example, the seedlings in the nursery must be watered regularly with water of good quality. Indeed, it is also necessary to shade young seedlings in order to shield them from intense sunlight, high temperatures, and rain. All of those conditions were respected while designing and assessing the NTS growth at the nursery level.

All the processes conducted at the nursery level, were done in eco and environmentally friendly way. In this case, instead of using plastic bag, net for shielding and chemical fertilizer for seedlings, banana leaves are used as seedling containers, grasses instead of net and organic manure are used in place of chemical fertilizer.

In case of reducing dryness, the planted seedlings were watered twice a day. While installing these nurseries, the communities played a key role and shared their knowledge for NTS propagation that they hold. They were mainly responsible of maintaining and protecting these nurseries and give some information related to seed sources and do other required activities to improve the nurseries requirements (such as sowing, watering, shading,...). Furthermore, the related pictures are annexed in Appendix 6.

According to survey results, the majority of respondents affirmed that there is a lack of nurseries, that hold native tree species and they need to own it locally in order to find easily planting material of NTS. The same situation is also observed all over the world: A study carried out in the USA found that the major barriers to NTS production are low demand, poor and low propagation in nurseries, limited availability of desirable species, and the lack of stakeholder education and mobilization about the value of NTS (Te Uru Rakau, 2022). In search of producing a good quality seedling; it is very crucial to identify at early stage the seedling development specifically in nursery (Riikonen & Luoranen, 2018). Seedling development or growth can be quantified by various vegetative parameters such as collar diameter, girth, diameter at breast height (dbh), crown diameter and total height (Mojiol et al., 2016).

For all tree species, they are useful growth indicators and reveal the performance of tree species. These parameters also predict the health, vegetative development and yield of tree species in the future. In addition to that, the tree growth performance can be also utilized as the database to choose the appropriate NTS to plant for forest and landscape restoration. According to Grossnickle and MacDonald (2018), morphological and physiological attributes are key factors used to measure seedling development in nurseries. Commonly measured morphological attributes include height, diameter, and root development for bare roots (Grossnickle & MacDonald, 2018). In this research, these morphological attributes are considered because they are directly related and predict the later field performance. In addition to that, these morphological characteristics of seedlings should affect the survival and growth of seedlings after out planting.

While assessing the growth performance of two NTS tested in nursery, *Markhamia lutea* has performed well in term of growth, however, *Garcinia buchananii* has grown hardly with a very low survival rate. This predicts the high mortality rate while they will be transplanted out into the field ( Figure 11 & 12). Normally, seedling mortality in tree population limits population growth rate(Roman et al., 2014).

In addition to that, apart from the height and collar diameter, the number of leaves were also assessed. One of the main visible characteristic that describe a plant's growth and development is the number of leaves it has (Dobrescu et al., 2017).The number of leaves indicates the growth rate estimation and is closely connected to the plant's health status and its yield potential. Indeed, leaves are central to a plant's function and survival. They act as a plant's food source, enabling it to absorb sunlight, make sugars, and carry water and nutrients(Van Volkenburgh, 1999). The results related to number of leaves revealed the same finding as other assessed parameters. Always *Markhamia lutea* has more leaves compared to *Garcinia buchananii*

However while using statistical test (t-test), it seems that there is no significant differences between two species in terms of number of leaves. Moreover, within the situation demonstrated above related to the growth performance of different tested NTS during this research.

The fourth hypothesis stipulated that: " *the seedling growth performance of NTS in community nurseries is not significantly different among NTS*" is rejected because the growth performance of *Markhamia lutea* is highly differ to those of *Garcinia buchananii*. According to lessons learned from this experiment, especially for NTS, it is very crucial to assess the availability of the seeds while planning to install the nurseries for restoration projects. In addition to that, the weather conditions and growth performance must be considered. Growing native tree species requires enough time and patience.

