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Benefits and challenges of agroforestry adoption: a case of Musebeya sector, Nyamagabe District in southern province of Rwanda

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ABSTRACT

Rwanda's natural forest is under pressure due to increasing rural population growth and subsistence farming. The Rwanda Ministry of Agriculture has therefore introduced agroforestry technology in forest-dependent communities to minimize the pressures on the forests and improve local people's livelihoods. This new technology has, however, not seen massive adoption in the country. This study examined the socioeconomic and environmental benefits of the agroforestry technology introduced particularly in Nyamagabe District and the challenges facing its adoption. Results showed that the agroforestry practices are contributing to an increase in income of agroforestry adopters compared to non-agroforestry adopters, and are improving soil fertility, reducing deforestation, and conserving soil and water in the district. However, results showed that, due to lack of skills and technical know-how, capital and quality seeds, some farmers are declining to adopt the new agroforestry practices. The respondents perceived that by providing subsidies to farmers, regular training, and informal education, establishing tree nurseries to improve the production of quality seeds, and also involving farmers in decision-making will increase agroforestry adoption. The government and other stakeholders should consider the views expressed by the farmers and take the necessary steps to address these challenges facing agroforestry technology adoption.

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Introduction

Agroforestry is considered as one of the ways to avoid deforestation in order to reduce CO_2 emissions into the atmosphere and mitigate climate change (Verchot et al. 2007; Mbow et al. 2012; Minang et al. 2014). Deforestation is a serious problem in many developing countries, mainly due to subsistence and commercial agriculture (Hosonuma et al. 2012; Weatherly-Singh and Gupta 2015). About 17% of global CO_2 emissions comes from deforestation (IPCC 2007), significantly contributing to climate change (Van der Werf et al. 2009; Pachauri et al. 2014). Therefore, it is important to adopt agroforestry practices to address the continuous depletion of forest resources and, also, improve the livelihood of forest communities.

Agroforestry is a system whereby a deliberate attempt is made to integrate and manage both forest and agricultural resources on the same landscape. This intermediary land use system is important for sustainable forestry and agriculture. Due to the various benefits of agroforestry many international bodies such as the United Nations and World Bank, government and non-governmental organizations (NGOs) have advocated for its adoption globally. Some countries have heeded the call and are employing agroforestry technology as a strategy to rehabilitate degraded forestlands, avoiding "slash-and-burn" farming, reducing soil erosion, improving soil quality, enhancing vegetation cover, and improving the living standards of forest-dependent communities (Bugayong 2003).

The government of Rwanda is focusing on tackling the rapid destruction of the country's natural resources due to subsistence farming and population pressures. The conversion of forestlands to agricultural lands in the region is rapidly increasing, which is reducing forest cover. However, the adoption of agroforestry techniques to avoid rampant deforestation has not been simple in the country due to existing challenges such as low literacy rate, insufficient credit facilities, the absence of farm inputs, and other sociocultural issues (MINAGRI 2006).

Nyamagabe is one of the rural districts in Rwanda with successful stories of agroforestry systems applied in the forest areas to boost food production and increase household income. However, a study has not yet been conducted to identify the benefits of these agroforestry practices and how much they contribute to farmers' incomes and Rwanda's environment.

Studies show that agroforestry is one of the key sustainable management practices in many parts of Africa with great impact on food security through increased productivity (Gudeta et al. 2009; Pretty et al. 2011; Pinho et al. 2012; Minang et al. 2014) as well as biodiversity conservation. Minang et al. (2014, p. 80) suggest that agroforestry is "a great candidate for achieving land sparing" and that it also provides opportunities for local people to engage in sustainable activities rather than deforestation.

Regmi (2003) examines how agroforestry has contributed to rural livelihoods in Dhading District of Nepal. He interviewed 42 households engaging in agroforestry activities in the district and found that the farmers recognize the role of agroforestry in maximizing their income, increasing diversity of tree species, and saving women time collecting fodder and fuelwood. Bugayong (2003) also examined the socioeconomic and environmental benefits of agroforestry practices in a

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community-based forest management site in the Philippines. Using key informants and individual farmer interviews he found that agroforestry has moderately improved the socioeconomic (farmers' income) and environmental wellbeing (soil fertility, erosion, microclimate, vegetation) of the local people living around the project site. However, he also found that farmers lack the requisite skills and technology for harvesting, processing, and marketing their forest products, which therefore needs to be addressed by the government. In this study, we compared the economic benefits between adopters of agroforestry technology and non-adopters in Rwanda, and identified the challenges associated with agroforestry adoption.

