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Research Article

The Assessment of Agroforestry Practices in Mukura Sector, Huye District, Southern Rwanda

Doreen Mukoobwa, Benitha Zaninka, and Canisius Patrick Mugunga

The Department of Forestry & Nature Conservation, College of Agriculture, Animal Sciences & Veterinary Medicine, University of Rwanda, P.O. Box 117, Huye, Rwanda

Correspondence should be addressed to Canisius Patrick Mugunga; mugungacp@gmail.com

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Agroforestry has the potential to contribute to the improvement of household livelihood, since its various forms offer multiple alternatives and opportunities to farmers. This study assessed agroforestry practice in Mukura sector, Huye district, Rwanda. A sample of 100 households was selected by stage sampling, randomly choosing four cells and two villages per cell in Mukura Sector. Face-to-face interview was dispensed to household heads, and data were collected on agroforestry practices, on-farm tree species, tree spatial arrangements, tree products, and the adoption rate. Woody species diversity and similarity were determined by using Shannon–Weiner diversity and Sørensen's indices, respectively. Sixty percent of the farmers practiced agroforestry. Ten woody species were observed to grow on farm, providing varied products of timber, firewood, food and fodder, stakes for climbing beans, and income. Low adoption of agroforestry practice was reported resulting from small land, land tenure, ignorance, unavailability of tree seedlings, and the avoidance of tree-crop competition. On-farm tree diversity was observed to be higher than several other sites in Rwanda. The different cells of Mukura Sector grow the same woody species on the farms as demonstrated by reasonably high indices of similarity. We recommend that efforts be made to reinforce extension services to improve farmers' awareness on the contribution of agroforestry to their social wellbeing. Ways of making seedlings available for planting should also be explored.

1. Introduction

Agroforestry is the combination of agricultural and forestry technologies to create integrated, diverse, and productive land use systems. It is the land use system in which woody perennials (trees, shrubs, palms, and bamboos) are deliberately used on the same land management unit as agricultural crops (woody or annual), animals or both, in some form of spatial arrangement or temporal sequence [1, 2]. It is also defined by [3] as a sustainable land management system which constitutes the overall yield of the land, combines the production of crops plus tree crops and forest plants and/or animals simultaneously or sequentially, on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.

Presently, land degradation and natural resource disasters are prevailing as environmental problems that affect people's livelihoods as also the economic growth is set back [4, 5]. In accordance with Rwanda's agroecologies and socioeconomic situation, agroforestry as a strategic way has been adopted and actively implemented to enhance food security for sustainable livelihood support and landscape restoration. The systems provide a variety of products and services which are very essential to people [6, 7].

Today, agroforestry is an important element in the Bonn Challenge [8, 9], with the global ambition to restore 150 million hectares of the world's deforested and degraded land by 2020 and 350 million hectares by 2030 [10, 11]. To contribute to this, a country with very limited land like Rwanda will not do without intensifying on-farm tree planting. Planting many trees on the farm will not only increase on-farm tree populations but also several benefits obtained from these trees [10]. Agroforestry plays a great role in improving present and future food security globally as trees have an integral part of food security strategies of rural people for so long [3]. Also, it enhances several key environment-related Sustainable Development Goals (SDGs) [11].

Agroforestry has long been part of Rwandan farming systems as farmers have always planted trees for food and fruits, timber, fuel, poles, fodder, stakes for climbing beans, and shade for livestock [12]. They planted trees for soil conservation since they believed agroforestry increases soil fertility, retains water, maintains, and improves the surrounding as well for medical purposes, and this practice can occur at a wide range of fields and farms to landscape [6].

In addition to the production of food and goods to sustain rural livelihoods, tropical landscape management also contributes to the conservation of biodiversity [13]. According to [13], agroforestry preserves, most probably, much more of the (usually forest-bound) biodiversity than would the conversion of forests to nonforest agricultural systems. At the same time, there may be an economic benefit in maintaining high biodiversity; hence, many beneficial ecological functions in an agricultural system. Experimental evidence from temperate-region grassland systems sustains this idea since it showed a beneficial effect of biodiversity on biomass production [14].

Mukura Sector is located near Huye town and supplies most of its farm produce to the latter. Nearness to the town plus small land holding per household has led to intensive agriculture [15] and land consequently; most trees planting in the area is done on-farm in different forms of agroforestry. Rarely trees are planted in woodlots and this keeps tree cover in the area to be very low or insignificant. Like in many areas in the country, agroforestry trees play a significant role in providing wood products for various uses as well as household income by selling tree products [12].

Despite the numerous advantages of agroforestry, little is known about the contribution of agroforestry to the improvement of rural livelihoods for people who practice it for a long time [16]. The value of agroforestry may vary depending on agroecology, socio-economy, and socio-cultural status of practitioners [17]. Therefore, the imperative aim of this study was to evaluate agroforestry practice in terms of the practice itself, the benefits and its contribution to on-farm diversity as an environmental conservation strategy in Mukura sector, Huye district in southern Rwanda.

