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FARMER'S PERCEPTION AND ADOPTION OF AGROFORESTRY TECHNOLOGIES IN EASTERN RWANDA

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ABSTRACT

Agroforestry systems are multifunctional settings that can provide a wide range of economic, socio-cultural, and environmental benefits; it also improves soil fertility. Through the LDCFII-EbA project, the government of Rwanda started to implement the ecosystem restoration activities in 2017 to restore landscapes and improve peoples' livelihoods including the Eastern part of Rwanda where this research was conducted and documented on how agroforestry technologies are contributing to ecosystem restoration. Direct observation and interviews with multi-stakeholder participants helped to document agroforestry tree species planted in the project sites, the contribution of agroforestry to the supply of tree products to the smallholder farmers, and the challenges affecting the adoption of agroforestry technologies in the study area. Hedgerow system was the dominant agroforestry technology. Firewood was the dominant benefit of practicing agroforestry technology according to the interview participants; whereas termite attack and drought were reported as the main challenges impeding the adoption of agroforestry technologies in the study area. Future research is recommended to identify most adapted tree species and their management practices. It is recommended that indigenous species be prioritized in agroforestry because they are already adapted to the local conditions while exploring exotics which may be beneficial.

Keywords: Agroforestry practices, benefits of agroforestry, ecosystem-based adaptation, on-farm woody species.

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INTRODUCTION

Smallholder farmers' marginal lands are vulnerable to low-yield crops as almost smallholder farmer is depending on subsistence farming (Rapsomanikis, 2015). Rwandan smallholder farmers generally have degraded small farmlands and lack knowledge of improved technologies in their daily farming activities (Olson and Berry, 2017), which resulted in loss of soil fertility and diversity. Hence, promoting ecosystem services through the Ecosystem based Adaptation (EbA) has been found to boost the monetary economy that improves people's livelihoods. It further helps to adapt to both current and future environmental sustainability, and also contribute to biodiversity conservation

(Daba and Dejene, 2018). The EbA represents all strategies that integrate the use of biodiversity and ecosystem services to help people adapt to the adverse impacts of climate change. The relevant strategies include measures for reducing land degradation, ecosystem restoration, biodiversity conservation, and their uses sustainably, ways to improve people's livelihoods at the same time conserving the ecosystems by applying agroforestry practices (Reid & Madrid, 2018). One of the approaches to the EbA strategy is the introduction of agroforestry technologies to improve peoples' livelihoods and also contribute to ecosystem health (Vignola et al., 2018) through economic, socio-cultural, and environmental benefits, including fodder, fruits, charcoal, stakes for climbing beans, timber, clean water, improved soil fertility, and controlling soil erosion and creation of microclimate (Kiyani et al., 2017).

Rwandans experienced extreme deforestation from 1960 up to 2007 due to human population growth (Ndayambaje, 2013). Consequently 80% of its forest resources has been lost (Mukashema, 2007) as a result of overexploitation of the forest resources for fuelwood and charcoal, land for agriculture and settlement. Furthermore, these activities caused rain irregularities and affected crop productivity (Okia, 2012). Indeed, food insecurity has been reported and expressed through extended droughts compared to the past years and sometimes unexpected hunger, which negatively affected the local peoples' livelihood (USAID, 2011). Rwanda took action and aggressively addressed the problem of food insecurity and also biodiversity loss by taking different measures such as promoting modern agricultural activities and ecosystem restoration though agroforestry practices across the country. This included the Eastern part of the country, Mushongi Cell in Kirehe district, Eastern Rwanda where this research was conducted and documented how the EbA is contributing to both ecological services and economy of the country.

In 2017, the Government of Rwanda introduced restoration activities through afforestation and reforestation in the area through a project entitled "Building the resilience of communities living in degraded forests, savannahs, and wetlands of Rwanda through an ecosystem-based adaptation approach (LDCFII-Eba) (Raasakka, 2013). Agroforestry was one of the main activities involved in landscape restoration and improvement of peoples' livelihoods in the area. Agroforestry species were planted on hillsides and a bamboo planting was established in a buffer zone around Mpanga Lake. One of the purposes of this research was to know if agroforestry technologies in the area are contributing to the reduction of human pressure on natural woodlands and also to the improvement of livelihoods of local communities' standard of living through the assessment of farmers' perceptions and adoption of agroforestry technologies.More specifically, this research aimed at i) identifying agroforestry tree and shrub species planted in the study area, ii) evaluating agroforestry technologies adopted by local farmers in the study area, iii) examining the contribution of agroforestry to the supply of tree products to the smallholder farmers in the study area, and iv) identifying the challenges affecting adoption of agroforestry technologies in the study area.