In Rwanda, the Ministry of Agriculture has given government backing to ensure the adoption of agroforestry in forest-dependent communities. This move by the government is aimed at increasing farmers' incomes while protecting the forest cover from destruction and reducing poverty by 50% in the next 20 years (ROR 2008). It is expected that, by 2020, agriculture will contribute about 33% to the country's GDP while agro-processing factories are expected to increase their GDP contributions from 14% to 26% (ROR 2000).

Although the literature on agroforestry is vast, studies on its benefit relative to the socioeconomic and environmental wellbeing of forest-dependent communities are significantly lacking. This study examined the socioeconomic and environmental benefits of agroforestry practices in Nyamagabe District, Rwanda, focusing on factors influencing the farmers' income levels within the district and challenges facing agroforestry adoption in the district. This study is important because it will enhance the government's efforts in the fight against deforestation, improve agroforestry practices and catalyze their adoption in the region and beyond, as well as contributing to the limited literature on the subject. This study can also help bring policy reforms in both agricultural and forest sectors to enhance sustainable development.

Methods

Description of study area

This study was conducted in Nyamagabe District, which is located at the southern province of Rwanda (Figure 1). The district covers an area of 1089 km^2 with a total population of 341,491 (2012 estimate), population density of 313.6 persons/km^2 and a growth rate of about 2% (www.citypopulation.com). The district is predominantly rural and residents therefore depend on subsistence agriculture for their livelihood. Nyamagabe District hosts the only remaining natural forest (Nyungwe National Park) in the country and it enjoys a humid tropical climate moderated by the effect of high altitude. Annual rainfall varies from 1300 mm to 1450 mm with a mean temperature of 18 °C.

Nyamagabe District soils are generally acidic in nature with a pH ranging from 3.6 to 5. This implies very poor soils considerably degraded by erosion. Land fragmentation due to agricultural expansion coupled with poor agricultural practices have led to acute impoverishment of available land.

Destruction of the Nyungwe natural forest in the district is prevalent. Cultivation of crops in the forest areas disturbs local ecological bioclimatic conditions and contributes to general degradation of the environment. Nyungwe forest exercises considerable influence on local and regional bioclimatic conditions. It acts as a sponge which retains water and releases it slowly during the dry season hence ensuring hydrologic functioning and regulation. A uniquely rich center of floral diversity, Nyungwe forest contains 1068 plant

