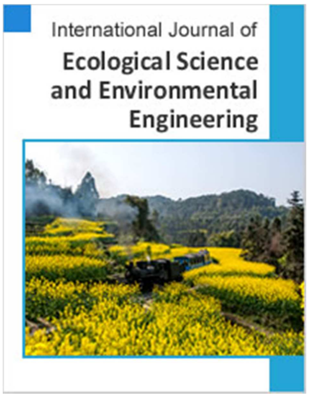
International Journal of Ecological Science and Environmental Engineering
2016; 3(1): 20-31
Published online February 26, 2016 (http://www.aascit.org/journal/ijesee)
ISSN: 2375-3854

American Association for Science and Technology



Keywords
Environmental Quality,
Smallholder Farms,
Agroforestry,
Livelihoods,
Adoption,
Agro-ecological Zone

Received: December 11, 2015
Revised: January 11, 2016
Accepted: January 13, 2016

Enhancing Adoption of Agroforestry in the Eastern Agro-Ecological Zone of Uganda

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Citation
Twaha Ali Basamba, Clement Mayanja, Barnabas Kiiza, Bob Nakileza, Frank Matsiko, Paul Nyende, Elizabeth Bacwayo Kukunda, Ann Tumushabe, Kassim Ssekabira. Enhancing Adoption of Agroforestry in the Eastern Agro-Ecological Zone of Uganda. *International Journal of Ecological Science and Environmental Engineering*. Vol. 3, No. 1, 2016, pp. 20-31.

Abstract
Widespread deforestation and increasingly intensive use of land to sustain a growing population has increased soil erosion, lowered soil fertility and reduced agricultural productivity in Uganda. This has raised concern over sustainability of farming systems in the Eastern Agro-ecological zone of Uganda. There is growing evidence that agroforestry can be a potential solution to these problems. However, enhancement of adoption of agroforestry as a viable alternative for farmers in diverse ecological and socio-economic conditions has remained low. The objective of this study was to identify the factors influencing the enhancement of adoption of agroforestry by smallholder farmers. Primary data on household, farm and technology characteristics was collected from 153 farming households. Results show that boundary planting, scattered tree planting, row planting and homestead gardening were the most commonly adopted agroforestry technologies in the study area. The Tobit model showed that sex, age, household size, education level, group membership, access to credit and extension visits had significantly positive effects on enhancing adoption of agroforestry. Mobilizing farmers to join groups, improving the quality and coverage of extension services, consideration of gender issues and intensifying agroforestry training among farmers with low levels of education were suggested as avenues to further enhance adoption of agroforestry in the Eastern agro-ecological zone of Uganda.

1. Introduction

Agroforestry is a dynamic, ecologically-based natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels [1]. Cultivating trees in combination with crops and livestock is an ancient practice. However, several factors have contributed to a rising interest in agroforestry since the 1970s, including the deteriorating economic situation in many parts of the developing world; increased tropical deforestation; degradation and scarcity of land due to population pressure; and the growing interest in farming systems, intercropping and the environment [2].

Brandle *et al*. [3], Clason [4] and Kurtz [5] argue that agroforestry provides cost-effective alternatives that increase farm profits and protects the environment within rural settings. In such a scenario, agroforestry practices that integrate trees, crops and animal components are emerging as part of an intensive land management approach focused on sustainable resource use and production within given economic, social and environmental settings [6, 7].

The ecological, economic and social benefits of agroforestry are further documented [8, 9, 10]. With its potential to increase farm productivity and diversity, agroforestry produces a range of products such as food, fuel-wood, building materials, medicine and fodder. Properly conceived and practiced, agroforestry can contribute to sustained productivity of the natural resource base by enhancing soil fertility, controlling soil erosion, enhancing the microclimate of cropping and grazing lands and can improve environmental quality.

Agroforestry has the potential to reduce poverty and can be put to efficient use in poverty reduction strategies of countries in the East African region. In forest-scarce countries, agroforestry has expanded greatly on small farms. In Kenya and Ethiopia, for example, farms account for most timber and pole production [11]. In agroforestry systems, the cost of tree production may be lower due to joint production with crops and livestock [12]. Trees may even have a positive effect from incomes generated from associated crops, as in the case of windbreaks.

The importance of trees in farming systems, particularly in Africa, has been enhanced by mainly two trends. The first is the scientific research that has broadened the types of services that trees can provide to farmers. Secondly, the conversion of natural forests and woodlands into agriculture coupled with the stagnation in plantation forestry has increased the importance of tree product supply from farms [13]. Tree planting is as well gaining increased attention by farmers with degraded lands and where labor shortages occur [14].

The Plan for Modernization of Agriculture of the government of Uganda recognizes agroforestry as one of the options for improving farm productivity and thereby eliminating poverty through increased household incomes [15]. The Uganda Forestry Policy also recognizes tree growing on farms for provision of firewood, poles, non-wood products, fruits and even timber. Through this policy, the government pledges to build the capacity of Non Governmental Organizations (NGOs), Community Based Organizations (CBOs) and private contractors as well as government agencies to provide agroforestry advice and training. It also pledges provision of extension and advisory services to support farmers, communities, organizations and entrepreneurs in the development of agroforestry.

Much as the government supports the development of agroforestry in Uganda, a tremendous reduction in tree cover and insufficient supply of tree products and services in Eastern agro-ecological zone of Uganda were identified [16]. This therefore calls for increased efforts to promote tree planting among smallholder farmers [17].

A specialized international agroforestry research institute, the World Agroforestry Centre (ICRAF), is involved in comprehensive research and development of agroforestry in Uganda. Several donors and NGOs have also been providing support in the development and promotion of agroforestry. However, in spite of their great efforts, current adoption levels of agroforestry at the farm level are still low [18].

