Understanding the factors influencing smallholder farmers's willingness to adopt agroforestry in Gomba Village, Rwanda

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Abstract

Agroforestry practices are crucial in promoting sustainable agriculture, increasing biodiversity, and enhancing farmers' livelihoods. However, despite extensive research and extension efforts, smallholder farmers' adoption of agroforestry practices in Rwanda remains low. This study examined farmers' agroforestry preferences and factors influencing their adoption in Gomba Village. The data was collected through a survey and focus group discussion with households in Gomba Village, using stratified sampling and classifying them into three wealth groups (better-off, medium, and poor). The results indicated that socioeconomic factors play a significant role in agroforestry adoption, whereby wealthier households (better-off) had high number of trees, wirh mean total of 80 trees per households, followed by medium farmers with 54 trees poor farmers with 40 trees. Fruit trees, present in 85% of households, were the most popular tree species among farmers. The most popular fruit tree species were *Persea americana* (74% of households), *Carica papaya* (65%), and *Mangifera indica* (56%). Multipurpose trees, such as *Grevillea robusta* and *Vernonia amygdalina*, were also widely used because they provide essential products like stakes and fodder. The number of tree species increased with farm size, with better-off farmers having an average of 11 tree species versus 9 and 8 for medium and poor farm types. However, several factors limited the adoption of agroforestry. The main challenges were a lack of tree seedlings, labor shortages, and small farm sizes, with poor farmers facing the most constraints. The high cost of seedlings, particularly for grafted fruit trees, posed a significant barrier to adoption. Strategies for widespread adoption of these sustainable land management practices should prioritize improved input access, strengthened extension services, and agroforestry adoption incentives.

Keywords: Tree niche, tree species, farm type, on-farm, household

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Introduction

Agroforestry is a sustainable land management approach that integrates trees and shrubs with crops and livestock (Smith et al., 2012). It has received considerable attention for improving food security, enhancing livelihoods, and mitigating climate change's impacts on smallholder farming systems (Taye Gifawesen et al., 2020). Agroforestry has the potential to be vital in strengthening the resilience and productivity of smallholder farms in Rwanda, where agriculture is the foundation of the economy and a substantial portion of the population depends on subsistence farming (Bucagu, 2013). Nevertheless, despite the potential advantages and extensive research and extension endeavors, smallholder farmers' uptake of agroforestry practices in Rwanda remains limited (Ngango et al., 2024).

The scarcity of land in Rwanda poses a significant obstacle, leading to intense competition among various land uses such as cropping activities, forestry, grazing, and others (Ndayambaje et al., 2013). According to the study conducted by NISR (2012), approximately 66% of households cultivate less than 0.72 hectares, 32% cultivate less than 0.2 hectares, and 16% cultivate less than 0.1 hectares. The limited availability of land per household poses a significant obstacle for small-scale farmers to participate in agroforestry activities, particularly in establishing woodlots or allocating land exclusively for tree cultivation.

Nevertheless, despite the scarcity of land, small-scale farmers in Rwanda are progressively incorporating trees into different areas on their farms. Approximately 70% of agricultural households have at least one tree on their farm, as NISR (2012) and Ndayambaje (2013) stated. The agroforestry practices mentioned include intercropped trees, home gardens, trees planted along erosion control ditches and contours, and trees planted on field boundaries or farm edges (Ndayambaje, 2013; Ndayambaje & Mohren, 2011). Including trees in various on-farm niches indicates that small-scale farmers successfully integrate agroforestry practices into their limited land holdings, even if they cannot create separate woodlots or larger tree-based systems (Derero et al., 2021).

Though diverse planting systems and tree species exist within small farming systems, access to tree products, particularly wood fuel, bean poles, fruit, and tree fodder, is becoming increasingly important (Ndayambaje & Mohren, 2011). Researchers, extensionists, and policymakers proposed strategies for more agroforestry tree integration into

Rwandan farming systems. They include intensifying research on best forestry technologies, suitable tree species for different agroecological zones, and promoting agroforestry species (Stainback et al., 2012). For any agroforestry technology to be appropriate and effective, it has to fit a wide range of agroecological and socioeconomic conditions (Akamani & Holzmueller, 2017; Bucagu et al., 2013) prevailing in the farming system. Important decisions regarding farm management, like adopting and managing agroforestry technologies, are often taken at the farm level. Therefore, studies at the farm level can provide comprehension of the socioeconomic factors and attitudes leading farmers to plant trees (Ndayambaje et al., 2013). Research in Ethiopia and Uganda has identified a wide range of tree and shrub species with specific preferences for different niches such as homesteads, gully sides, and stream sides (Asmare et al., 2024; Kyarikunda et al., 2017; Sisay & Mekonnen, 2013). However, the availability of seedlings of desired species and water-logging have been identified as critical constraints to tree and shrub integration (Sisay & Mekonnen, 2013). Farmers in Ethiopia have expressed a desire for a high diversity of tree species, particularly those that yield edible fruits, but face challenges in meeting these demands due to limited seedling supply (Asmare et al., 2024; Kyarikunda et al., 2017). The scarcity of land and financial capital have been highlighted as significant constraints to tree planting (Kyarikunda et al., 2017).

The purpose of this study was to investigate the preferences of farmers regarding agroforestry practices and the factors influencing their willingness to adopt these practices by exploring agroforestry practices and farmers' preferences for trees at the farm level. Specifically, the study aims to (i) assess current on-farm tree species and niches, (ii) assess tree management practices and uses, and (iii) identify the constraints encountered by farmers at tree planting.

Research Approach

Research site characterization

The research was carried out in Gomba village, on the border of Lake Kivu (Lake Kivu border Agroecological zone (AEZ), Bwishyura Sector, Karongi District, Western Province. The selection of the research site was based on three criteria. Firstly, the assumption is that all farmers in Rwanda will be involved in agroforestry practices so that we are not tied to a particular geographic area. Secondly, little is known about agroforestry in Lake Kivu border AEZ because few researchers have worked so far on this region, and there is a need to document the agroforestry in this particular region. Lastly, Gomba village, situated in the middle of Kivu shores AEZ, shares major socioeconomic characteristics of the zone and can be considered a suitable representative study site for a detailed assessment of agroforestry diversity.