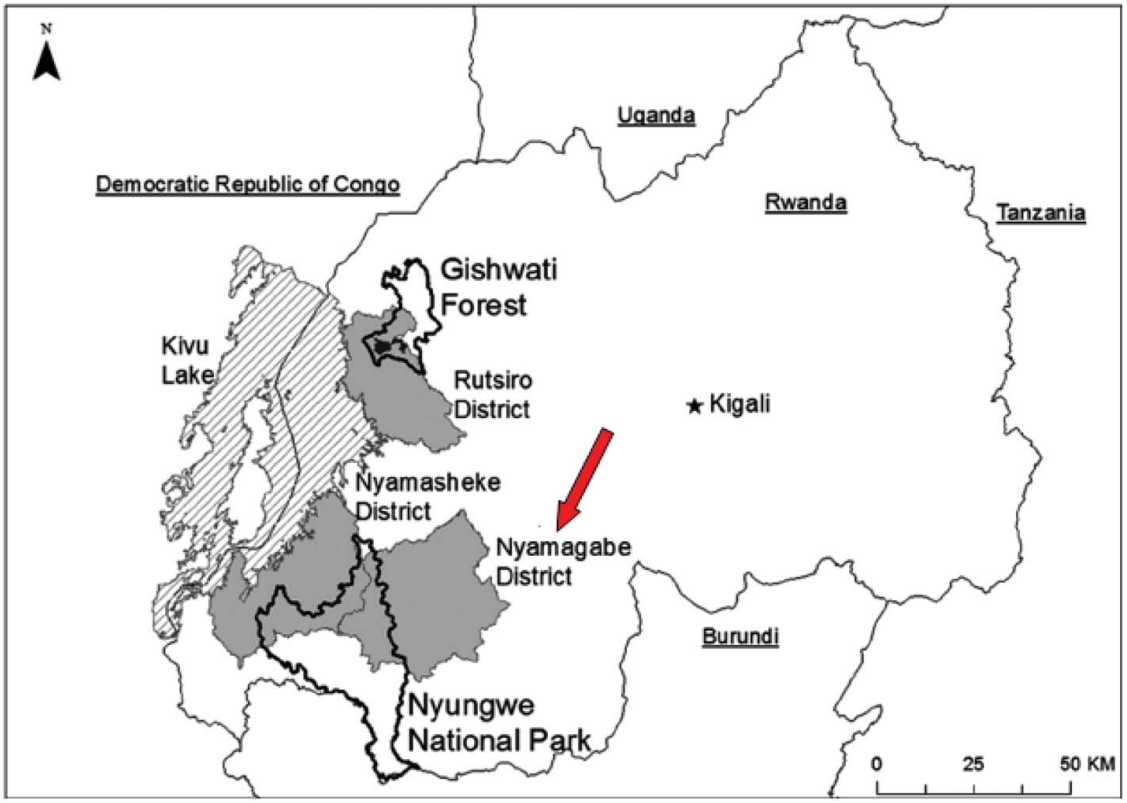

Figure 1. Nyamagabe District in southern province of Rwanda.

species including more than 200 different types of tree and a myriad of flowering plants including the otherworldly giant lobelia and a host of colorful orchids.

Data collection

This study targeted households in the Nyamagabe District that have either adopted agroforestry practices or have not and still practicing the conventional farming. In this regard, purposive random sampling technique was used in the selection of the targeted households.

The sample size for the study was determined using the formula by Kothari (Kothari 2004). The sample size was determined from 6245 households in the district, which gave 116 samples. However, we used 118 households, comprising 69 agroforestry adopters (AFAs) and 49 non-agroforestry adopters (NAFAs). The selected households were interviewed using structured survey questionnaires to elicit information relevant to the study objectives. However, prior to the field interviews, the survey questionnaire was pre-tested to ascertain the reliability and validity of the instruments being used. The researchers also engaged some district officers of the Ministry of Agriculture and key informants through email correspondence to get secondary information about the agroforestry activities in the district.

Data analysis

The data collected from the respective respondents were edited to correct any missing information on the questionnaires and to ensure accurate results. Later, the data were coded with the aid of SPSS v23. The coding of the data helped the researchers to categorize the views of the respondents and analyze the data accordingly. The researchers used descriptive statistics and correlations to analyze the data collected. The descriptive statistics which include frequency distribution, percentage, mean, and standard deviation were used to summarize the respondents' socioeconomic characteristics. The Pearson correlation coefficient was used to determine the factors influencing the income levels of AFAs. Based on the results, the researchers were able to make some deductions and provided appropriate recommendations for policy action.

Results and discussion

Demographic characteristics of respondents

Most of the respondents were male (75.4%), with just 24.6% female (Table 1). This implies that the majority of local residents engaging in agroforestry and conventional farming in Nyamagabe District are males. There is gender disparity in agriculture in the region and this may explain the low number of females observed in this study. In Rwanda most men have access to land and credit facilities whereas women do not.

Generally, agroforestry practices are mostly done by men because of the cultural values and responsibilities of men in Rwandan families. Women tend to be more interested in cultivating crops for food consumption rather than cultivating tree crops. According to Fortmann and Rocheleau (1985), women are traditionally important participants in both agricultural and forestry components of agroforestry production but are frequently ignored in the design of agroforestry projects because of commonly held myths about their participation in both production activities and in public life.

Table 1 . Respondents' demographic characteristics.