MATERIALS AND METHODS

Study site description

The present study was conducted in Mushongi cell, which is located in Mpanga Sector, Kirehe District, Rwanda (Figure 1) near Lake Mpanga. It is located between 02°05'09" S and 030°50'44" E (https://earthexplorer.usgs.gov/). The annual average temperature ranges between 20-21ºC and the annual rainfall from 700 mm to 950 mm (USAID, 2019). Soils are mostly loamy sandy (Kirehe DDP, 2018). The climate is characterized by four seasons: a long dry season (June to September), a light rain season (Mid-September to end of December), a short dry season (January to mid-February), and a long rain season (March to May) (MINIRENA, 2007). Mushongi cell covers a total area of 1250 km^2 and is subdivided into six villages, with 867 households. The main economic activity in this area is agriculture practiced by around 91% of the population (NSIR, 2012). Dominant crops are banana, beans, maize, sorghum, and other different types of Fruits and vegetables such as watermelon, tree tomatoes, passion fruits tomatoes and etc.

Data collection

The data were collected in Mushongi cell, particularly in its four villages; namely, Ngugu I, Ngugu II, Gitoma, and Mushongi where the activities of the LDCFII-Eba Project are based around Mpanga Lake (Figure 1). A formal survey was used during data collection according to de Graaff (1996). A total of 235 participants in the survey (an established sample size using eq. 1 below) were informed about the aim of the research project before obtaining their information about farmers' perceptions and adoption of agroforestry technologies in Eastern Rwanda. A predesigned questionnaire was used during data collection in the peoples' households. The interviewees of Mushongi cell were asked to respond to a set of questions on how they appreciate the use of agroforestry technologies in their daily lives. The questions briefly included the age distribution of the farmers, marital status of farmer, education level, agroforestry technologies in their farmlands, agroforestry species present in their farmlands, including benefits of practicing agroforestry. A further inquiry was made on the frequency of being visited by extension staff, and the challenges that they faced while practicing the agroforestry.

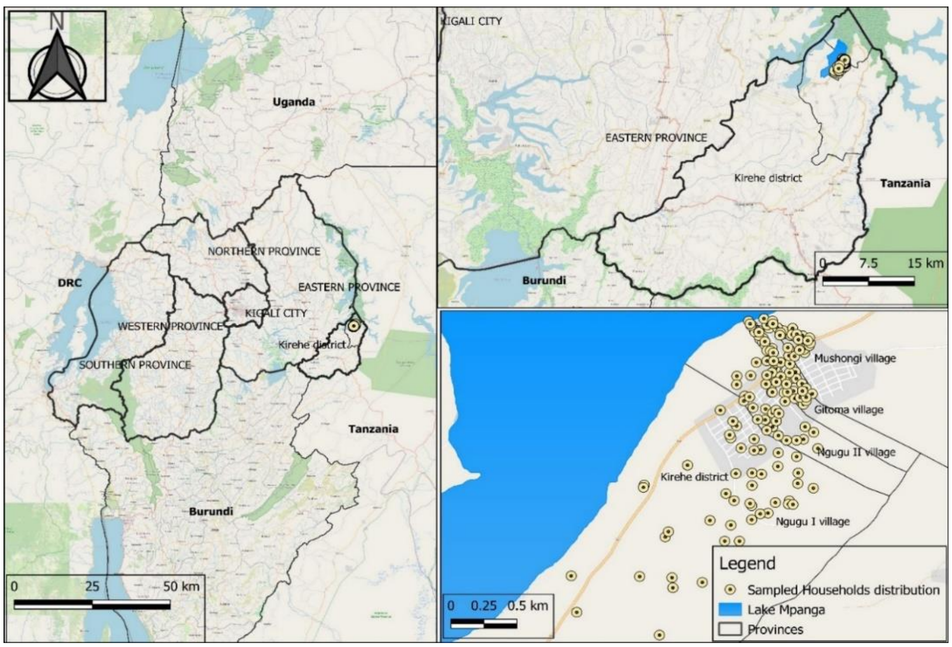


Figure 1. Research sites nearby Lake Mpanga (upper right-hand corner of the top panel).