# CHAPTER 5 CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The purpose of the present study was to raise the awareness about the reduction and disappearing of NTS and propose the best pathway to improve native tree seed germination and seedling production in order to avail native tree seedlings for NTS regeneration and enhance the use of NTS in agricultural landscape. In this regard, this study investigated the potential in seed germination in vitro conditions and analyze how to produce good quality nursery seedling in agro climatic conditions in Eastern Province specifically in Ntarama and Musenyi Sectors of Bugesera District, in order to satisfy local people needs in agroforestry. The findings on comparative farmers' native tree species preference recommended five native tree species in the region namely *Markhamia lutea*, *Garcinia buchananii*, *Ficus thonningii*, *Acacia sieberiana*, and *Kigelia africana*. This chapter summarizes the major findings about NTS germination and their growth performance from this study, explains the research significance, highlights the main contributions and recommendations as well as proposes the future research direction.

Concerning the first objective, which aims to analyze the community's perceptions about NTS in study area, The study found out that the common NTS, that are well adapted in Bugesera District are *Markhamia lutea*, *Euphorbia tirucalli*, *Erythrina abyssinica*, *Ficus thonningii*, *Acacia polyacantha*, *Acacia sieberiana*, *Vernonia amygdalina*, *Combretum molle*. The most preferred were *Markhamia lutea*, *Ficus thonningii* and *Garcinia buchananii*. However, some NTS namely *Teclea nobilis*, *Parinari curatellifolia* and *Olea africana* that were grown previously in Bugesera landscape are no longer available at this moment. This emphasizes the reduction of these trees species in community landscape. This statement was justified by 80.2% of respondents who have testified that there are many NTS that were grown previously in Bugesera ,and currently, are no longer available.

The most preferred species have a big potential to be commercialized, they also provide poles, firewood, and timber of good quality. In addition to that, *Markhamia lutea* is compared to eucalyptus in terms of providing good quality of timber. The problem of native tree seed availability is also raised.

More clearly, the findings show that among 14 NTS selected in top ten list, only 4 species (*Markhamia lutea*, *Combretum molle*, *Garcinia buchananii* and *Kigelia africana*) have seeds, that can be found easily and locally. This represents seed availability rate of only 28.5%, which is very low. In addition to that, among the most preferred in top five, seeds for *Olea africana*, *Teclea nobilis*, *Ficus ovata* and *Mitragyna rubrostipulata* are no longer found in the region.

On this point, the study indicate an urgent need to give attention these trees species who are on high risk of being extinct, in case there is nothing done and also to be integrated in agroforestry practices and other forest initiatives.

With the second and third research objectives of investigating suitable seed treatment, that can be used to increase germination success, four NTS (*Markhamia lutea*, *Garcinia buchananii*, *Kigelia africana*, and *Acacia sieberiana*.) were tested. Among these selected species, the type of dormancy varies for each species and requires pre-treatment for easy germination. More, clearly, *Acacia* species produce seeds that have physical dormancy due to a water-impermeable seed coat, which needs to be cracked or treated in another way. The findings show that *Markhamia lutea* possesses moderate dormancy and germinates quickly after being sown; hence, it is not required to be treated. *Garcinia buchananii* and *Kigelia africana* have a prolonged dormancy and demonstrate a low ability to germinate successfully. The results indicate that pre-sowing treatment is required for *Garcinia buchananii*, *Acacia sieberiana* and *Kigelia africana* to break their dormancy and increase the germination. Cold-water treatment increases significantly the germination of *Garcinia buchananii* while using hot water and sulfuric acid treatments increase the germination of *Kigelia africana* and *Acacia sieberiana*.

Concerning the fourth objective of assessing and comparing the growth performance of NTS in community nurseries, the findings indicate that the propagation method of NTS varied depending on possible propagation form and seed availability. Results from this study show that the growth performance of *Markhamia lutea* was much better than *Garcinia buchananii* at the nursery level. In addition to that, *Markhamia lutea* perform well in term of rapid germination and fast growth compared to other tested species, and is very recommended in dry regions specifically in eastern party of Rwanda including Bugesera landscape. The study also confirms the variation among the growth performance of NTS. It depends to the morphological attributes and taxonomy of each species.