Variable	Response categories	Frequency	%
Age(years)	20–35	6	5.1
	36–50	63	53.4
	51–65	33	27.9
	>65	16	13.6
Gender	Female	29	24.6
	Male	89	75.4
Marital status	Single	3	2.5
	Married	98	83.1
	Widowed	10	8.5
	Separated	7	5.9
Education	Illiterate	37	31.3
	Primary	53	44.9
	Secondary	18	15.3
	Informal	10	8.5
Household size	<5	17	14.4
	5–7	82	69.5
	>7	19	16.2

The results show that 83.1% of respondents were married, 5.9% divorced or separated, 8.5% widowed, and 2.5% single. According to age distribution the majority of respondents (56.5%) were in the 36–50 year bracket, which suggests they are more likely to adopt new farming technologies than the older generation, since the majority of them have had some form of primary education. ICRAF (2001) indicates that younger farmers are more likely to adopt a new technology since they have had more schooling than the older generation, or perhaps have been exposed to new ideas as migrant laborers. However, in this study, nearly 40% of the farmers are illiterate. This may bring some constraints in agroforestry technology transfer and adoption.

According to the results, the majority of respondents have a household size of between five and seven people, with a mean household size of about six, which is higher than the national mean household size in Rwanda. According to the National Institute of Statistics of Rwanda (2007–2008), the national mean household size is 4.6 individuals (4.5 in rural areas and 4.8 in urban areas). The consequences of large family size are increasing pressure on the ecosystem, land fragmentation, and forest ownership problems.

Agroforestry practices adopted in Musebeya sector, Nyamagabe District

This study identified agroforestry practices being employed in Nyamagabe District. From the survey, the predominant agroforestry practices include alley cropping, woodlots, and boundary planting (Figure 2). The results also reveal that the tree species that is most frequently patronized by the farmers is *Grevillea robusta* (Grevillea).

Economic status of respondents

The income level of respondents (AFAs and NAFAs) is presented in Table 2. The results reveal significant income disparity between the two groups. The mean annual income of AFAs is shown to be higher than that of NAFAs at 278,000 RWF (about US$331) and 249,000 RWF (about US$297) respectively. This result supports findings by various authors (Hossain et al. 2005; Safa 2005; Rahman et al. 2007; Rahman 2011; Islam 2013; Hasanuzzaman et al. 2014) that income of agroforestry practitioners is usually higher than those

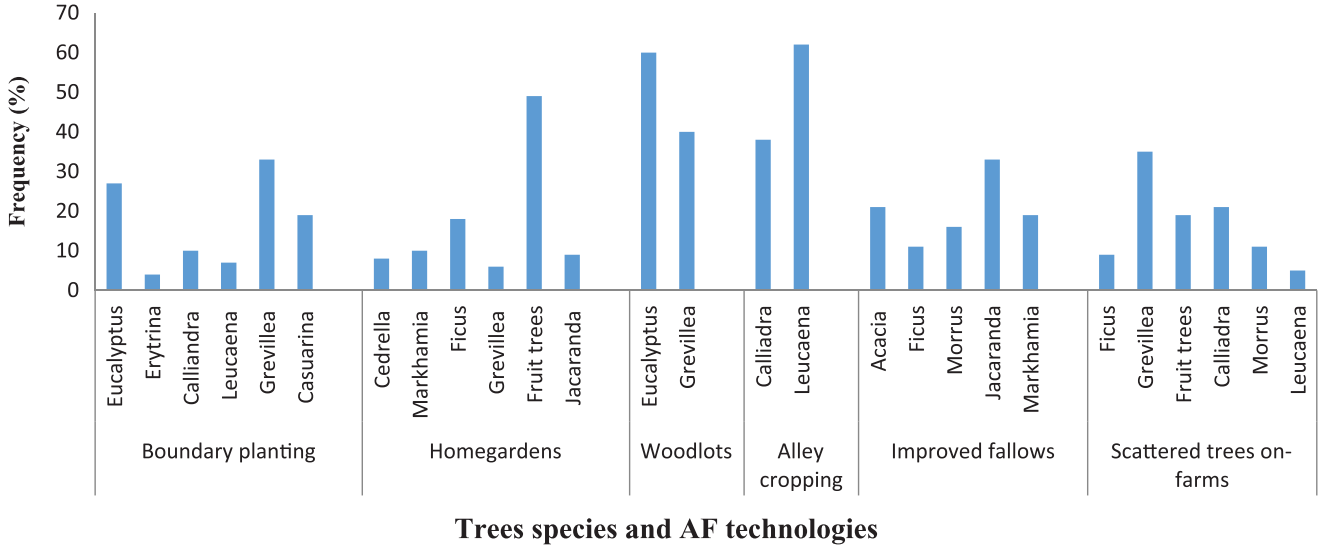

Figure 2. Agroforestry practices with respective tree species in Nyamagabe District.