2. Materials and Methods

2.1. Site Description. Mukura sector is located in Huye District, Southern Province, Rwanda (latitude: 2°39′37″S and longitude: 29°44′48″E) [18]. Mukura sector covers an area of 28.14 km^2, having a population census of 20,191 (2012) with 717.5/km^2 population density (2012) [18, 19].

2.2. Field Data Collection. For data collection, four cells, namely, Rango A, Bukomeye, Buvumo, and Icyeru of Mukura Sector were selected at random. From each of the four cells, two villages were chosen also at random to constitute a total of eight sample villages (Figure 1). By using Yamane's formula and applying 0.1 as the error margin, the sample size was taken as 100 respondents.

$$n = \frac{N}{\left[1 + N(\alpha)^2\right]}, \quad (1)$$

where n: sample size, N: population size, and α: the precision sampling error as 10% = 0.1.

Data were collected through face-to-face interview using a pre-prepared questionnaire. The sample size was constrained by limited resources but since the variation in agroforestry practice was expected to be small among households in the study site, we assumed that the size of sample would give precise output. Field observations were also made to evaluate agroforestry practices in the area. On-farm trees were identified and counted.

The diversity of tree and shrub species was measured using the Shannon–Weiner diversity index (H').

$$H' = -\sum_{i=1}^{s} pi\,(\ln pi), \quad (2)$$

where H' is Shannon–Weiner diversity index, S is the richness of species i, pi is the ratio of the number of individuals of a species (n), and the total number of individuals (N) (or n/N) [20].

A similarity index was used to test how similar or dissimilar the different cells of Mukura Sector were in terms of on-farm trees. For this purpose, Sørensen's index [21] was applied as follows:

$$S = \frac{2a}{2a + b + c}, \quad (3)$$

where a = the number of species shared between agroforestry system types of a given pair of cells in Mukura Sector, b = the number of species present only in a certain cell, and c = the number of species present only in another cell among the two cells being compared. Since the sector has four cells, six such comparisons were made.

2.3. Data Analysis. The Quantum Geographic Information System 3.24.0 was used for map extraction and location of Mukura Sector and the cells where data were collected. Species and survey data were summarized using Excel.

3. Results

In this research we found out that the sex ratio of household respondents engaged in agroforestry was 52% men and 48% women (Figure 2) and most of all respondents were engaged in agriculture. About 40% of the respondents were aged between 30 and 40 years. Those in the age class 40–50 were 28% while the third largest class was 20–30 years with 18%. The remaining 16% was in the old age (50–70 years) (Figure 3).

In Mukura Sector, 62% of the population acquired land through inheritance, 30% purchased it and only 7% rented the land on which they carryout agricultural practices