According to the verification of hypothesis, the first hypothesis, which states, “Local community testify that NTS are gradually disappearing in agricultural landscape” was approved. And the second one which states that: “ Treatment of soaking native tree seeds in cold and hot water increase the NTS germination rate” was also approved. The third that said that “the effects of seed treatment of native trees are not significantly different from the germination of untreated seeds, as result; the null hypothesis is rejected specifically for three species (*Garcinia buchananii*, *Kigelia africana*, and *Acacia sieberiana*). However, the null hypothesis was accepted for the case of *Markhamia lutea*. The last one related to the seedling growth performance is also rejected because the growth performance of *Markhamia lutea* is highly different from those of *Garcinia buchananii*.

## **5.1 Significance and contribution of this research**

This research contributed theoretically and practically to the following points:

1. One of the biggest barriers to NTS propagation is the lack of knowledge related to seed characteristics, germination traits in NTS, and their growth performance. The findings obtained from this research contribute to the knowledge by providing useful information about five NTS tested; even if there are still gaps that need to be filled in order to build a solid knowledge about seeds of NTS.
2. The results of seed pre-treatment for increasing the germination rate in these four NTS will be useful for future seed management and restoration initiatives, particularly in arid regions. However, as the research’s findings and conclusions were delivered from limited-species experiments, it cannot be extrapolated to the diversity of all NTS. Germination response to environmental conditions and seed pre-treatment varies not only among the seeds of the same population but also among seeds of NTS from different provenances.
3. Mistaken beliefs concerning germination limitations are frequently encountered; these opinions are only based on experience but lack the scientific rigor to interpret observations correctly. This study was able to disprove the population belief that generalizes the dormancy and germination limitation to all NTS.

4. Identifying the suitable tree species, that can adapt easily in regions sometimes is not very easy, this research revealed the most preferred species in the study area and indicated the most adaptive species that can cope with dryness situations and climate change effects.
5. The seedling produced in nurseries experiments, were planted into community farmland. This will contribute to increase the number of NTS, that were grown and furthermore, it will reduce the extinction of these tree species. Within the study, while concluding this research, more than 700 NTS seedlings were planted in 30 households. Indeed, the planting session is continuous in order to increase and restore NTS in Bugesera communities.

### **5.3 Recommendations**

In line with this research, the study suggests hierarchically the following recommendations:

#### **1. To the governments and policymakers:**

- ✓ RFA as a government institution in charge of forest conservation should increase the number of tree seed centers and take into consideration the suitable NTS to propagate depending on the agro-ecological zone and ecosystem service that they provide. In addition to that, the seeds would be then distributed countrywide through local leaders or foresters to reach the farmers at reasonable prices for planting in their farmlands.
- ✓ All stakeholders in this sector should cooperate to raise awareness about how NTS are currently disappearing and to ensure that farmers and other actors consistently get all necessary information about the enhancement of NTS in agroforestry systems.
- ✓ Further, academic institutions should also intensify research on fast growing NTS and varieties that are best suited to the local environment. This will resolve the problem of the misconception that NTS is not growing easily and quickly.

- ✓ NTS restoration requires policies and supportive programs emphasizing on private and community-based nurseries; to ensure an adequate supply of native tree seedlings and to provide the necessary incentives to increase the local population commitments and to foster an emerging forest restoration economy.
- ✓ The government should work closely with donor organizations to avail funds for rural forest projects that prioritize native tree species.

## **2. To local authorities and foresters:**

- ✓ The local tree nursery owner should be motivated by foresters to use the few seeds of these indigenous tree species that may be available to multiply the population, so that farmers can easily access to them for planting. This will increase NTS diversity in landscape;
- ✓ Foresters should in future prioritize NTS instead of ETS; because in comparison, NTS provide more ecosystems services needed by local communities;
- ✓ It is recommended to take into account the local knowledge and the existing traditional practices of farmers on the management and adoptions regarding NTS;
- ✓ It is advised that local authorities should assist farmers ‘associations and communities in organizing and preparing them for native tree propagation and plantation.