Table 2. Annual incomes of respondents in Rwandan Franc (RWF).

Respondents	No.	Minimum	Maximum	Mean
AFAs	69	50,000	700,000	278,000
NAFAs	49	43,000	678,000	249,000

involved in pure agriculture. Neupane and Thapa (2001) argue that integrating agricultural systems with cropland agroforestry is more profitable in the hills of Nepal. Agroforestry adoption has contributed to the increase of famers' income in the Philippines (Bugayong 2003) and Nepal (Regmi 2003). Thus, agroforestry adoption by NAFAs will be important in improving their income status and enhancing their livelihood activities in the district.

The researchers went on to find out from the respondents whether agroforestry technology introduced by the government is increasing household income based on their experiences over the years as well as environmental improvement. Figure 3 summarizes the respondents' views on this matter.

The majority of respondents (60%) recognized that agroforestry technology contributed either highly or very highly to their household income, whereas 23% considered agroforestry's contribution to household income as medium, and just 17% were of the view that its contribution to household income was low (Figure 3).

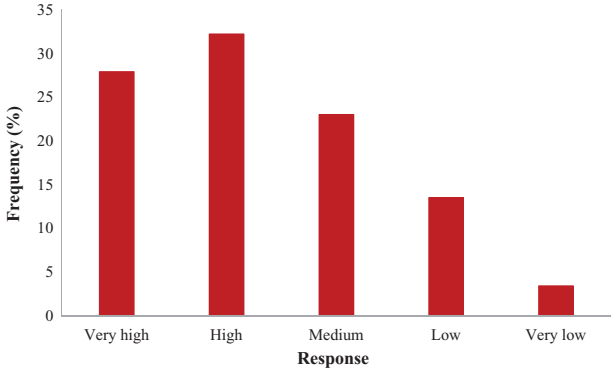

Figure 3. Respondents' views on whether agroforestry is increasing household income.

AFAs' characteristics influencing their household income

Results from the correlation (Table 3) show that land size, education, and experience of the AFAs are the factors that may influence their household income at the 1% significance level. The correlation coefficients determined were land size (0.75), education (0.83), and experience (0.63). However, age of respondent and household size of AFAs were found to be not statistically significant with household income.

According to ICRAF (2001), farmers with more experience in farming are more likely to adopt a new technology since they are better able to understand the benefits of innovations based on their previous experiences. Sarfo-Mensah (1994) argues that high literacy rate would increase technical efficiency in adopting agroforestry innovations, and this may affect farmers' income. According to Sood and Mitchell (2009), educated farmers are considered to be innovative or opinion leaders and willing to take more risks than illiterate farmers. This result implies that farmers lacking education need to be given some form of informal education to enhance their skills and capacities to adopt new technologies, which will have a significant impact on their livelihood. The government, however, needs to put in measures to regulate the population pressures or household size which are likely to affect livelihood activities and the environment in the district.

Environmental benefits of agroforestry in the district

In this study, respondents were asked to indicate the environmental benefits that agroforestry brings to the district (Figure 4). Eighty-four respondents said that, since its introduction, agroforestry has increased soil fertility in the area, 86 said it has reduced deforestation of the natural forests,

Table 3. Relationship between AFA (n = 69) characteristics and household income.

AFA characteristics	Correlation coefficient (r)	Sig. (2-tailed)
Experience	.628**	.000
Land size	.746**	.000
Education	.830**	.000
Household size	−.207	.088
Age	−.018	.884

Note:
**Significant at 0.01 level.