The research site is between 1482 and 1701 m in altitude and is characterized by highlands with steep slopes characteristic of the Karongi district. Karongi District has an altitude varying between 1470 and 2200 m, an annual rainfall of 1100-1500 mm, and slopes of 20-55% for about 80% of its surface (DDP, 2013; MINAGRI, 2010). The area has two rainy seasons, from mid-September-December & February-June, and two dry seasons, from December-January & June-mid September. The annual average temperature varies from 16 to 21°C. The dominant soils in the Karongi district were Acrisols and Cambisols. Cambisols were found on steep slope lands. They were shallow in depth. Acrisols were relatively deep, with an average soil depth of over 50 cm. These soils were strongly acidic due to the intrinsic parent materials and climatic conditions, shallow due to continuous erosion, and usually light to medium in soil texture (MINAGRI, 2010). The Greysols were also primarily found in different valleys between convex mountains and on the shores of Kivu Lake. The main crops were *Phaseolis vulgaris*, *Glycine max*, *Musa spp.*, *Manihotis esculanta*, *Ipomea batatas*, *Coffea* and fruits such as *Persea americana*, *Cyphomandra betacea*, *Carica papaya*, *Psidium guajava*, *Mangifera indica*, and different vegetables like *Daucus carota*, *Brassica oleracea, Solanum melongena*, *Amaranthus spp.*, etc. (DDP, 2013).

Household selection and characterization

The stratified sampling technique was applied to form a representative sample for data collection. A baseline survey was carried out to identify the significant socioeconomic features influencing the performance of agroforestry technology in the region. While all farmers share almost the same local conditions (soil, climate, etc.), social and economic conditions differ. Thus, this significantly influences decisions regarding agroforestry, as farmers in different groups enjoy different resources and face various constraints (Muthuri, 2017). A household typology was created based on critical criteria such as construction material of the house, land availability, off-farm income, and livestock ownership (Bucagu et al., 2013; Klapwijk et al., 2014).

The wealth ranking techniques allowed the identification of three farm groups, viz. better-off (B), Medium (M), and Poor (P) groups. The farmers in the same groups were nearly identical in many features, such as livestock ownership, land availability, labor and income availability, woodlot size, etc. (Table 1). The population list obtained from the Bwishyura sector office contained 161 HHs from the village, constituting the sampling unit for this research. From the list and with the help of local leaders, 27 households (HH) were randomly selected. Out of the households, 11HHs, 6HHs, and 10HHs were classified in the Poor, Medium, and Better-off categories, respectively (Table 1).

Table 1. ***Farm-type characterization***

Variable	Poor	Medium	Better-off
Sample size (n)	11	6	10
Land-availability (average)	0.5 ha	0.7 ha	1.4 ha
Woodlot size	0.08 ha	0.05 ha	0.37 ha
Household head	Mostly female-headed (8/12)	Mostly male-headed (5/6)	Mostly male-headed (9/10)
Livestock ownership	Own goat kept for a neighbor cow, or given a cow, few have one own cow	Own 1-3 goats and one cow	Three cows or more and goats
Off-farm income	None	Low-income generating off-farm activities	Salary, pension fees, small home business
Labor	Sell labor	Never sell labor, sometimes buys labor	Hire labor
Type of floor of the house	Earthen floor	Earthen floor	Cemented/lined house floor

Data collection and analysis

This research used surveys, field observations, and focus group discussions to collect data from 27 HHs. A survey questionnaire was used, and the collected data included the family composition, age of family members, education level, total number, size, ownership of fields, and off-farm income. Data collected on farm trees included the number of trees, tree species, tree niches, and management, which was paired with field observation. Focus group discussion helped collect information on farmer constraints while managing trees on their farms, perception about tree use, and choice for tree niches. Descriptive analysis was performed and means and percentages were reported to present the agroforestry status of different farm types. ANOVA was performed using the GenStat software program (VSN International, 2011) to statistically compare results on the number of trees between farm types.

Results

Tree species distribution on different farm niches

Several 30 species of trees and shrubs were inventoried at the research site. *Euphorbia tirrucalli* and *Dracaena afromantana,* which mainly used species to mark farm boundaries, were not counted. All trees were distributed in woodlots, around the homestead, on field limits, intercrop (staggered trees), on infertile pieces of land or rock outcrops, along roads and riversides, and gullies.

Seventeen tree species were around the homestead, the niche with more diverse species (Fig. 2-a). Trees on this niche were planted as house fences or scattered within the compound, planted next to the compound, or simply in the courtyard. Poor farmers had the highest percentage of trees (47%) concentrated around homesteads and fewer trees (30%) on field limits. Across all farm types, 94% of *Ficus spp.* and 64% of *Cypress spp.* were planted as live fence/enclosure components. The niche was also home to *Manihot glaziovii* (58%), *Markhamia lutea* (50%), *Jacaranda mimosifolia* (50%), *Tedradenia ripari* (43%), and fruit trees, namely *Mangifera indica (*39%), 35% of *Carica papaya* and 28% of *Psidium guajava.*

The highest number of trees (54% and 38%) was found around the farm/field boundaries in medium and better-off farms, respectively. About 15 tree species were planted on farm boundaries (Fig. 2-b, c). Trees were planted on terrace risers and contours, fields' limits within the same farm, or as the demarcation between two adjacent farms. The common species were *Calliandra calothyrsus (*94%), 77% of *Grevillea robusta*, 50% of *Jacaranda mimosifolia,* and 50% of *Vernonia amagdelina*. Also, some trees for human consumption, like *Psidium guajava* (52%), 44% of *Mangifera indica,* and 38% of *Manihot glaziovii* were found in these niches. Almost all trees for *Euphorbia tirrucalli* and *Dracaena afromantana* were planted on farm boundaries.