## **3. To local farmers:**

- ✓ Farmers should protect the existing NTS such as *Markhamia lutea*, *Ficus thonningii*, *Acacias ssp.* And others for allowing them to grow to maturity and to propagate them in their farmlands;
- ✓ It is highly recommended to use local seeds to maximize the local adaptation and always consider the genetic diversity in order to get a good quality seedling and establish a self-sustaining population;
- ✓ In order to ensure the successful germination of seeds, it is recommended that farmers consider the type of seed and other limiting environmental factors such as temperature humidity, season, etc., and reflect all required silviculture management practices.

## **5.4 Direction of future research**

As the study did not test all the preferred native tree species and other necessary aspects, further studies should focus on these unexplored areas such as:

1. Only four out of nine NTS that were preferred in the top five list in Bugesera District were tested during this study. In this case, further research could be conducted with the remaining species in order to get full information in order to boost these NTS potential for regeneration in the future.
2. While assessing the growth performance and testing NTS germination, we didn't consider other aspects such as seed viability or vigor and seedling survival rate; more research is needed to match the germination rate to the seed vigor and later the seedling survival rate. As a limitation of this trial, we have not conducted and assessed the growth parameter and germination in the same environmental condition. For further research, it will be great to assess the situation of growth performance and germination in the same condition precisely at the nursery level. In addition, while assessing the growth performance, we focus on height, root collar diameter, and number of leaves but there are other possibilities to assess other parameters such as stem diameter, root system, morphological and biochemical attributes.

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## APPENDIX

### Appendix 1: Questionnaire used in survey conducted in farmers communities to explore NTS in Bugesera District

#### 1. Questionnaire instruction

An online questionnaire will be used to guide the personal interview, and will last around 45 min. The researcher will interview the respondent using the question from the pre-established questionnaire and then record the answers on the mobile device. The open-ended questions and close questions; both will be used. The respondent were allowed to add any further information that seems pertinent for the study. For clarity, a second follow-up interview may be required if necessary. At the end of the interview, the information can be shown to the respondent in order to confirm the content. It is voluntary, if there is any information that the respondent does not want to be included, it will be removed without any problem and he/ she can stop at any time. In addition, before confirming the reliability of a questionnaire answered; it will be reviewed by the project principal investigator Dr Myriam Mujawamariya. The data furnished and the identity of the respondent will be kept confidential.

The questionnaire is anonymous; the data furnished and the identity of the respondent will be kept confidential. The participant's name will not be used or identified in any reports using information obtained from this interview. The research project team will ensure that confidentiality of participants in this study will remain secure.

#### Household Questionnaire for communities in Bugesera District

Sector: ..... Cell: ..... Village:  
.....

Enumerator Names:

<b>SECTION A: RESPONDENT IDENTIFICATION</b>
---

Indicate your:

- Gender: female //  
Male /

2. Age: 16-25 /\_\_/  
 26-35 /\_\_/  
 36- 45 /\_\_/  
 46 -55 /\_\_/  
 56-65 /\_\_/

3. Marital status: Single /\_\_/  
 Married /\_\_/  
 Separated /\_\_/  
 Divorced /\_\_/  
 Widow/widower /\_\_/

4. Educational qualification :  
 Primary /\_\_/  
 Secondary level /\_\_/  
 A<sub>1</sub> Diploma /\_\_/  
 Bachelors'(A<sub>0</sub>) /\_\_/  
 Post graduate /\_\_/

5. Profession :.....

6. Number of people living in your home:  
 Under 5 members /\_\_/  
 Equal to 5 members /\_\_/  
 More than 5 members /\_\_/

**SECTION B: NATIVE TREE IDENTIFICATION AND KNOWLEDGE**

1. a. Do you know what a native tree is? Yes /\_\_/ No /\_\_/  
 .....  
 ...

b. If Yes, is there any native tree grow in your farm? Yes /\_\_/ No /\_\_/

c. If yes, list them?  
 .....  
 ...

2. How many indigenous trees are located in your land?  
 No indigenous tree /\_\_/ Less than 3 native trees /\_\_/ more than 3 native trees /\_\_/  
 more than 5 native trees /\_\_/

3. Are they planted or naturally grown? Planted /\_\_/ naturally grown /\_\_/

If planted, what is the source of seeds?