The sample size for the survey was determined by using Yamane's formula (Israel, 2003): $n = N/\left[1 + N(\boldsymbol{\alpha})^{2}\right]$ ……. (1)
Where **N**: is the total population of Mushongi Cell, $\boldsymbol{\alpha}$: confidence limit when the confidence percentage was taken as 95% in this study, and **n**: the size of the sample. The latter is detailed in Table 1 for the different sample villages.

$n=N/ [1+ N (\alpha)^2]$.
$n= 570/ (1+570(0.05)^{\wedge 2}))$
$n= 235.05$
$n \approx 235$.

The N applied in the formula above was obtained from literature (NISR, 2012).

Table 1: Number of households per village in the study area

Sampled villages	Total population of each village	Number of samples household per village (n)
Ngugu 1	135	135***235**/570 =56
Ngugu 2	145	145*235/ 570=60
Gitoma	135	135*235/ 570=56
Mushongi	155	155*235/ 570=63
TOTAL	**570**	**235**

To collect data, the households sampled per village were selected randomly using a village inhabitants list provided by the local authorities. In addition to 235 sample households, nine key informants (mainly technical experts) were chosen from extension agents and local leaders. A list of these was obtained from the district agricultural office, REMA technician, and cell's executive secretary. In total, the number of respondents that were interviewed was 244. At each sample household, the interview was dispensed to the head of household or her/his representative, when this was not available.

On-farm woody species were identified and recorded when interviews were dispensed at each sample household. Woody species that were established through the LDCFII-Eba Project plus those which existed even before the commencement of the project were considered in this study to get a broad view of on-farm tree planting practice. Specimens of the woody species whose names were not known were taken and these were identified later at the National Herbarium at the University of Rwanda Huye Campus using appropriate keys.

Data analyses

During data collection, a hand-held GPS was used to record the geographic coordinates of the visited households; whereas, Statistical Package for Social Science (SPSS) Version 21.

RESULTS

Agroforestry tree species preferred by the local people in Mushongi cell

The agroforestry trees most adopted as reported by the respondents in the study area were *Calliandra calothyrus*, *Grevillea robusta* and *Senna spectabilis* compared to those less preferred: i.e., *Percea americana*, *Cedrela serrata*, and *Mangifera indica* (Figure 2).

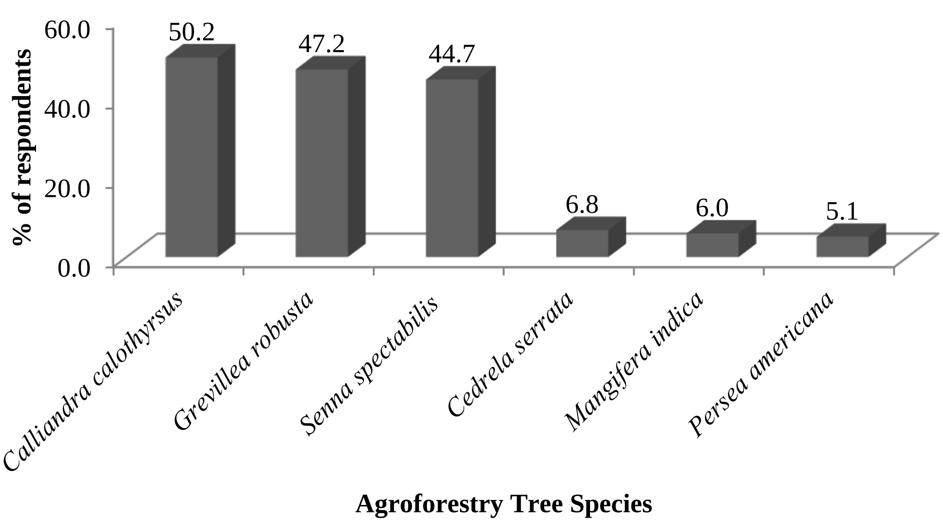


Figure 2: Adoption of agroforestry species cultivated by the farmers in Mushongi cell, Mpanga sector, Kirehe district, and Eastern Rwanda.

On-farm trees observed that were not planted through the LDCFII-EbA project were twenty, seven of which were native species and thirteen exotics species (Table 2). Farmers were asked to report which use these species were put to, and the responses provided are shown along with species names in table2. Sometimes strange answers were given. Examples include using *Euphorbia candylobrum* for green manure, or *Senna siamea* or *Melia azedarach* for timber production.