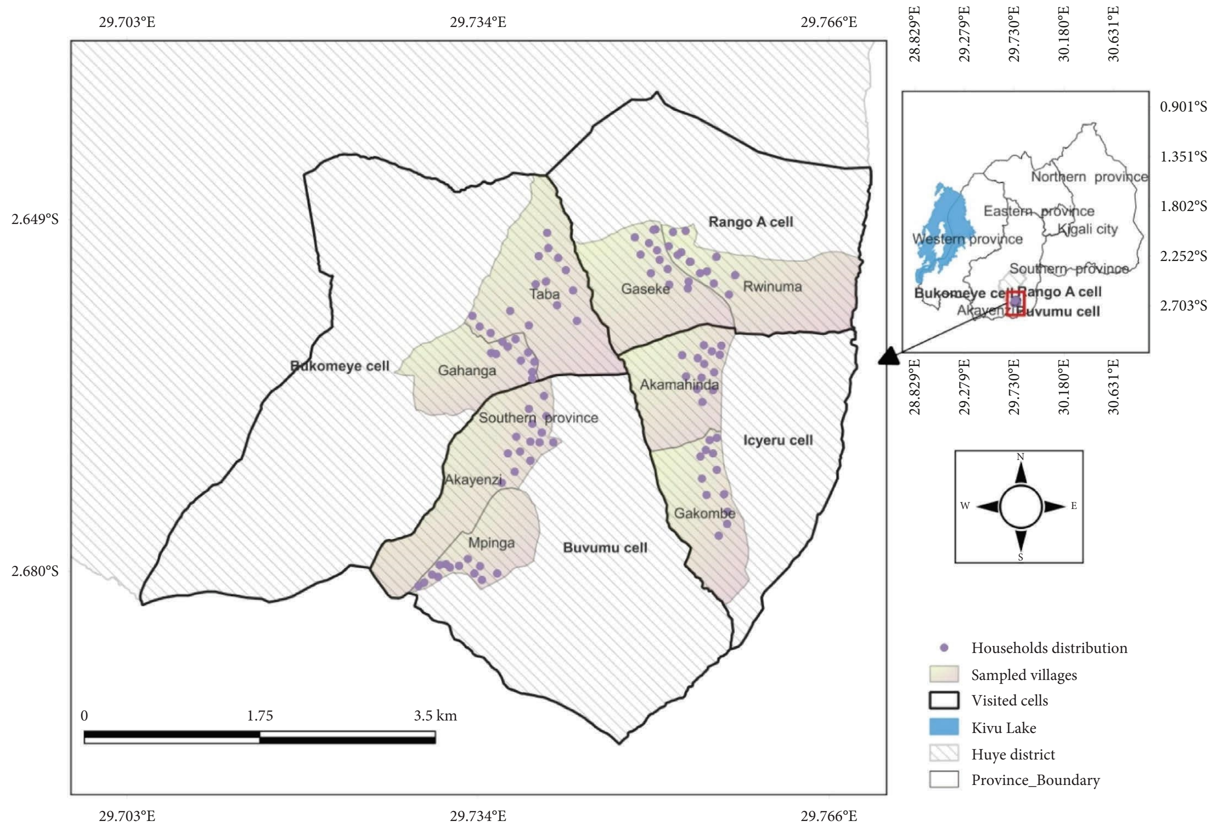

Figure 1: Location of the four cells where data were collected in Mukura Sector, Huye District, southern Rwanda.

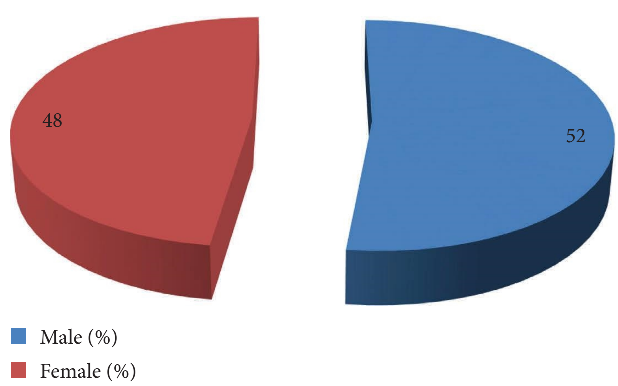

Figure 2: The gender participation of the respondents in agroforestry in Mukura Sector, Huye district, Rwanda.

(Figure 4). Ten on-farm woody species were identified in Mukura Sector (Figure 5). It was evident that farmers practice agroforestry and use different technologies such as boundary planting, home garden, scattered trees on farm, and woodlot for different purposes (Figure 6).

It was observed that 60% of the farmers in Mukura Sector intercropped food crops with agroforestry trees (Figure 7). Farmers who practiced agroforestry reported a number of products and services that they get from agroforestry (Figure 8). Of those practicing agroforestry, five main benefits were identified in the study area. In Bukomeye, respondents identified food and fruits and income diversification as the main benefits obtained. They also intercrop different agroforestry tree species with crops on their farmlands for soil fertility improvement and for provisioning of food, fodder, and poles, as well as for income diversification (Figure 8).

While some farmers practice agroforestry as their main agricultural occupation, others do not integrate crops with trees but rather separate them. The interaction of trees with crops in Mukura Sector was found to be positive where it increased productivity and enhanced soil fertility. The proportion of respondents reporting negative tree effects on crop was very small (Figure 9). The low rate of adoption of agroforestry practice was attributed to the lack of seedlings, inadequate extension services, and the lack of land (Figure 10).

3.1. On-Farm Woody Species Diversity. Ten woody species were identified across the four cells of Mukura Sector and most of them were present in all cells except *Cymphomandra betacea*, *Leucaena diversifolia,* and *Persea americana*. *Cymphomamdra betacea* was missing in Buvumo and Cyeru cells; *L. diversifolia* in Buvumo; and *P. american* in Rango A, Buvumo, and Bukomeye Cells (Table 1).

The diversity of ten on-farm woody species identified in the four cells of Mukura Sector is shown in Table 2. Using the Shannon index formula, it was observed that *Grevillea robusta* had the highest diversity in Rango A cell, Mukura sector, followed by *Calliandra calothyrsus*, *Persea*