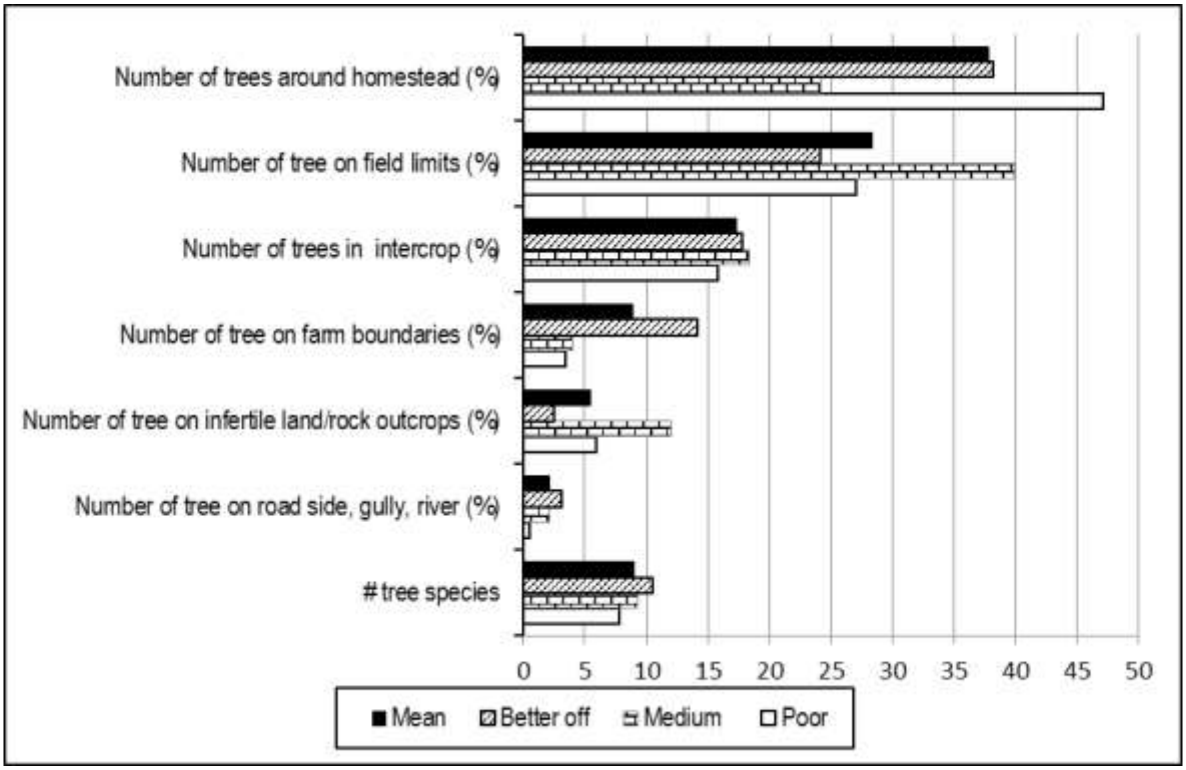
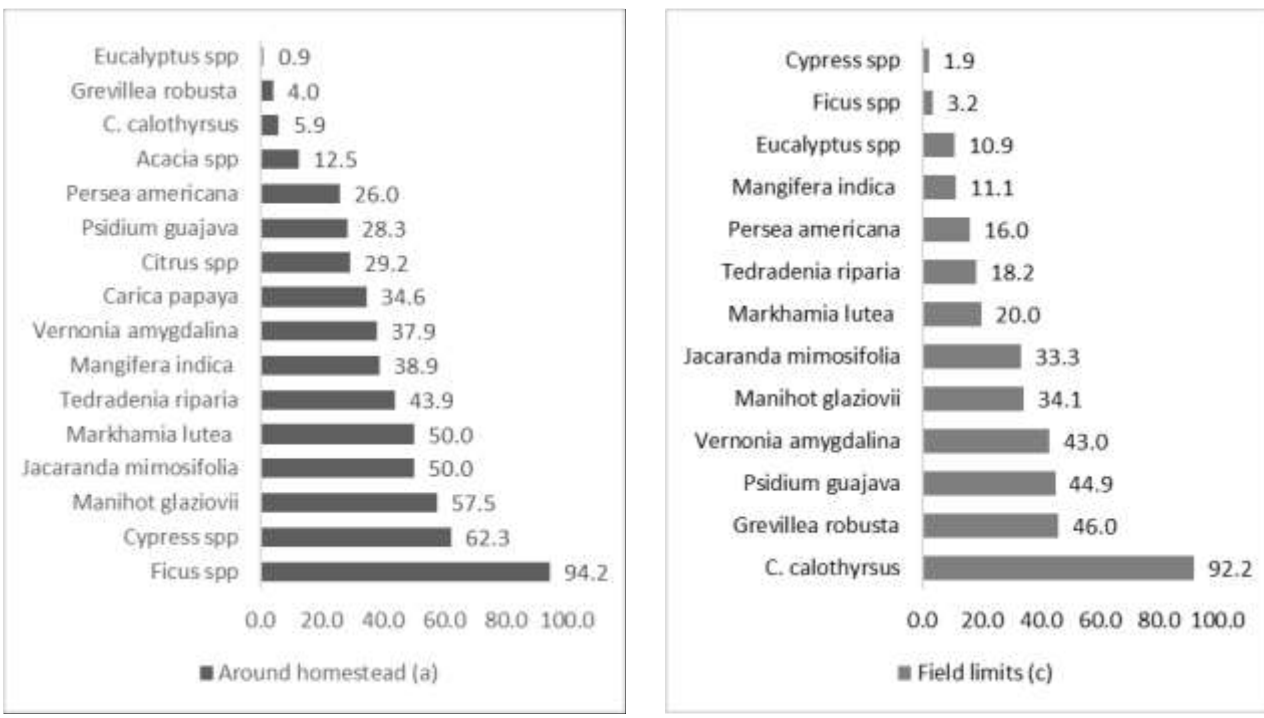