Table 2: On-farm tree species that were not planted by LDCFII-EbA project **in Mushongi Cell**

Species name	Category	*Uses of tree species not planted by REMA										
		1	2	3	4	5	6	7	8	9	10	11
Acacia melanoxylon	Exotic		×					×	×	×	×	×
Albizia spp.	Exotic		×					×	×	×		×
Carica papaya	Exotic					×	×					×
Casuarina equisetifolia	Exotic							×		×	×	×
Citrus sinensis	Exotic				×	×						×
Erythrina abyssinica	Native			×	×							×
Eucalyptus tereticornis	Exotic		×					×	×	×		×
Ficus thonningii	Native	×		×								×
Jacaranda mimosaefolia	Exotic			×				×		×	×	×
Markhamia lutea	Native		×					×	×	×	×	×
Psidium guajava	Exotic					×						×
Vernonia amygdalina	Native	×		×	×			×				×

***1** *= fodder, 2 = timber, 3 = green manure, 4 = medicine, 5 = fruits, 6 = soil fertility improvement, 7 = stakes for climbing beans, 8 = charcoal, 9 = firewood, 10 = soil erosion control and 11 = carbon sequestration.*

Agroforestry technologies practiced by farmers in the study area

The results indicate that farmers in Mushongi Cell practiced more than one form of on-farm tree spatial arrangement. The proportion of respondents practicing different spatial arrangements of trees on farm decreased from hedge planting (74.9%), dispersed trees/shrubs (44.7%), home gardens (31.9%), woodlots (10.2%) and boundary planting (4.7%) (Figure 3). Agroforestry technologies practiced in the Mushongi cell differed significantly between households ($p = 0.001$). Hedge planting and dispersed trees were the most commonly practiced while home gardens, woodlots and boundary planting were the least practiced (Figure 3).

The farmers prefer hedge planting because it is used as windbreak, maintaining household privacy, control soil erosion (Mpanga lake protection), produces fodder for livestock and improves soil fertility through nitrogen fixation and green manure application. On-farm dispersed tree practice is important for timber production**.**

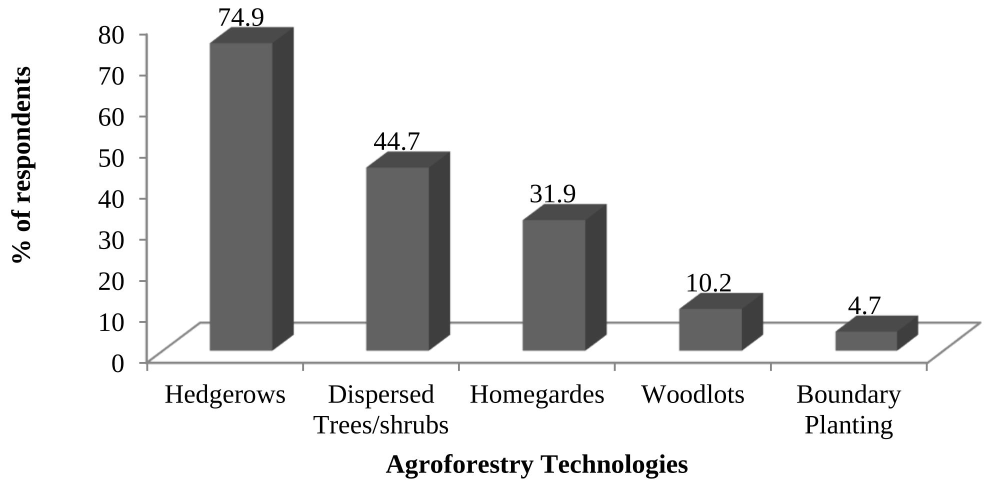


Figure 3: Agroforestry technologies appreciated by local people in Mushongi cell, Mpanga sector, in Kirehe district in Eastern Rwanda.

Hedge species include *Calliandra calothyrsus* and *Senna spectabilis*.

Benefits of Agroforestry

Four main benefits of agroforestry were recorded in the area namely: fodder (74.9%), firewood (54.5%), green manure (51.1%) and soil erosion control (41.3%) (Figure 4).

Farmers' adoption of agroforestry practices in Mushongi cell

The analysis of respondents' age classes showed significant differences ($p = 0.001$) in terms of practicing agroforestry technologies. The results showed that the majority of the people who practiced agroforestry (n=132) are in the range of 36-55 years, followed by those who are between 18-35 years (Table 3). The last age class with least count (n=40) is composed of elders (>55 years). This implies that agroforestry potential in Mushongi cells is high and its sustainability may be assured since it is practiced by the dynamic and young age groups.