.....  
....

4. Where are the native trees grown on your farm?

Scattered on the farm /\_\_/

At the boundary of the farm /\_\_/

Homestead /\_\_/

5. Are there any other types of indigenous tree which was grown in this location but currently are no longer available? Yes /\_\_/ No /\_\_/ I don't know /\_\_/

If yes,  
specify.....

6. A. Based on your preference, between exotic and indigenous tree, which one is more preferred than another? Exotic tree/\_\_/ indigenous trees /\_\_/

Explain the reason why?

.....

7. Would you be willing to grow native tree species on your land without any incentives? If yes, explain what motivates you to be willing to grow native trees on your land. If no, please explain why not?

.....  
.....

8. List under below indigenous tree species do you like to use?

.....  
.....

Explain why?

.....

<b>SECTION C: NATIVE TREE SEEDS AVAILABILITY</b>
--

1. How do you access to native tree planting materials:

We collect the seeds in close natural forest /\_\_/

We collect the seeds on scattered remnant trees on farmland /\_\_/

We pick samplings from natural forest /\_\_/

We use Cuttings taken from remnant native trees /\_\_/

We get seedlings from local governance, civil society (N G Os) /\_\_/

Other provenances of planting materials (Please specify under below) /\_\_/  
.....  
.....

2. Can you mention the challenges you encounter in tree seed collection/getting the planting material?  
.....  
.....

3. Do you have the knowledge and skills to produce and grow native tree? No idea /\_\_/ insufficient skills /\_\_/ sufficient skills /\_\_/

4. A. Do you have a local tree nursery where native tree seedlings can be found? Yes /\_\_/ No /\_\_/

b. If no, do you need to own it locally? Yes /\_\_/ No /\_\_/

5. Have you ever got training on growing multipurpose native trees? Yes /\_\_/ No /\_\_/

6. If you do not have the knowledge and skills on growing multipurpose native trees. You need to get trained on these themes: ( you can choose more than one option)

- Native tree species identification and its multi functionality /\_\_/
- Seed collection and pre-treatment /\_\_/
- Seed bed preparation /\_\_/
- Seed sowing /\_\_/
- Seedling management in the nursery /\_\_/
- Seedling planting /\_\_/
- Tree management on farmland /\_\_/

<b>SECTION D: CLIMATE CHANGE RESILIENCE AND NTS</b>
---

1.a. Indicate the kinds of disasters or other big important events, which have occurred in your region and are caused by the climate change?  
.....  
.....

b. Show the impact of this disaster or other specified event.....  
.....  
.....

c. Which measures have been undertaken to mitigate them.....  
.....  
.....

d. Does existing native trees be affected? Yes /\_\_/ No /\_\_/ don't know /\_\_/

2. In term of pest, disease, between exotic and native tree species, which one is more affected.

Exotic tree /\_\_\_/ Native tree /\_\_\_/ I have no idea/\_\_\_/

Explain the reason why?

.....

3. Do you know some pest and diseases attacking native species in your farm?

Yes /\_\_\_/ No /\_\_\_/

Are there traditional methods to control them?

.....

**APPENDIX 2: FOCUS GROUP DISCUSSIONS WITH NTS GROWERS**

**1. Questionnaire instruction**

This questionnaire will be used as guide during the Focus Group Discussion (FGD). More clearly, the participants will be divided into small groups, and will be assigned specific tasks to be completed based on needed information. After, the results will be presented to the whole groups for the verification of information obtained. At the end, all necessary information will be collected and analyzed in order to complete and verify the information collected during the household survey. This discussion could be planned for a full day. Under below, there is a checklist of questions to ask in order to determine the main point of discussion in the FGD session.

All the information furnished and the identity of the respondent will be kept confidential. The participant’s name will not be used or identified in any reports using information obtained from this FGD. The research project team will ensure that confidentiality of participants in this study will remain secure.

**2. RESPONDENT CONSENT FOR PARTICIPATION IN A RESEARCH PROJECT**

My participation in this project is voluntary. I give consent to be interviewed and to give any other relevant information if needed. I can refuse to answer any questions that are asked, and I may withdraw and discontinue participation at any time without penalty. If I feel uncomfortable in any way during the FGD, I have the right to decline to answer any question or to end the interview.