Figure 1. Presence of trees per niche and farm type



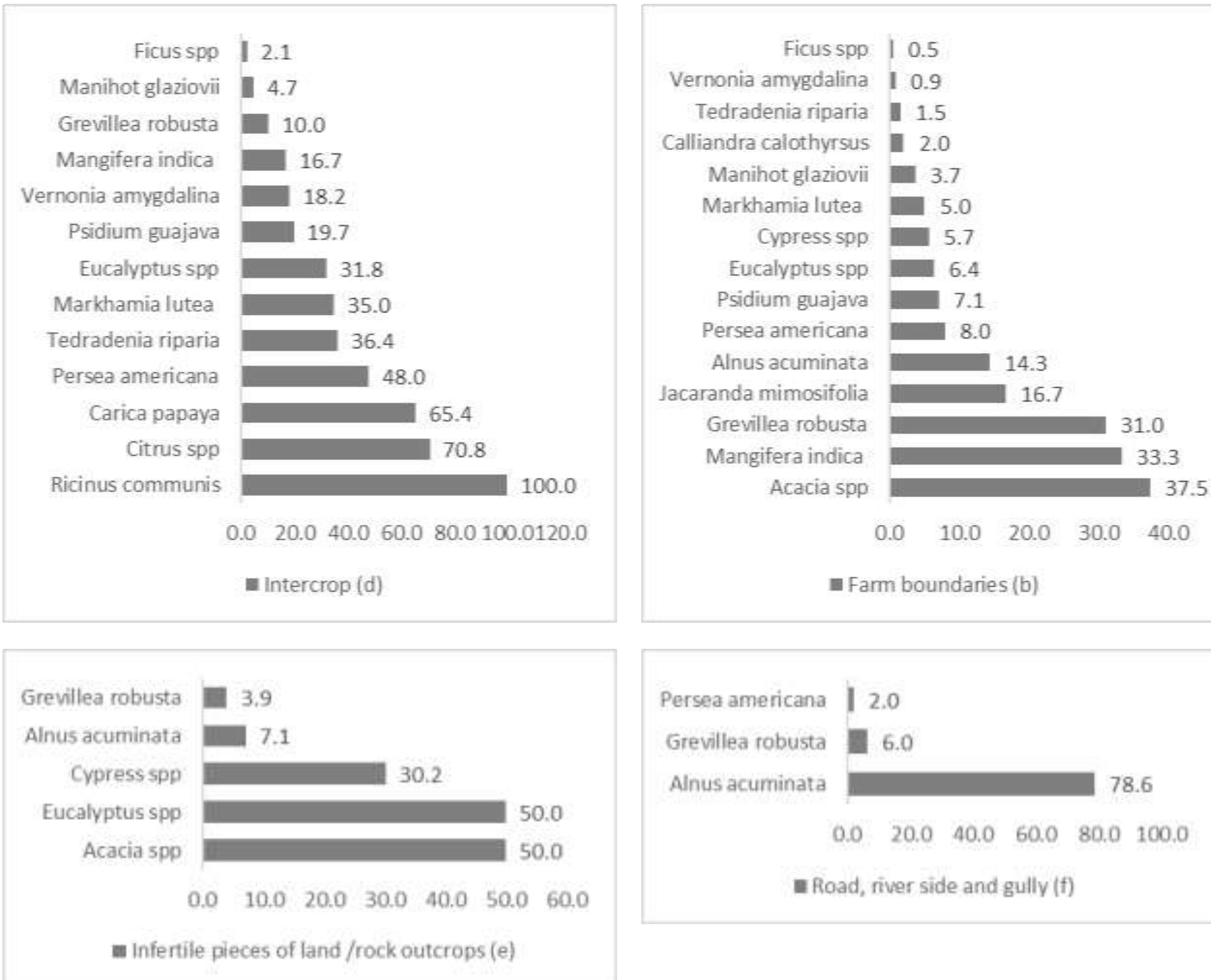


Figure 2. Number (in %) of trees around the homestead (a), field limits (b), farm boundaries (c), intercrop (d), infertile pieces of land/rock outcrops (e), and road, riversides and gully (f)

About 16-18% of all planted trees were mixed with farm crops. Fruit trees mainly were intercropped, where 71% of *Citrus spp*., 65% of *Carica papaya*, and 48% of *Persea americana* were intercropped (Fig. 2-d). The banana & common bean (*Musa spp. & Phaseolus vulgaris*) cropping systems prevail in the research site. Our results for season A showed that 42% of farmlands were under this system, except in a few banana sole plantations, *Phaseolis vulgaris* were intercropped in *Musa spp.* Plantations. About 22% and 13% of the land were under fallow and woodlots (*Eucalyptus spp*. and a few *Grevillea robusta*), respectively. The rest of the land was occupied by cassava (9%), coffee (4%), sweet potato (4%), maize (3%) and taro (1%). There was also 1% land under sugar cane, pineapple, eggplant, soybean, and amaranths. Also, 100% of *Ricinnus communis* were found under banana plantations (around 99% of trees), and the rest were found in standard bean fields. Other tree species found in intercrops were *Tedradenia riparia* (36%), *Markhamia lutea* (35%) and *Eucalyptus spp.* (31%). A high percentage of households intercropped fruit trees; common species were *Persea Americana* (41% of HHs) and *Citrus spp*. (30% of HHs), *Carica papaya* (15%) and *Psidium guajava* (18% HHs). *Grevillea robusta* (in 26% HH).

Infertile pieces of land/rock outcrops were naturally much eroded, very shallow soil or very rocky land zones, mostly found on steep lands commonly present in research sites. These zones were not cropped, and fewer trees (3-10 trees) were found grouped here in a form that cannot be either a woodlot or intercropped trees. The 12%, 6%, and 3% of trees were planted on medium, poor, and wealthier farm types. Only 5% of trees were found in these niches (Fig. 2-e). The predominant species were *Eucalyptus spp.* (50%), *Acacia spp.* (50%) and *Cypress spp.* (30%). A few species (2% of trees) were found along roads, riversides, and gullies (Fig. 2-f). The most important species on niches were *Alnus acuminata* (79%) and 6% of *Grevillea robusta*, which were cultivated with the main objectives of helping stabilize the sides of river gullies and delineate roads and pathways.

Farmers' preference for tree species

Among 30 species of trees and shrubs inventoried in the research site, several species were only present in a few households and were deficient in numbers. Only species in at least 10% (N=3/27) of households were considered to assess farmers' preferences. Twenty species were present in at least 10% of households: the more significant land availability, the more diversified the tree species. The results showed that better-off farmers had a mean of 11 tree species, compared to 9 and 8 for medium and poor farm types. The results on tree species distribution among households were reported in Fig. 3.

Trees species used for human consumption (fruit and leaves) dominate the research sites. Manihot glaziovii and Psidium guajava were at the lead, both present in 85% of households, and Persea americana was found in 65% of households. Others were common fruit species such as Citrus *spp.* (42% HHs), *Carica papaya* (38% HHs) and *Mangifera indica* (31% HHs). Multipurpose trees like *Grevillea robusta*, *Vernonia amygdalina,* and *Ficus spp.* were present in 81%, 77%, and 62% of households, respectively. They are preferred as timber (*Grevillea robusta*), stakes, and firewood sources (*Grevillea robusta*, *Vernonia amygdalina,* and *Ficus spp.*). They also provide fodder

(*Vernonia amygdalina* and *Ficus spp.*) and medicine (*Vernonia amygdalina*). Another highly present species was *Euphorbia tirrucalli*, found in 54% of households, where it was mainly used to mark field boundaries or as live fence trees. Among tree species less distributed in households were *Acacia spp*., *Jacaranda mimosifolia*, and Markhamia lutea, which were only present in 11% of households. Also, *Erythrina abyssinica*, *Polyscias fulva*, *Cajanus cajan*, *Morus alba,* and *Annona reticulata* were present in only 7% of households of the study sample.