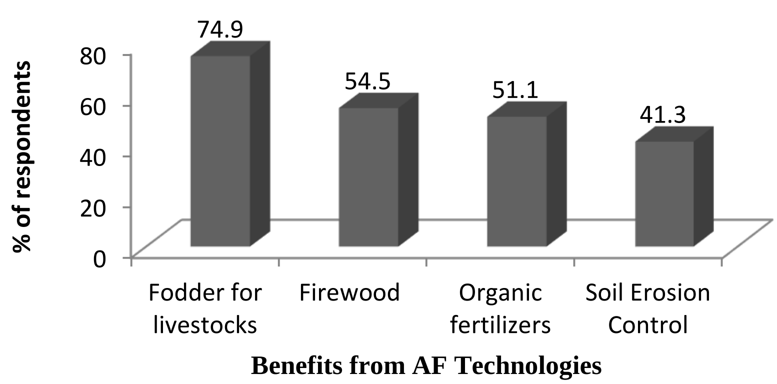


Figure 4: Benefits from practicing the agroforestry technologies in Mushongi cell, Mpanga sector, Kirehe district in Eastern Rwanda.

Table 3: Farmers practicing agroforestry as affected by age, gender, education level, and extension support in Mushongi cell, Eastern Rwanda.

Variable	Row labels	No. of respondents	Respondents as % of the total
Age class	>18-35	72	29.5
	>36-55	132	54.1
	>56	40	16.4
Gender	F	135	55.3
	M	109	44.7
Education level	None	19	7.8
	Primary	174	71.3
	Secondary	47	19.3
	University	4	1.6
Extension Agents	Quite often	159.0	67.7
	Rarely	42.0	17.9

According to the local leaders, initially local people in Mushongi Cell resisted planting trees but now after sensitization by extension agents, farmers' willingness to promote agroforestry has gained pace. The results below show the contribution of leaders'/extension staff to the farmers' application of agroforestry technologies. This is supported by the farmers' response that they received quick responses from extension staff whenever they need their help and that extension officers often visited and provided advice to attain the success of the agroforestry technologies. They revealed that the agronomists from REMA and Mpanga sector worked with them at least 4 times (days) in a week guiding them on how to care for the plants. According to Orisakwe (2011), the highest adoption of agroforestry technologies depends on the frequency of extension agent contact with the farmers.

Monetary benefits from agroforestry technologies

Farmers reported insignificant income gains from agroforestry across the Mushongi cell (Figure 5) following the newness of the project that introduced on-farm tree planting practice in the area. Only preliminary products such as fodder, green manure, and firewood collected from on-farm trees were collected from the young trees. About 45% of the study population earned an income of less than 15,000 Rwf per year, while only 2.5% earned above 92,000 Rwf per year (Figure 9). This income level from agroforestry is low but it is not unexpected since most of the trees were still too young to harvest. However, farmers are optimistic that the trees will earn them a high income when they grow since wood products sell at high prices.