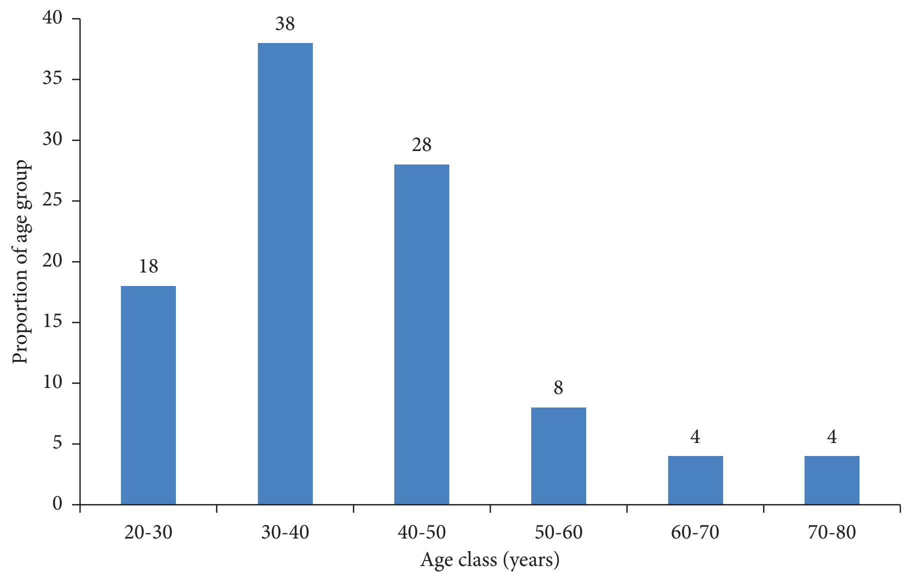

Figure 3: The age groups of the respondents in Mukura Sector, Huye, southern Rwanda.

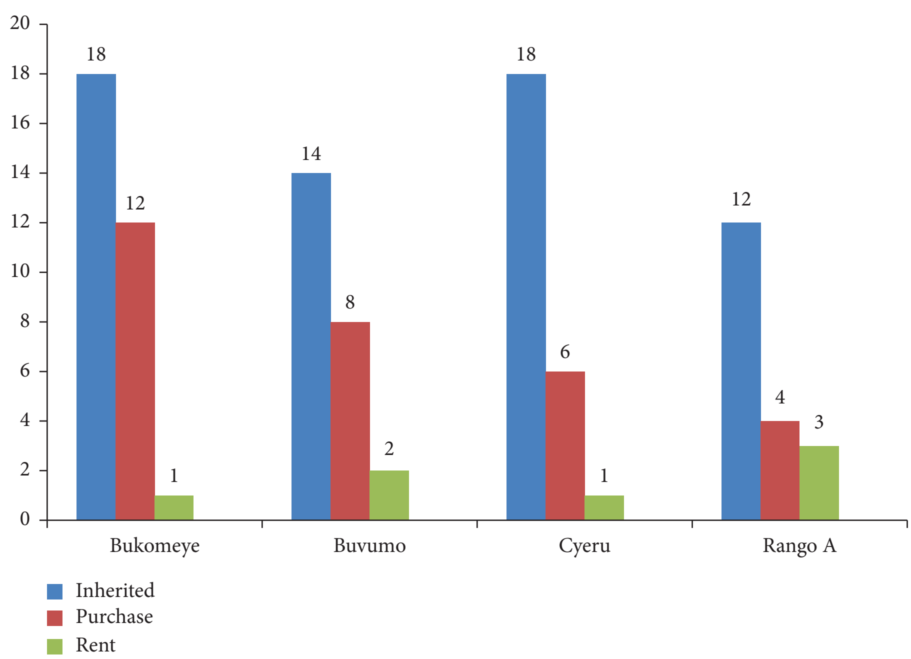

Figure 4: The land ownership of the respondents in the four cells of Mukura Sector, Huye District, Rwanda.

americana, and *Mangifera indica* consecutively. *Carica papaya* and *Cedrela serrata* had equal diversity, followed by *Cymphomandrabetacea* and *Eucalyptus camaldulensis* also with the same diversity in Rango A. *Markamia lutea* had the least diversity in Rango A among the agroforestry tree species planted in that Cell (Table 2).

4. Discussion

Demographic characteristics of the study sites of 52% male and 48% female is lower than the one observed in other areas in Rwanda. Thacher et al. [22] havereported that 65 and 35% of respondents were male and 35% were female in Bugarama Sector, south-western Rwanda, whereas 67% and 33% w male and of female in Busogo, northern Rwanda, respectively. Burnett J.E. [21] reported the same proportion as 75.4 male and 24.6% females in Musebeya area, Nyamagabe district, southern Rwanda. The ratio is also less than the national average, reported to be 70.3% male and 29.7% female [23]. The variability in men-women proportions in Rwanda is not unexpected since the 1994 genocide against Tutsi affected the community at different rates in different areas across the country [24]. Different communes had different intensities of genocide and this affected sex ratio differently [25].