Better-off farmers also had a higher number of trees, with a mean total of 80 trees per household (23-215 trees), followed by medium farms with 54 trees per household (28-103 trees) and a low number of 40 trees per household (6-107 trees) on poor farms. Better-off HH had a high mean number of trees for *Grevillea robusta* (20 trees/HH) compared to the medium HH (4 trees/HH) and poor HH (3 trees/ HH), and for *Vernonia amygdalina* with 11 trees/HH compared to 7 trees/HH on medium farms and eight trees/HH on poor farms. It was the same case for *Ficus spp.* (15 trees/HH) against 4 and 1 tree/HH on medium and poor HHs, respectively; *Psidium guajava* (6 trees/HH) against 5 and 4 trees/HH on medium and poor HHs, respectively; *Citrus spp*. (2 trees/HH) against 0 and 1 tree/HH on medium and poor farms, respectively. Better-off households were also found to have a relatively high average number of trees for *Carica papaya*, *Cypress spp., Mangifera indica,* and *Acacia spp.*

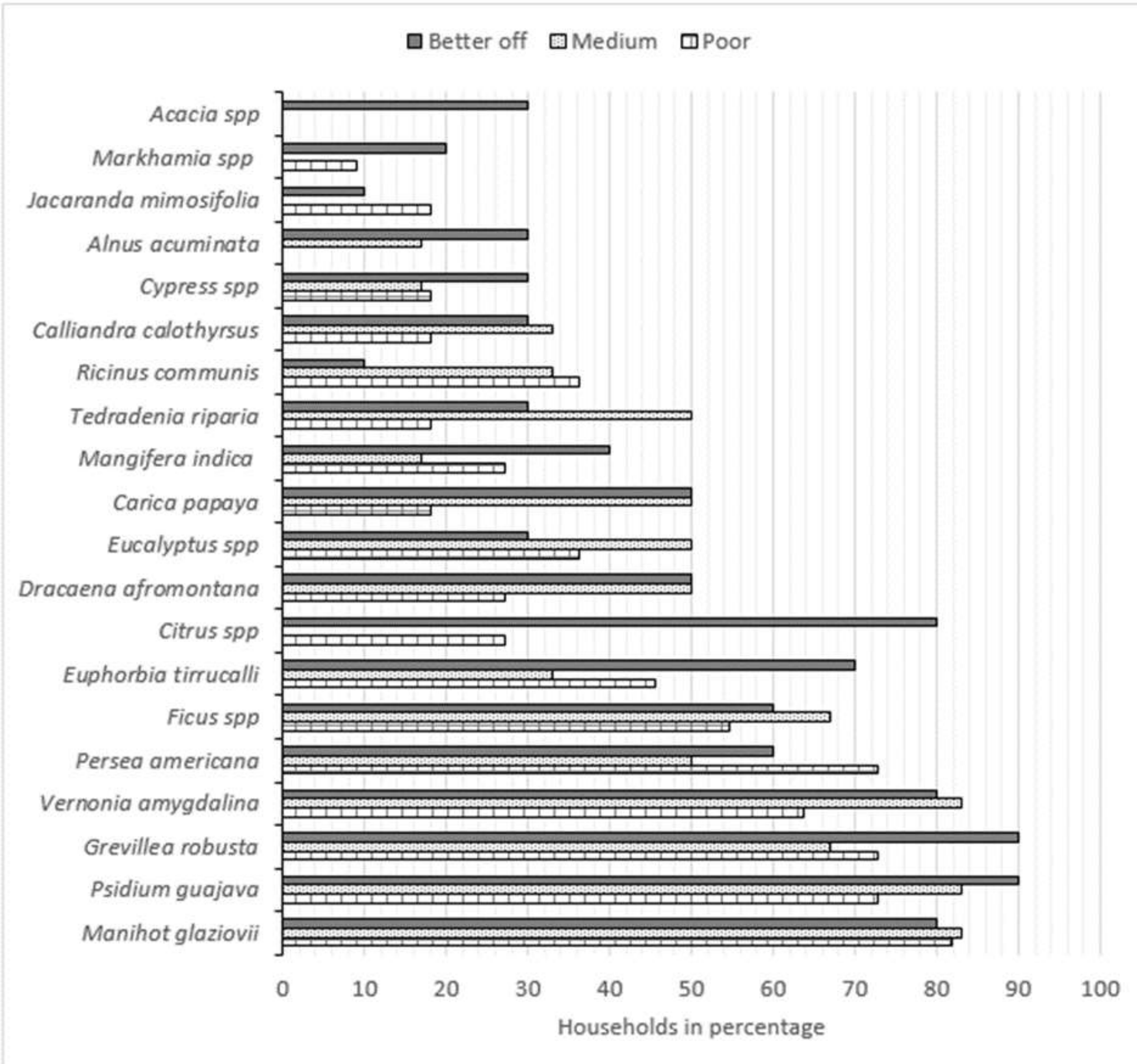


Figure 3. Percentage of households with tree species per farm type

Management practices

The main tree management activities were fertilization, weeding, and pruning (Table 2). Maintenance activities depend on several factors; the important ones were niches where tree species were planted, the cropping systems in the field, and farmer appreciation for tree species. Fruit tree species like *P. americana*, *M. indica*, *C. papaya*, *P. guajava*, and *Citrus spp.* Often intercropped were commonly weeded and fertilized. This was the same for *Ricinus communis,* mainly established in banana and bean plantations. All the above species benefited from the maintenance activities of associated crops. Except for some fruit tree species (ex., *C. papaya,* and *Citrus spp.*), farmers confirmed that they did not directly target tree species for weeding and fertilization but rather the associated crops. Thus, the trees (ex., *G. robusta* and *V. amygdalina*) on field and farm boundaries also profited from caring activities targeting the nearest field crops. Pruning was destined for trees that have the coppicing ability, such as *G. robusta, C. calothyrsus*, *V. amygdalina,* and *A. acuminata,* to give them an excellent growing structure, to minimize competition but also to obtain from them stakes, fodder, or fuelwood.