I understand that my response will be kept strictly confidential. I give permission for members of the research team to have access to my anonymous responses. I understand that my personal identification will not be linked with the research and I will not be identified in any report that results from this research study.

I agree for the data collected from me to be used in future research   
I agree to take part in the above research project

REPRESENTATIVE'S SIGNATURE

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

For further information, please contact: Dr Myriam MUJAWAMARIYA on phone number:  
0788422497

C0- INVESTIGATOR SIGNATURE

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

### Checklist for focus group discussions

Sector: ..... Cell: ..... Village:.....

<b>SECTION A: NATIVE TREE IDENTIFICATION AND CHARACTERISTICS</b>
--

#### Native trees found in respondent's land during the survey conducted in Bugesera District

N <sup>o</sup>	Native tree (kinyarwanda)	Scientific name	Frequency	Percentage
1	Umusave	Markhamia Lutea	55	60.4
2	Umuko, umurinzi	Erythrina abyssinica	50	54.9
3	Umuvumu	Ficus thoningii	42	46.2
4	Umuharata	Acacia polyacantha	20	22.0
5	Umunyinya	Acacia sieberana	19	20.9
6	Umubirizi	Vernonia amygdalina	20	22.0
7	Umuravumba	Tetradenia riparia/ Iboza riparia/ lithonia diversifolia	7	7.7
8	Umukunde	Cajanus cajan	5	5.5
9	Umurama	Combretum molle	14	15.4
10	Igicunshu		2	2.2
11	Umuzibaziba	Mitragyna rubrostipulata	1	1.1
12	Umunzenze	Hypericum revolutum	3	3.3
13	Umusibya	Apodytes dimidiata	1	1.1
14	Umumuna	Lanea schimperi	1	1.1
15	Umububa	Albizia versicolor	2	2.2
16	Umusagwe	Acokanthera schimperi	1	1.1
17	Umusagara	Vangueria infausta	3	3.3
18	Umusasa		1	1.1
19	Umugenge	Acacia hockii	2	2.2
20	intare y'irungu	Zanthoxylum chalybeum	1	1.1
21	Umurehe	Ficus ovata	4	4.4
22	Umuduha	Ephorbia candelabrum	2	2.2
23	Umwanya		2	2.2
24	Umubumbafuro		1	1.1
25	Umusange		2	2.2
26	Umuyenzi	Ephorbia tirucalli	53	58.2
27	Umuturamugina	Blighia unijugata	2	2.2
28	Igihondohondo		2	2.2
29	Akateye		1	1.1
30	Umusarasi	Garcinia buchananii	1	1.1
31	Umuhumuro		1	1.1
32	Umuruku		1	1.1
33	Umuvungavungo		2	2.2
34	Umutarama		1	1.1
35	Umutaba		1	1.1

36	Umunyaonza		2	2.2
37	Umunya gasozi		1	1.1
38	Umunazi		2	2.2
39	Umushikiri	Euclea racemosa	1	1.1
40	Umusabanyama		1	1.1
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				

1. The list under below specify the principle indigenous trees grow in this region.

Are there other types of indigenous trees which are not found in given list? Please list them

2. Among the listed NTS, what are the top ten list of preferred ones:

.....

( After, there will an exercise of performing pairwise ranking matrix to choose the most preferred in order to identify the top five list)

3. For the ones who are planted, what is the source of seedling?

.....

4. List the types of indigenous tree that was grown in this location but currently are no longer available?

**SECTION B: KNOWLEDGE AND COMMUNITY PERCEPTION ON NATIVE TREE**

1. Based on community preference and according to the information given in survey, why exotic trees are more preferred than indigenous trees?

.....

2. Among the listed indigenous trees, and based on your knowledge, which grow faster than others? .....

3. Is there any history about indigenous tree? Yes/\_\_\_/ No /\_\_\_/.....

If yes,

Explain.....