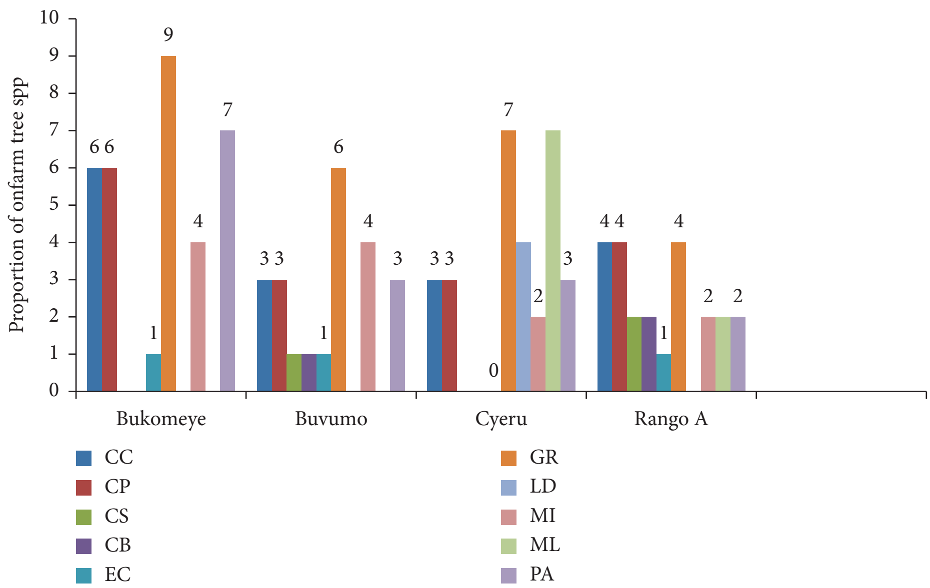

FIGURE 5: On-farm woody species identified in Mukura Sector, Huye District, southern Rwanda. Key: the letters denote the following tree species: CC: *Calliandra calothyrsus*, CP *Carica papaya*, *Cedrela serrata*, CB: *Cymphomandra betecea*, EC: *Eucalyptus camaldulensis*, GR: *Grevillea robusta*, LD: *Leucaena diversifolia*, MI: *Mangifera indica*, ML: *Markhamia lutea* and PA: *Persea americana*.

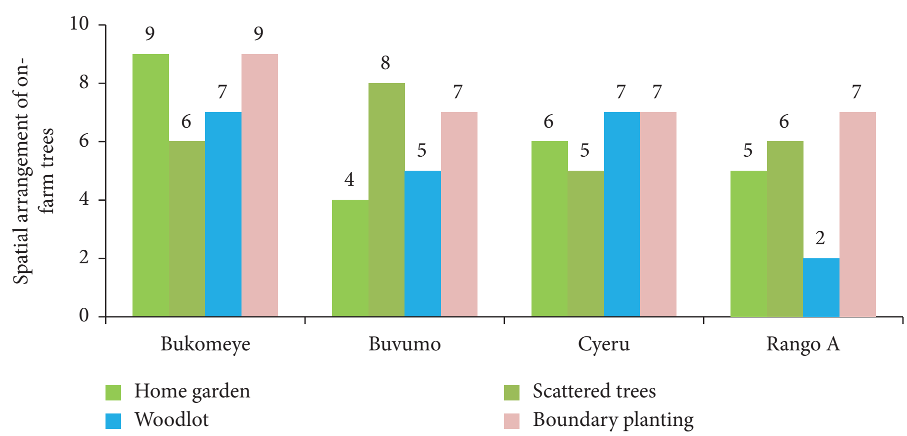

FIGURE 6: Agroforestry technologies practiced by farmers in Mukura Sector, Huye District, southern Rwanda.

4.1. Similarity/Dissimilarity of Agroforestry Species in Different Cells. There were no significant differences ($p > 0.05$) between Sørensen's similarity index in the four cells of Mukura Sector (Figure 11). The indices were reasonably high and ranged from 0.670 to 0.880.

The active involvement of the young farmers in agroforestry presents strength. This agrees with the literature. Umuhoza, E. et al. [26] explain that young people tend to adopt new technologies easier and faster than the old. The elderly in Rwanda also adopt agroforestry because it supports livelihoods by providing wood products and income and protects fragile environment to ensure sustainable land productivity [17].

The observed land ownership pattern is in commensurate with findings elsewhere in Rwanda and in other areas with high population density and consequently small landholdings per household. Land fragmentation in Rwanda has been encouraged by the high population growth rates and the nature of policies on land property rights [26].

The woody species identified in the different agroecological systems in Rwanda are varied. Gracia-Barrios, L. et al. [27] reported nine agroforestry woody species in Busogo Sector, northern Rwanda and six in Bugarama Sector, south-western Rwanda. Seven on-farm woody species were identified across six agroecological zones of Rwanda [17]. Gracia-Barrios, L. et al. [27] reported a more diversifies situation in Musebeya Sector, Nyamagabe District with 12 woody species and even a bigger number (14 woody spp.) was reported in Mpanga Sector, Kirehe District, eastern Rwanda [28]. Such variation can be a result of combined attributes such as edaphic and weather conditions, farmers' awareness, which may result from exposure to extension services, and availability of seedlings among others.