Table 2. ***Maintenance practices per tree species***

Tree name	N	HH weeding trees (%)	Tree name	N	HH weeding trees (%)
Ricinus communis	22	100	*Calliandra calothyrsus*	8	50.0
Persea americana	11	64.7	*Psidium guajava*	22	45.5
Mangifera indica	8	62.5	*Citrus spp.*	12	41.7
Carica papaya	10	60.0	*Grevillea robusta*	21	38.1
Psidium guajava	22	64.7	*Vernonia amygdalina*	20	35.0
Manihot glaziovii	22	54.5	*Eucalyptus spp.*	10	10.0
Tree name	N	HH pruning trees (%)	Tree name	N	HH fertilizing trees (%)
Grevillea robusta	21	85.7	*Carica papaya*	10	30.0
Alnus acuminate	4	75.0	*Citrus spp.*	12	25.0
Calliandra calothyrsus	8	50.0	*Persea americana*	11	11.8
Vernonia amygdalina	20	25.0	*Psidium guajava*	22	4.5
Psidium guajava	22	9.1	*Grevillea robusta*	21	4.8
Cypress spp.	6	16.7			
Jacaranda mimosifolia	3	33.3			

Potential for on-farm tree planting

To assess the potential for on-farm tree planting, farmers were requested to list the trees they needed and niches (woodlots excluded) where they wanted to plant trees. Almost all households (89%) claimed to be unsatisfied with the number of trees they already had. Farmers unwilling to plant more trees claimed they already possessed sufficient trees or were too old to grow them again. Results showed field limits and farm boundaries as niches where farmers intended to plant many trees (56% of trees). Farmers planned to grow 50% and 6% of the trees on field limits and farm boundaries, respectively. Only 22% of trees would be intercropped, and 12% of trees were destined to be planted around the homestead. Farmers wished to produce 5% of trees on other niches, comprising infertile pieces of land, roads, riversides, gullies, and standard fields. Fields around the homestead were the niche highly populated with trees (38%), and farmers intended to plant only 12% of trees there, undoubtedly due to limited space remaining in this location. With 56% of trees destined for on-farm boundaries and field limits niches, the results explicitly show that farm boundaries were the niches to host most of the trees to be established by farmers shortly.

Apart from *Grevillea spp. and Calliandra calothyrsus,* which were needed in 56% and 22% of households, respectively, fruit trees were the tree species most required by farmers. *Carica papaya* and *Citrus spp*. were needed at the lead by 48% and 44% of households. Also, *Cyphomandra betacea* (37%), *Mangifera indica,* and *Persea americana* (33%) were among the species most needed by farmers. For tree species, there was a significant difference (p = <.001) in number of trees requested for planting. *Grevillea robusta* (11-20 trees/HH), *Cyphomandra betacea* (2-11 trees/HH), *Calliandra calothyrsus* (5 trees/HH), *Carica papaya* (1-5 trees/HH) were much more needed compared to other species like *Persea americana* (0.3-0.6 tree/HH). The poor farmer category needs to plant more trees than other farm categories. For instance, *Grevillea robusta*, *Carica papaya,* and *Citrus spp*. were required by 79%, 55%, and 55% of poor households, respectively, but required by only 40%, 40%, and 30% of households for better-off farmers. On average, a poor household needed a higher mean number of trees than a better-off household for all tree species except for *Cyphomandra betacea* and *Persea americana*. Expressed on the size of land tenure, poor farmers also emerged to be ones that wanted many trees per hectare for five of seven needed tree species; these were *Grevillea robusta*, *Carica papaya*, *Citrus spp.*, *Persea americana,* and *Calliandra calothyrsus.* Better-off farmers already had more diversified tree species, a comparatively high number of trees, and a big forest area. It was apparent that their need for trees was comparatively slightly low.

From 20 tree species found in at least 10% of households, only eight (*Eucalyptus spp*. not reported as it was destined for forests and woodlots) have been requested by farmers for further planting. When tested about trees knowledge, few farmers hardly knew the other two extra trees (for example, *Gliricidia sepium, Senna spectabilis, Acassia angustima*, etc.) apart from what was already in the region. Particular trees may not be listed as needed simply because farmers have already not actively planted them. They include trees that often germinate naturally (ex. *Ricinus communis, Vernonia amygdalina,* *Markhamia lutea, Ficus spp*) or those when used for other purposes as fence components, stakes, etc. (ex. *Euphorbia tirrucalli, Vernonia amygdalina, Draceana afromontana*) sprout and grow into new trees. Though farmers could produce seedlings for some fruit species (ex., *Mangifera indica,* and *Persea americana*), they were more interested in getting quality materials (for ex., grafted seedlings) that they could not produce themselves.

Constraints in tree planting

A focus group discussion (FGD) was held to assess farmers' main constraints vis-a-vis tree planting. The main constraints were lack of seedlings, labor scarcity, land scarcity, and fear of tree competition with crops (Fig. 4). Among constraints, the major one was the lack of seedlings raised by 81% of households. No tree nursery was near the study site, as the closest was located at 2.5 to 3 hours walk. Also, farmers reported the unavailability of some tree species in nurseries as a big concern. It is even worse for farmers wanting seed to produce seedlings themselves, as there is no seed selling point in the region. Some seedlings were planted by private farmers in surrounding areas or collected from wildlife for tree species that quickly germinate in nature, even if their quality is questionable.