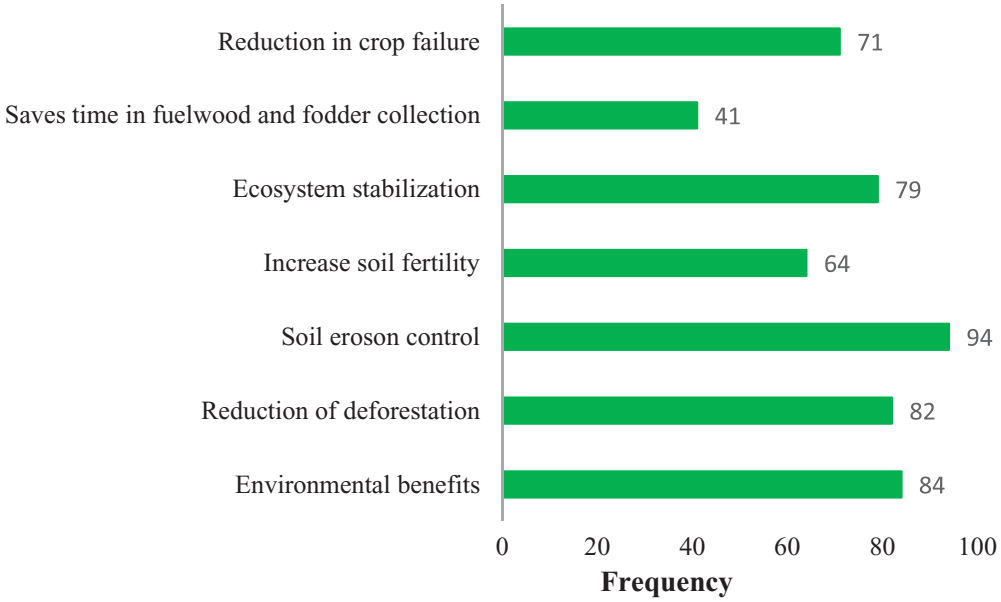

Figure 4. Respondents' perspectives about the environmental benefits of agroforestry in the district.

and 82 agreed that this new technology has reduced soil erosion. Again, 79, 71, 64, and 41 respondents alluded that the new farming practice stabilizes the ecosystem, reduces crop failure, increases soil fertility and saves time during fuelwood and fodder collection, respectively. Jose (2009) suggested that past and present evidence clearly shows that agroforestry, as part of a multifunctional working landscape, can be a viable landuse option that, in addition to alleviating poverty, offers a number of ecosystem services and environmental benefits. Bugayong (2003) also argues that agroforestry introduced in Nepal has improved soil fertility, soil erosion control, microclimate, and vegetation cover. The government of Rwanda needs to increase its efforts in the fight against deforestation through subsistence farming by encouraging NAFAs to adopt this new system of farming being rolled out in the region. This will ultimately improve rural communities' livelihood, forest cover, and mitigate climate change.

Challenges affecting the adoption of agroforestry in the sector

According to the results lack of capital was ranked high (87.0%) among the limitations preventing farmers from fully adopting agroforestry practices, followed by lack of technical skills (76.4%), lack of quality seeds (67.8%), lack of manpower (57.5%), and market inaccessibility (27.8%) (Figure 5).

Farmers' suggestions to the challenges facing adoption of agroforestry in the district

The results show that most respondents (89.5%) suggested that giving subsidies to farmers can play a vital role in agroforestry adoption, while 85.5% suggested that species for agroforestry should made available, 81.3% said there should be tree nursery establishment, and 76.1% said community participation may help overcome the challenges affecting agroforestry adoption to help farmers feel part of the decision-making process regarding agroforestry policies and programs. Also, 64.7% said capacity building through training and field demonstrations is important to increase the adoption rate of agroforestry technology. Furthermore, 33.2% said that making markets for agroforestry products more accessible can improve agroforestry adoption in the district (Figure 6).

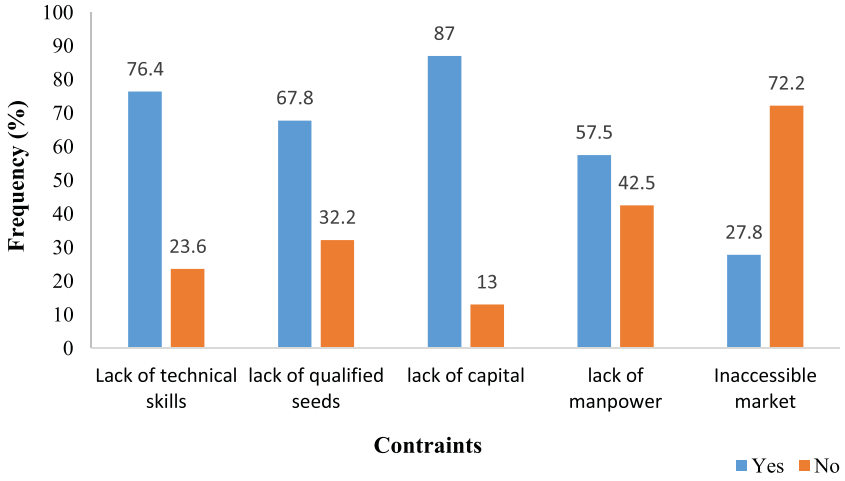

Figure 5. Challenges facing the adoption of agroforestry in the sector.