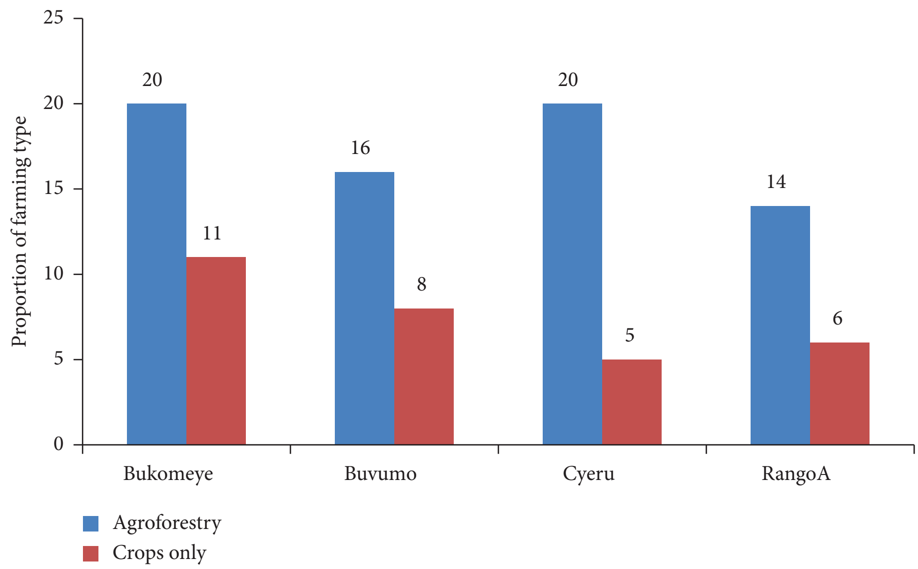

Figure 7: The proportions of farmers practicing agroforestry or not in the four cells of Mukura Sector, Huye District, southern Rwanda.

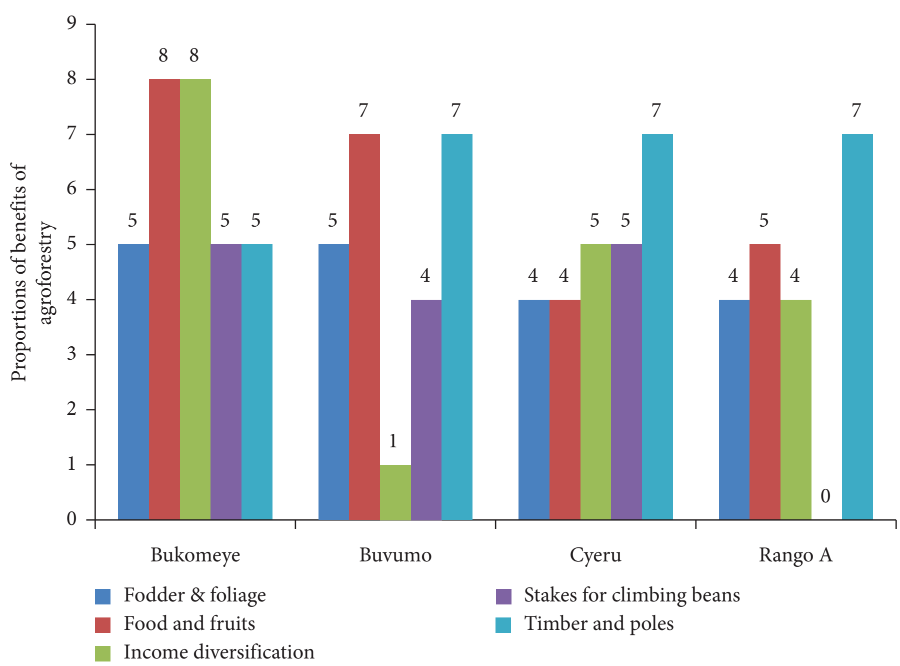

Figure 8: The benefits of agroforestry reported by farmers in Mukura Sector, Huye District, southern Rwanda.

The four on-farm tree spatial arrangements and the benefits observed in this study are common in all agro-ecological zones with slight differences in some places [17]. A range of products and services provided by on-farm trees reported here are also reported in other agroecological zones of the country and elsewhere [22, 27]. Trees in crop fields work as insurance in case of sudden crop failure or to support crops against environmental hazards and also to provide extra income [29]. Therefore, agroforestry is largely evolved with sustainability concerns, resiliency, and diversity [30].