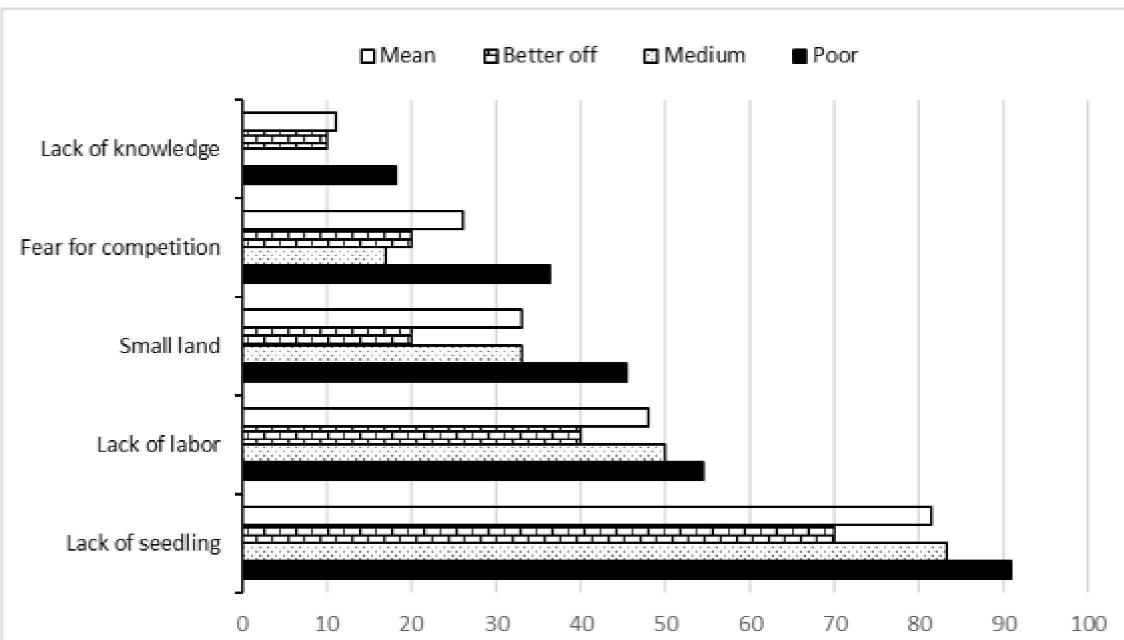


Figure 4. Constraints for tree planting per farm types

Another big issue was the high cost of seedlings. In the study area, the price was 150 Frw per seedling for *Grevillea robusta* or *Eucalyptus* spp. and 1500 Frw for grafted fruit trees (ex. avocado and mango). The price was judged as very high for some tree species (ex., *Grevillea robusta* or *Eucalyptus* spp.) while it was said to be pretty low (30 Frw/seedling) in other regions like Huye, Muhanga and Kigali city. The gathered information (personal communication) showed the same price range (1000-2000 Frw) for the grafted fruits in those regions.

Other standard and significant constraints were labor and land shortage, raised by 48% and 33% of households, respectively. Poor farmers were the most constrained, with 55% and 45% of households facing labor and land shortages. Better-off farmers can afford to pay for tree seedlings, transport, and planting labor. The land size highly affects the choice of tree species, the number of trees to be produced, and the tree planting system (ex, woodlot, boundary planting, etc.). This research showed that more trees in boundary planting and big-size woodlots were for better-off farmers whose farmlands were extensive compared to their counterparts in the rest of the farm types. Many poor farmers feared tree competition with crops and had mentioned it as a severe challenge, holding them from planting trees with their crops.

Discussion

Diverse on-farm tree niches

Better-off farmers had more diversified species and a higher average number of trees per household for many tree species (Kassa et al., 2015). This superiority over other farm types could be attributed to different factors, among them large farm sizes and comparatively high-income resources. The results showed that many trees on the farm were found around the homestead and on farm/field limits across all farm types (Fig. 2-a, b). It is a traditional system in Rwanda to grow live fences around the house to protect against animals and thieves and to preserve some life privacy. Many of the trees (ex., *Ficus spp., Tedradenia riparia, Vernonia Magdalena, and Manihot glaziovii*) grew from branches and stems that were used for fencing (Balasubramanian & Egli, 1986). Also, fruit seeds eaten at home spread all around the homestead, with prevailing fertile soils (Bucagu, 2013; Kiyani et al., 2017); they germinate and are left to grow into trees (ex., *Carica papaya*, *Psidium guajava*, *Persea americana*). They were kept near home compounds for protection and accessible product collection (Kiyani et al., 2017; Muthuri, 2017). Better-off farm size (1.4 ha) doubles a farm in medium (0.7 ha) and triples that of poor farmers (0.5 ha) (Table 1). Klapwijk et al. (2014) found the variation in the number of fields and, therefore, the number of field edges in farmers' lands in different wealthier groups. Better-off and medium farmers planted many trees on farm and field boundaries (Fig. 2-b), while many poor farmers planted a high percentage of trees around the homestead, probably due to low land availability. *Grevillea robusta* and *Calliandra calothyrsus* dominate on field and farm boundaries (Fig. 2-b, c). Farmers' choices were influenced by neighbors or the experience of extensionists (Muthuri, 2017). Extensionists considered their role in risers/embankment stabilization, contributing to soil erosion control, though farmers did not recognize it as an essential motive for tree planting (Ndayambaje et al., 2013). Many *Psidium guajava* (52%) and *Mangifera indica* (44%) were found on farm and field boundaries. *Psidium guajava* is a common and less protected fruit tree in the area, and it is also observable in bushes where children and birds harvest it. *Mangifera indica* needed ample space to grow and were found either around the homestead or on limited fields close to it to limit its competition with the crops.

Fruit trees were commonly intercropped in the predominant banana-bean system (Fig. 2-d). It is a widespread culture in Rwanda to intercrop fruit trees in crop fields (Ndayambaje et al., 2012). While some fruits were less competitive (e.g., *Carica papaya*, *Citrus spp*.), others (e.g., *Persea americana*) occupy ample space and compete highly with crops. Despite that, farmers accepted the trade-off yield decrease, underscoring their economic importance to farmers (Schaffer et al., 2024). They also mixed crops with indigenous trees that are known to be less competitive, such as *Ricinnus communis, Markhamia lutea,* and *Tedradenia riparia.* Though highly competitive with crops, some *Eucalyptus spp.* were found intercropped. They were often left in the field after cutting and uprooting the woodlot of *Eucalyptus spp*. or from the nearest closer woodlot invasion. They were regularly cut to limit their competition with surrounding crops or left to grow, changing the field into a woodlot in the future. To restrict their competition with the crops, *Eucalyptus spp.*, *Acacia spp.,* and *Cypress spp.* were often found on shallow, rocky, and infertile soils (Ndayambaje et al., 2013). Local leaders mainly influenced the move to plant trees in these niches to protect rivers and roadsides.

Tree niches were essential determinants for weeding, pruning, and fertilizer application. Trees in intercrop and at field limits were the ones that mainly were weeded and fertilized. Coppicing trees in crop fields or their vicinity were often pruned to minimize their competition with the crops and to find stakes, firewood, and fodder (Chavan et al., 2018; Swieter et al., 2022). The proximity to food crops allows farmers to care more for these species.

Farmer's preference for tree species

The research results show a high distribution of many tree species across households in the research location. Compared to research results from different AEZs of Rwanda, many tree species were highly distributed in Kivu Shore AEZ households. This superiority can be attributed to good biophysical prevailing in Kivu Shores AEZ (DDP, 2013; MINAGRI, 2010), where some constraints to tree planting, like prolonged droughts, termites, and low temperatures, are not succeeding. Tree species for human consumption (mostly fruit) were highly preferred and predominant species. The results corroborate different research on the high affinity of Rwandan farmers to fruit tree species (Ndayambaje et al., 2012). Nduwamungu et al., 2012, reported that only 30% of Nyanza, Southern Province households had fruit trees. In Volcanic highlands, (Nahayo et al., 2013) reported 20% of households with *Persea americana*, while (Muthuri, 2017) reported 16% and 14% of households for *Persea americana* and *Mangifera indica,* respectively, in Eastern Rwanda (Bugesera District). A rough estimation indicates that 37% and 17% of households cultivate avocado and papaya throughout Rwanda (NISR, 2012). Ndayambaje et al. (2013) reported *Persea americana* in 40% of HHs, *Carica papaya* in 10%, and *Mangifera indica* in 9% of Rwanda's low, medium and highitude AEZ.