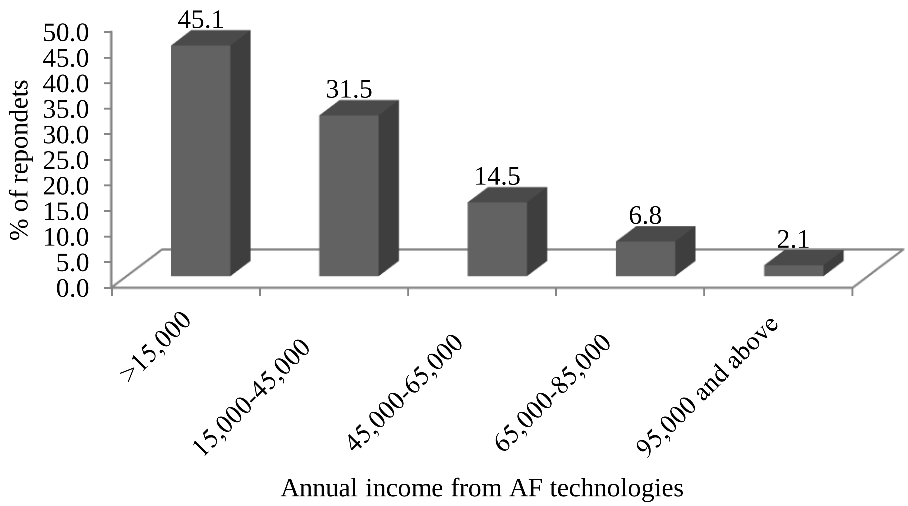
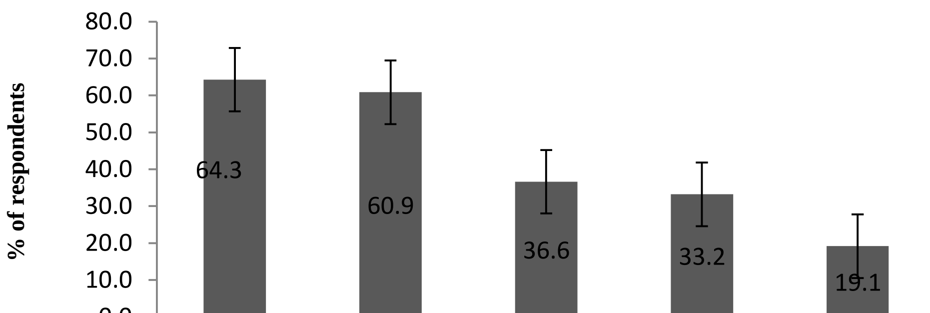


Figure 5: Monetary benefits from agroforestry Trees in Mushongi cell, Mpanga sector, Kirehe district in Eastern Rwanda.

The challenges for practicing agroforestry technologies by farmers

Five constraints were cited as the principle factors affecting tree planting in the area. These included termite attack (63.3%), drought (60.9%), insufficient seedlings (36.6%), lack of technical skills (33.2%) and lack of quality seedlings (19.1%) (Figure 6). Apart from the lack of enough and suitable seedlings for tree planting purposes, even a few supplied was reported to be available infrequently and untimely. Farmers showed interest in planting *Eucalyptus* species (*Eucalyptus tereticornis*), which they reported to be resistant to termite attack. While resistance to termites may be true with some *Eucalyptus* spp., the latter may not be a preference since they demand much water, a resource already scarce in the area. Extension agents also reported the lack of enough seedlings, poor field survival, and low species diversity as strong factors retarding agroforestry practice in all villages of Mushongi cell.



	termites	Droughts	Insufficient seedlings	lack of technicl skills	Lack of quality seedlings
% of respondents	64.3	60.9	36.6	33.2	19.1

Challenges of Agroforestry tree plantation

Figure 6: Challenges for farmers while practicing agroforestry technologies in Mushongi cell, Mpanga sector, Kirehe district in Eastern Rwanda.

DISCUSSION

The most agroforestry tree species adopted include *Calliandra calothyrus*, *Grevillea robusta* and *Senna spectabilis*. The results concur with findings by Ndayambaje (2013) who confirmed that 47.8% of farmers preferred *Grevillea robusta*, followed by *Senna spectabilis* (17.5%). According to Nduwamungu (2019) showed that the main agroforestry tree species adopted in the Eastern Province of Rwanda, include *Senna siamea and Calliandra calothyrus.* Rwanda environmental management authority focused on these tree species because they are known to tolerate termite attack and dry conditions, and also that they are suitable for both hedges and dispersed agroforestry technologies (John et al., 2012). In addition, the research conducted in Murang'a district of Kenya, showed that *Calliandra calothyrsus* and *Senna spectabilis* planted for soil erosion control and the production of fodder and firewood (Warner,1993).

The most common practiced agroforestry technologies were hedge planting and dispersed trees while home gardens, woodlots and boundary planting were the least practiced. Our results agreed with findings reported by Current et al. (1995) in small-scale farming areas. The farmers prefer hedge planting because it is used as windbreak, maintaining household privacy, control soil erosion, produces fodder for livestock and improves soil fertility through nitrogen fixation and green manure application. According to ICRAF (1992) states that hedges as trees and shrubs planted in thick bushes around farms help in soil erosion control, protection of cultivated fields against destruction, and also for fuelwood production.

According to Warner (1993), the farmers in Murang'a district of Kenya planted trees and shrubs on hedgerows for soil erosion control and the production of fodder and firewood. Hedgerow technology also helps them in push-pull strategies as the method against crop pests (Warner, 1993). In addition, this technology was also involved in increasing biodiversity and modifying microclimate in the same way as the home garden and woodlot technologies (Wafuke, 2012).