**SECTION C: NATIVE TREES VALUES**

1. List under below indigenous tree species the community like to use?  
.....

2. List the type of indigenous trees which provide the fruits?  
.....

**SECTION D: ACCESS TO INDIGENOUS TREES AND THEIR SERVICE**

1. In this region, is there a natural forest with indigenous trees? Yes /\_\_\_/ No /\_\_\_/

If yes, state their location.....

2. If the native trees adoption already exists, where do you collect seeds of native tree species? .....

3. What are the main challenges encountered for seed collection?  
.....

4. Do you have any traditional method of treating seeds to avoid their rotting or to facilitate their germination? Yes /\_\_\_/ No /\_\_\_/

If yes, explain.....

5. Do you have access to extension services about native trees management from planting to pruning and harvesting? Yes /\_\_\_/ No /\_\_\_/

If yes, what is your impression of the services ..... If no, what is the problem with the services? .....

**APPENDIX 3: PAIRWISE RANKING MATRIX OF 10 MOST PREFERRED TREES CHOSEN IN MUSENYI SECTOR**

	<b>Markhamia lutea</b>	<b>Ficus Thonningii</b>	<b>Acacia sieberiana</b>	<b>Combretum molle</b>	<b>Parinari curatellifolia</b>	<b>Teclea nobilis</b>	<b>Garcinia buchananii</b>	<b>Kigelia africana</b>	<b>Lannea schimperi</b>	<b>Olea africana</b>
<b>Markhamia lutea</b>		Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea
<b>Ficus thonningii</b>	Markhamia lutea		Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii
<b>Acacia sieberiana</b>	Markhamia lutea	Ficus thonningii		Combretum molle	Parinari curatellifolia	Teclea nobilis	Garcinia buchananii	Kigelia africana	Lannea schimperi	Olea africana
<b>Combretum molle</b>	Markhamia lutea	Ficus Thonningii	Combretum molle		Parinari curatellifolia	Teclea nobilis	Garcinia buchananii	Kigelia africana	Lannea schimperi	Olea africana
<b>Parinari curatellifolia</b>	Markhamia lutea	Ficus thonningii	Parinari curatellifolia	Parinari curatellifolia		Teclea nobilis	Garcinia buchananii	Kigelia africana	Parinari curatellifolia	Olea africana
<b>Teclea nobilis</b>	Markhamia lutea	Ficus thonningii	Teclea nobilis	Teclea nobilis	Teclea nobilis		Garcinia buchananii	Kigelia africana	Teclea nobilis	Olea africana
<b>Garcinia buchananii</b>	Markhamia lutea	Ficus Thoningii	Garcinia buchananii	Garcinia buchananii	Garcinia buchananii	Teclea nobilis		Kigelia africana	Garcinia buchananii	Olea africana
<b>Kigelia africana</b>	Markhamia lutea	Ficus thonningii	Kigelia africana	Kigelia africana	Parinari curatellifolia	Teclea nobilis	Garcinia buchananii		Garcinia buchananii	Olea africana
<b>Lannea schimperi</b>	Markhamia lutea	Ficus thonningii	Lannea schimperi	Combretum molle	Lannea schimperi	Teclea nobilis	Garcinia buchananii	Lannea schimperi		Olea africana
<b>Olea africana</b>	Markhamia lutea	Ficus thonningii	Olea africana	Olea africana	Olea africana	Olea africana	Olea africana	Olea africana	Olea africana	
<b>Times preferred</b>	<b>9</b>	<b>8</b>	<b>0</b>	<b>2</b>	<b>3</b>	<b>6</b>	<b>6</b>	<b>5</b>	<b>2</b>	<b>7</b>
<b>Rank</b>	<b>1</b>	<b>2</b>	<b>8</b>	<b>7</b>	<b>6</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>7</b>	<b>3</b>