Apart from fruit trees, other predominant trees were *Grevillea robusta* and *Vernonia amygdalina,* the primary sources of stakes, alongside other essential products and services (Ndayambaje & Mohren, 2011). Stake supply is a growing concern that needs to be addressed. Standard bean cropping systems prevailed in the research areas, and farmers favored climbing beans that were more productive, leading to an increased need for stakes. *Grevillea robusta* (in 81% HHs) is a popular tree species in Rwanda and was widely planted on soil erosion trenches, which later became field limits (Klapwijk et al., 2014). These trenches were created during community works under the guidance of extensionists and local leaders. While all households owning *Alnus acuminata* planted it for soil erosion control, *Calliandra calothyrsus* and *Vernonia amygdalina* were recognized by only 13% and 10% of farmers as purposely planted for soil erosion control. Farmers quickly realized this role for Alnus *acuminata* because it was produced on riversides to stabilize the embankment. For the rest of the tree species, it was obvious that many farmers were not aware of the role of trees in soil fertility management and environmental protection. *Vernonia amygdalina* (77% HHs) are highly appreciated for stakes, fodder, fuelwood, and medicine, while *Ficus spp* (62% HHs) is used to construct the live fence and as the source for fodder.

Grevillea robusta household distribution is comparable with that in Nyabihu and Nyanza districts, where 77% and 69% of households were found with it (Nduwamungu et al., 2012). There were relatively low figures for households with *Grevillea robusta*, *Vernonia amygdalina,* and *Ficus spp* for the rest of the regions. For example, *Grevillea robusta* was found present in only 26% of households in the dry area of Bugesera (Muthuri, 2017) and in 33% of HHs across low, medium, and high-altitude AEZ of Rwanda (Ndayambaje et al. 2013). Ndayambaje et al. (2013) reported only 9% and 12% HHs with *Vernonia amygdalina* and *Ficus spp*.

Potential for on-farm tree planting

Most farmers (89%) want to plant more trees on the farms, and fruit species were at the lead among tree species. Only eight (8) tree species were requested for planting, showing the farmer's rigorous selection of tree species and probably the farmer's limited knowledge of other existing tree species. Particular tree/shrub species (*Ricinus communis, Markhamia lutea, Ficus spp.*, *Euphorbia tirrucalli*, *Vernonia amygdalina, Dracaena afromontana, etc.*) may not be listed as needed simply because they were already not actively planted by farmers. Requested fruit trees were common (except *Cyphomandra betacea*) in the region, and many farmers already have them, underscoring their economic roles in rural livelihoods. Our results corroborated many findings, stating that fruit trees were among the species most needed by farmers (Bucagu et al., 2013; Ndayambaje et al., 2012). There is a shift from homestead planting to boundary planting (56% of trees) and intercropping (22%) for available niches—only two non-fruit tree species, viz. *Grevillea robusta* and *Calliandra calothyrsus* have been requested. With a predominant banana & beans system, farmers were increasing interest in climbing bean stakes (Breure & Kool, 2014). *Grevillea robusta* and *Calliandra calothyrsus* are continuous sources of stakes, later used as wood fuel when old. They are also sources of timber (grevillea) and fodder (Calliandra) and are less competitive with crops.

The results indicated that many households lacked seedlings for tree planting (Fig. 4). Seedlings were scarce because of the absence of seed sourcing points and the long distance to the nursery, the lack of diversified and suitable quality tree species, and the cost of seedlings (Nahayo et al., 2013). So, farmers relied on their collected seeds, private and wild-grown seedlings (Stainback et al., 2012). In addition to a lack of seedlings, labor and land shortages constrain poor farmers from tree planting. Better-off farmers can either plant or afford to pay for labor for tree seedlings transport and planting. Despite the smaller land size, the need for trees per household and per share is higher in poor farmers than in other farm types for many tree species. These results collaborate on different findings where the immense land size highly affects the choice of tree species, number of trees, and tree planting system (ex., woodlot, boundary planting, etc.) (Bucagu, 2013; Kassa et al., 2015). Better-off farmers (40%) claimed that having sufficient trees (in forest/woodlots and on-farm) means no need for them to plant more. Many poor farmers feared tree competition with crops and had mentioned it as a severe challenge, holding them from planting trees with their crops.

Conclusion

Farmers' practices were widely diversified and differed according to socioeconomic conditions in different farms. The better-off farm has more diversified species and many trees, which could be related to more available land and other socioeconomic conditions characterizing this particular farm type. Better-off farms possess a big farm size, resulting in the allocation of many trees on the boundaries of fields and farms. As the farm size reduced, farmers tended to concentrate the trees around the home compound, resulting in poor and medium farms focusing more trees around the home compound.

The tree species used for human consumption (fruits and leaves) dominate the research location most. They were followed by multipurpose tree species like *Grevillea robusta*, *Vernonia amygdalina,* and *Ficus spp.*, which provide a range of products like timber, stakes, fodder, and firewood. Generally, trees meant for human consumption were planted around home compounds for protection and accessible collection of products. Also, less competitive trees were planted on field limits or mixed with crops, while the rest of the tree species were planted on rock outcrops and road/river sides. In intercrop and on-field limits, trees were weeded and fertilized, while pollarding trees were pruned to minimize competition with crops, and collected branches were used as fodder, stakes, or firewood. The move for more on-farm tree planting is high in poor and medium farm types, though they were more constrained by the lack of seedlings, labor, and small land. Better-off farm types do not feel this move because they already have many trees on their farms. For potential tree niches and practices, places for trees were more available in boundary planting and intercropping systems and were increasingly decreasing around home compounds.

Regarding available niches, the selection of tree species for propagation in research and extension should involve farmers, and the focus should be on less competitive and high-economic value tree species for farmers to accept trade-offs in crop production. Fruit, fodder, and stakes supplying trees/shrubs should be highly considered in the research and development priorities for slight farming improvement. There was a need for research and promotion of indigenous trees and shrubs, as farmers were familiar with their propagation, planting, and maintenance. There was hope that more trees could be planted if the seed center and tree nurseries could be available near small farmers. The above facilities could provide diverse and good quality seedlings at a low cost, motivating farmers to plant more trees. Therefore, all main actors (private, NGOs, and public institutions) should use seeds and seedlings near small farmers.

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