The observed low adoption rate of agroforestry practice is not unexpected since with small or hired land holdings, growing long-term crops such as trees may hardly be prioritized. It has been reported that the adoption of agroforestry is positively correlated with land size [31–33]. A positive relationship between secure tenure and tree planting on-farm has been reported [34]. Additionally, land renting has been observed to discourage efforts to tree planting like any other long-term projects [35]. Also, insufficient technical knowhow for agroforestry implementation may account for the low adoption [36]. Exposure to extension

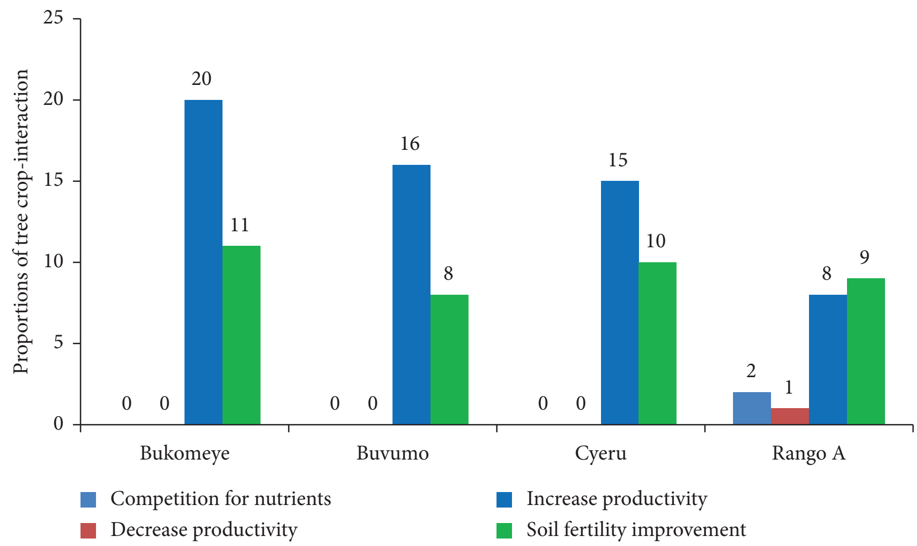

FIGURE 9: Effects of tree-crop interactions reported by farmers in Mukura sector, Huye District, southern Rwanda.

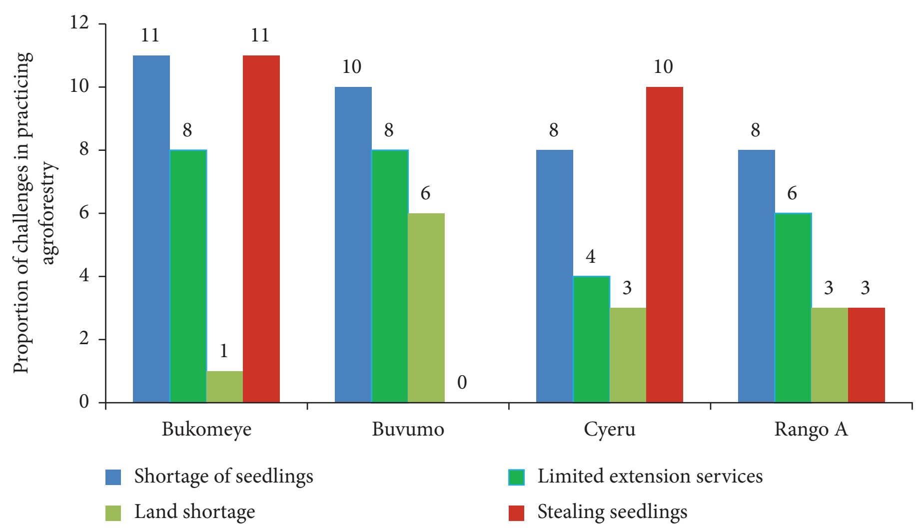

FIGURE 10: The challenges farmers face in practicing agroforestry in Mukura sector, Huye District, southern Rwanda.

TABLE 1: Presence or absence of ten on-farm woody species identified in the four cells of Mukura Sector, Huye District, southern Rwanda.

Species	Cell			
	Rango A	Bukomeye	Buvumo	Cyeru
Calliandra calothyrsus	*	*	*	*
Carica papaya	*	*	*	*
Cedrela serrata	*	*	*	—
Cyphomandra betacea	*	*	—	—
Eucalyptus camaldulensis	*	*	*	*
Grevillea robusta	*	*	*	*
Leucaena diversifolia	*	*	—	*
Mangifera indica	*	—	*	—
Markhamia lutea	*	—	*	—
Persea americana	—	—	—	*

And* and—denote presence or absence, respectively, of a particular species in a given cell.

Table 2: The diversity of agroforestry tree species in the four cells of Mukura Sector, Huye District, southern Rwanda.