**APPENDIX 4: PAIRWISE RANKING MATRIX OF 10 MOST PREFERRED TREES CHOSEN IN NTARAMA SECTOR**

	<b>Markhamia lutea</b>	<b>Ficus thonningii</b>	<b>Dombeya torrida</b>	<b>Mitragyna rubrostipulata</b>	<b>Ficus ovata</b>	<b>Garcinia buchananii</b>	<b>Parinari curatellifolia</b>	<b>Olea africana</b>	<b>Pappea capensis</b>	<b>Acacia sieberiana</b>
<b>Markhamia lutea</b>		Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea	Markhamia lutea
<b>Ficus thonningii</b>	Markhamia lutea		Ficus thonningii	Mitragyna rubrostipulata	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii	Ficus thonningii
<b>Dombeya torrida</b>	Markhamia lutea	Ficus thonningii		Mitragyna	Ficus ovata	Garcinia buchananii	Dombeya	Dombeya	Dombeya	Dombeya
<b>Mitragyna</b>	Markhamia lutea	Mitragyna	Mitragyna		Mitragyna	Mitragyna	Mitragyna	Mitragyna	Mitragyna	Mitragyna
<b>Ficus ovata</b>	Markhamia lutea	Ficus thonningii	Ficus ovata	Mitragyna		Garcinia buchananii	Ficus ovata	Ficus ovata	Ficus ovata	Ficus ovata
<b>Garcinia buchananii</b>	Markhamia lutea	Ficus thonningii	Dombeya	Mitragyna	Ficus ovata		Garcinia buchananii	Garcinia buchananii	Garcinia buchananii	Garcinia buchananii
<b>Parinari curatellifolia</b>	Markhamia lutea	Ficus thonningii	Dombeya	Mitragyna	Ficus ovata	Garcinia buchananii		Olea africana	Parinari	Acacia
<b>Olea africana</b>	Markhamia lutea	Ficus thonningii	Dombeya	Mitragyna	Ficus ovata	Garcinia buchananii	Olea africana		Olea africana	Acacia sieberiana
<b>Pappea capensis</b>	Markhamia lutea	Ficus thonningii	Dombeya	Mitragyna	Ficus ovata	Garcinia buchananii	Parinari	Olea africana		Acacia
<b>Acacia sieberiana</b>	Markhamia lutea	Ficus thonningii	Dombeya	Mitragyna	Ficus ovata	Acacia	Acacia	Acacia	Acacia	
<b>Times preferred</b>	<b>9</b>	<b>7</b>	<b>5</b>	<b>8</b>	<b>6</b>	<b>5</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>3</b>
<b>Rank</b>	<b>1</b>	<b>3</b>	<b>5</b>	<b>2</b>	<b>4</b>	<b>5</b>	<b>8</b>	<b>7</b>	<b>9</b>	<b>6</b>

**Appendix 5: Effect of different treatments on native tree seed germination**

NTS	Germination (%)												MGT (days)											
	T <sub>0</sub>			TCW			THW			TAS			T <sub>0</sub>			TCW			THW			TAS		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
<i>Markhamia lutea</i>	64	61.00	64	73	62	65	-	-	-	-	-	-	6.1	6.9	6.7	7.3	6.5	6.9	-	-	-	-	-	-
<i>Garcinia buchananii</i>	22.8	26.00	22.5	87	80	77	-	-	-	-	-	-	31.2	26.8	32.1	29.4	31.3	25.8	-	-	-	-	-	-
<i>Kigelia africana</i>	-	10	-	-	-	-	30	20	10	40	20	50	-	10	-	-	-	-	10.0	10.0	10.0	10.0	10.0	10.0
<i>Acacia sieberiana</i>	5	7.00	11	-	-	-	20	24	24	22	26	20	13.0	10.4	10.7	-	-	-	13.2	12.7	14.0	15.9	15.3	15.2

*T<sub>0</sub>: Control treatment TCW: Treatment with cold water for 24 hrs THW: Treatment with hot water for 24 hrs TAS: Treatment with acid sulfuric*

**Appendix 6 : Annexed photos of this research**



Figure 14: *M. lutea* in nursery at Musenyi site    Figure 15: Seedling of *G. buchananii* in nursery



Figure 16: *M. lutea* after 2 months after sowed in nursery    Figure 17: Status of *M. lutea* after 6 months



Figure 18: A session of measuring the growth performance of *M. lutea* in Ntarama nursery