According to Motis (2007), dispersed trees is when trees are planted alone or in very small numbers on cropland or pasture. On-farm dispersed tree practice is important for timber production, in addition, the practice allows for intercropping trees with crops to produce food. Dispersed tree agroforestry was reported by Jara-Rojas *et al*. (2020) as the second important system after forestry due to its varied benefits. The farmers reported that agroforestry tree species are very important for improving local peoples' livelihood in the intervention area. This is also supported by Franz *et al*. (2014), who stated that sustainable soil organic matter management in organic farming can most easily be achieved by mixed farms with fodder legumes and animal manure in line with building resilience of the soil. The number of farmers practicing agroforestry responded that the benefits of *Percea americana, Cedrela serrata* and *Mangifera indica* species are still minimal. This may be a consequence of agroforestry tree species in the area being too young to provide fruits, timber and firewood products to the growers. According YASU, Hiromi (1999), shown that the *Grevillea robusta* can be pruned from the period of seven or eight years after plantation and needs to be pruned every two or three years for stakes and fire wood production while timber production after fifteenth year on average.

According to Braja (2012), firewood was the most preferred benefit from agroforestry technologies in Kenya. The readily adoption of agroforestry practices by the young age has been reported in other studies (Sangeetha *et al*., 2016; Mwase *et al*., 2015; Wafuke, 2012). This together with the continued government policies supporting and promoting agroforestry (MINILAF, 2018) indicate that the benefits of agroforestry technologies in the study area may be improved in the present and future generations.

The analysis of gender implication in agroforestry technologies showed that women proportion was significantly higher than the men proportion. This gives supporting evidence that women are known to easily adopt agroforestry technologies more than men (Kiptot and Franzel, 2011). Men are typically interested in trees for commercial purposes while women are more inclined to plant trees for subsistence uses such as firewood, soil fertility improvement, fodder and fruits (Kiptot, 2015).

Education level does not significantly have an effect for local people's perception of the use of agroforestry technologies in the study area. Our findings agree with Wafuke (2012), who also found no significant effect of education in the adoption of agroforestry technologies in the Nzoia division of Lugari District (Kenya) ($p > 0.05$ at $p=0.961$). According to Orisakwe (2011), the highest adoption of agroforestry technologies depends on the frequency of extension agent contact with the farmers.

The population adopted agroforestry technologies earned income through sale of agroforestry products. Studies conducted by Kinyanjui (2007) noted that the local farmers in Kenya highly adopted agroforestry technologies because the letter improves their livelihoods through the sales of tree products such as firewood, timber, fruits and also indirect services for environmental protection.

The termite and drought were the main challenges to adoption of agroforestry technologies in the Mushongi cell. This observation is not surprising because afforestation programs in arid and semiarid areas are usually constrained by little and irregular soil moisture and termite attack (Parihar, 1981).

CONCLUSION

Most farmers reported *Calliandra calothyrus* and *Senna spectabilis* to be the most preferred species for hedgerows and *Grevillea robusta* for timber, areas on why the three were the most dominant. Through farmers' interview and own observation, agroforestry practice is common to the farmers in the study area. This observation is also strongly supported by the local authorities. However, both local people and their leaders reported challenges faced in practicing agroforestry to include insufficient and/or lack of quality seedlings that can resist drought and termites, and lack of enough technical skills. Irrespective of serious constraints of drought and termite attack affecting tree planting programs in the area, a variety of benefits farmers obtained from agroforestry were recorded in the Mushongi cell. These include fodder for livestock, green manure, firewood, fruits, timber, etc. Tree planting should be strongly supported not only for the direct benefits they provide to the farming communities but also for their contribution to environmental protection, especially soil erosion control (including siltation of Lake Mpanga), soil fertility improvements among others.

RECOMMENDATIONS

i. It is recommended that means be devised to ensure the availability of enough seedlings to meet planting needs by the farmers. Research may enlighten on the species adapted to the local environment, especially resistance to drought and termites.
ii. In addition, appropriate establishment and management practices should be explored.
iii. Besides planting trees on farms, planting in grazing lands can increase tree population in the area and the availability of tree products.
iv. The use of native species adapted to the environment may be a favourable startup option. With the above recommendations, and considering the fragility of the field conditions of the study area, it is imperative to ensure a strong extension service to support on-farm tree planting in this intervention area.

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