Tree species	Cell				Average
	Bukomeye	Buvumo	Cyeru	Rango A	
Calliandra calothyrsus	0.660	0.680	0.650	0.690	
Carica papaya	0.700	0.590	0.660	0.610	
Cedrala serrata	0.620	0.530	0.001	0.410	
Cyphoomandra betacea	0.200	0.001	0.001	0.260	
Eucalyptus camaldulensis	0.420	0.170	0.510	0.540	
Grevillea robusta	0.540	0.510	0.510	0.590	
Leucaena diversifolia	0.420	0.001	0.460	0.260	
Mangifera indica	0.001	0.410	0.001	0.410	
Markhamia lutea	0.001	0.680	0.001	0.190	
Persea americana	0.001	0.001	0.680	0.001	
Shannon-Weiner index (H')	3.570	3.590	3.480	3.980	3.660

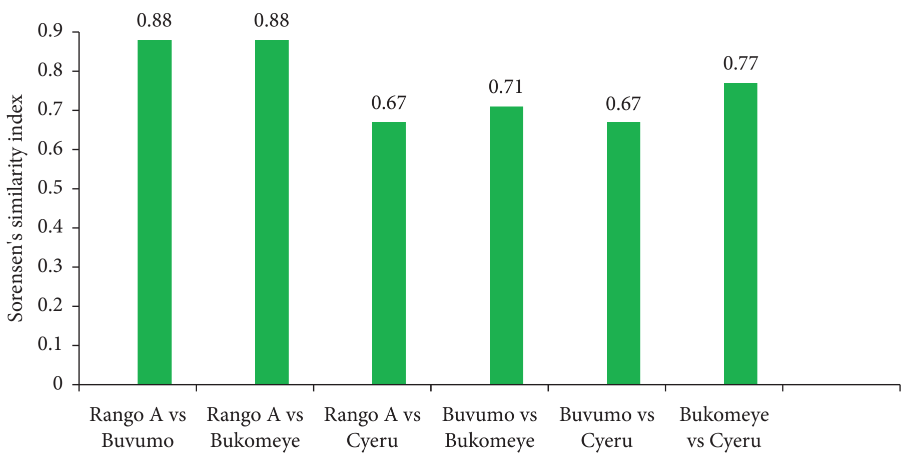

Figure 11: Sorensen's similarity indices obtained through comparisons of on-farm woody plants found in four cells in Mukura Sector, Huye District, southern Rwanda.

agents has been reported to lead to higher adoption rates [37].

The effect of intercropping trees with annual crops, as has been demonstrated in this study, presents varied perceptions by different farmers, and is usually a complex phenomenon. Trees being big plants occupy large space thereby competing with crops for space. Owing to their big crowns and far reaching lateral roots compete for light and soil water and nutrients to reduce crop yield when trees and crops are grown in close proximity [38, 39]. On the other hand, trees may demonstrate a facilitative role thereby increase yields of the crops intergrown with them or grown next to them. Examples may include those reported in Kenya by [40] and Uganda by [41].

Waldron, A. et al. [42] and [43]explain the interspecific interaction and facilitation between plants, how these interact under different environmental resource conditions and how this impose trade-offs, biophysical limitations, and management requirements in tree-crop mixtures. They state that, in introducing trees in croplands to promote low-input sustainable agroforestry systems is a challenging undertaking due the following reasons: (i) trees provide useful products for smallholders and strongly facilitate crops but can also exert stronger competitive effects; (ii) practices aimed at increasing trees' beneficial effects can sometimes also enhance trees' competitiveness; (iii) the interplay between positive and negative effects of trees change-sometimes significantly.

The observed on-farm tree diversity between cells of Mukura Sector in this study is higher than that observed in some other sites in Rwanda. Uwera et al. (in press) reported a Shannon–Weiner diversity index of 1.2 in Bugarama, south-western Rwanda and 1.33 in Busogo, northern Rwanda. Basing on environmental conditions, the study site is potentially in between the other two sites and one would expect the index to be about the average of the other sites although it presented a higher diversity index value. As seen above however, on-farm tree planting is a complex, unpredictable practice varying depending on many factors including the environment or agroecology [42], socio-economic and socio-cultural aspects [44], and others.

5. Conclusion

It was observed that agroforestry in Mukura Sector is practiced by about 60% of the farmers, others being constrained by the small land size, land tenure, ignorance, unavailability of tree seedlings, and the avoidance of tree competition. With proper advice, the worries on the effects of tree effects on crops may not hold since certain tree species facilitate crop production and small land holdings may not be an issue. Agroforestry practice is important in intensively cultivated cropping systems to keep soil carbon high to ensure sustainability.

Ten woody species were observed to grow on farm, providing varied products such as timber, firewood, food and fodder, and stakes for climbing beans plus income. On-farm tree diversity was observed to be higher than several other sites in Rwanda. The diversity of woody plants in different cells of Mukura Sector did not vary significantly as demonstrated by reasonably high indices of similarity between cells.

We recommend that efforts be made to reinforce extension services to improve farmers' awareness on the contribution of agroforestry on their social wellbeing. Ways of making seedlings available for planting should also be explored.

Data Availability

All the data used to support the findings of this study are included in this article.

Conflicts of Interest

The authors declare that there are no known conflicts of interest to the best of their knowledge.

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