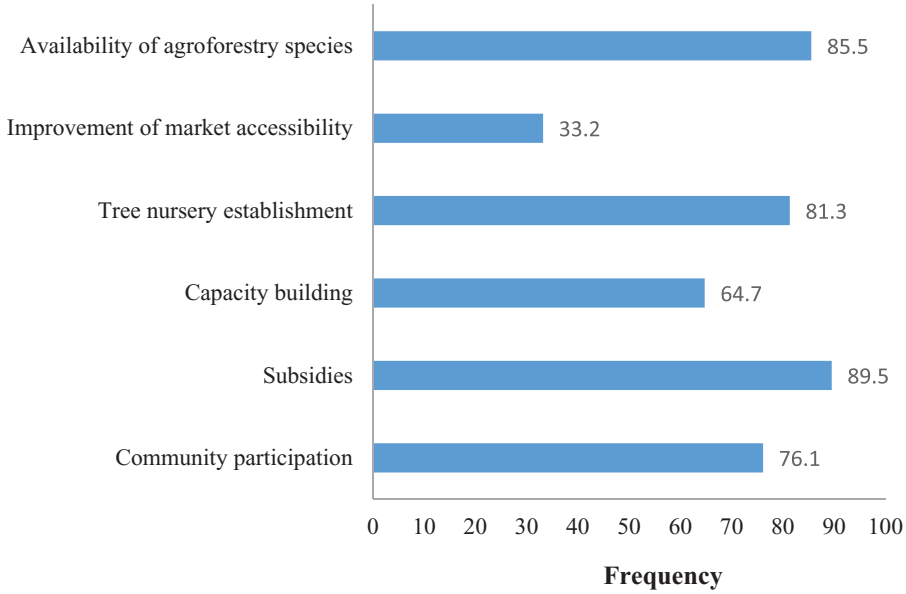

Figure 6. Respondents' suggestions to overcome the challenges.

Conclusions

Rwanda's remaining natural forest is under intense pressure due to increasing rural population growth and subsistence farming. Through the Ministry of Agriculture, the government has introduced agroforestry practices in forest-dependent communities in order to promote sustainable agriculture and forestry as well as to improve the livelihood of local people. This new technology has, however, not been widely adopted, with many farmers still practicing conventional subsistence farming which is continuing to cause land degradation in some areas. This research surveyed 118 household heads to find out the socioeconomic and environmental benefits of the introduced agroforestry technology by comparing two groups (AFAs and NAFAs), and to identify the obstacles standing in the way of adoption.

Results revealed an income disparity between AFAs and NAFAs. The NAFAs mean annual income was 29,000 RWF less as compared to that of the AFAs. The respondents acknowledged that the income of farmers who have adopted agroforestry practices is increasing since its introduction in the district. Also, respondents said that the introduction of agroforestry has essentially been beneficial to the environment regarding soil fertility improvement, reduction of deforestation, and soil and water conservation.

However, the respondents recognized that the adoption of agroforestry practices is facing some challenges in the district. They attributed these challenges primarily to lack of skills and technical know-how, capital, and quality seeds. The respondents perceived that these challenges can be surmounted by the provision of subsidies to farmers, regular training and informal education to help farmers build their skills and capacities, establishment of tree nurseries to improve the production of quality seeds, and to involve farmers in decision-making with regard to agroforestry policies and programs.

The Rwandan government should show commitment by providing adequate funding and by subsidizing agricultural inputs for farmers to encourage them to adopt this new technology. The government should also partner with the private sector and NGOs to establish tree nurseries for quality seeds and agroforestry species to help farmers maximize their output in the Nyamagabe District and other parts of the country. Further, the Ministry of Agriculture should encourage community participation by involving all stakeholders in the design and implementation of the agroforestry program. Additionally, the Ministry of Agriculture and local agencies should intensify capacity-building training programs to equip farmers to effectively adopt this new technology to achieve its intended purpose in the country.

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Disclosure statement

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