Trees are useful in livelihood and production strategies especially among rural communities [19]. Muok *et al.* [20] noted that growing trees on farms is a very important livelihood strategy in rural communities of sub-Saharan Africa. Agroforestry, as a science and practice, has the potential to contribute to the improvement of rural livelihoods due to the capacity of its various forms to offer multiple alternatives and opportunities to smallholders to enhance farm production and income, while protecting the agricultural environment.

While growing of trees on farms was identified as an important production and livelihood strategy in rural communities of Sub-Saharan Africa [21], adoption levels remain low among smallholder farmers in the eastern lowland agro-ecological zone of Uganda [18]. In addition, the review of existing literature and experience from past agroforestry initiatives reveals little information about the intensity of adoption of agroforestry in Uganda. For example, Kiwuso *et al.* [22] identified the indigenous methods of controlling termites in Uganda's agroforestry systems and Katumba *et al.* [23] examined the domestication of medicinal tree species in the Lake Victoria shore region. The highlighted studies reveal limited information on the types of agroforestry technologies adopted by farmers and the intensity of adoption. It is against this background that the current study seeks to fill this significant gap.

Given the high demand for a wide range of agroforestry products both locally and regionally [24, 25], enhancement of the adoption of agroforestry technologies has potential to alleviate poverty among smallholder farmers.

NARO (The National Agricultural Research Organization of Uganda), ICRAF and Africa 2000 Network have been involved in extensive promotion of agroforestry technologies in Eastern Uganda, including Busia District, but there has been no study conducted to determine the level of adoption and factors influencing the enhancement of adoption of agroforestry technologies.

The general objective of our study was to assess the factors affecting the enhancement of adoption of agroforestry technologies in Busia District in the Eastern Agro-Ecological zone of Uganda. The specific objectives of the study were:

1. To compare the socio-economic characteristics of adoptors and non-adoptors of agroforestry technologies
2. To determine the level of adoption of various agroforestry technologies
3. To evaluate the factors influencing the level of enhancement of adoption of agroforestry technologies

The study was guided by the following hypotheses;

1. Access to credit significantly affects enhancement of adoption of new agroforestry technologies
2. Membership in farmer organizations increases the probability of adopting agroforestry

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Busia District which is located in the eastern agro-ecological zone of Uganda, north of Lake Victoria and west of the Republic of Kenya. It is approximately 196 kms from Kampala, the Capital city of the Republic of Uganda. With a population of 243,298 people (117,564 males and 125,734 females) [26], the District covers a total area of 743 sq. km.

The District was selected because tree growing is the third major source of income after crops and livestock [27]. Therefore, agroforestry has a great potential to improve farmers' livelihoods [18]. Secondly, the District is experiencing serious land degradation due to deforestation, over cultivation and bush burning. Fragile ecosystems such as forest reserves and wetlands have been degraded through deforestation and wetland drainage. The District is predominantly rural, with 84% of the population leaving in the rural areas and about 85% of this population survives on agriculture. Agricultural activities carried out depend entirely on nature and thus any actions that affect the natural environment have a negative impact on the livelihoods of the population [28].

NARO, ICRAF and Africa 2000 Network have been promoting tree growing and general sensitization on environmental protection. The rural economy of the District is characterized by smallholder farmers who predominantly practice subsistence agriculture with the main crops grown being sorghum, millet, cotton, cassava, sweet potatoes, maize and beans.

2.2. Sample Size and Sampling Procedures

Using purposive and simple random sampling techniques, cross-sectional data was collected from a total sample size of 153 farmers. Dabani and Bulumbi Sub-Counties (local government administrative units) in Busia District were purposively selected to represent high and low levels of adoption of agroforestry technologies, respectively. This was followed by the purposive selection of Nangwe Parish from Dabani Sub-County and Bubango Parish from Bulumbi Sub-County where NARO Agroforestry research and dissemination activities had taken place. From each parish, a list of farmers that was used as a sampling frame was generated with the help of agricultural extension officers. A simple random sampling technique was used to select 60 farmers from Nangwe parish and 93 farmers from Bubango parish to make a total sample size of 153 farmers for the study.

2.3. Data Collection

Both primary and secondary data were collected during this study. A semi-structured, pre-tested questionnaire was used to capture primary data from selected farmers at their respective farms using direct interviews. Primary data included farmer's age and gender, marital status, household size, number of household members involved in farming and not involved in farming, main occupation, farming experience, farm ownership, farm size, education level of farmer, education level of spouse, membership to farmers' organizations, access to credit facilities, access to agroforestry output markets, main agroforestry production objective, agroforestry production technologies adopted and not adopted, reasons for adoption and non-adoption, types of tree species grown by farmer, types of crop enterprises grown and livestock reared, contact with extension personnel, distance to trading centre, distance to District capital, prices of agroforestry products, and the major reasons for adoption and non-adoption. Secondary data from NARO and Africa 2000 Network included the types of agroforestry technologies or practices that farmers were trained in [18].

2.4. Analytical Procedures

2.4.1. The Tobit Model

The Tobit model was used to analyze factors influencing the probability and intensity of adopting agroforestry. A farmer who has been trained in various agroforestry technologies has full information about the new technologies and may choose to apply them all, apply part of them or not to apply any. Given that a number of factors affect the farmer's decision to apply or not to apply the acquired information, the dependent variable becomes zero for non-adopters and the maximum is one or 100% for full adoption. Such a situation is appropriately analyzed using a Tobit model.

The Tobit model measures the probability and intensity of adoption [29]. The model is preferable to binary adoption models when the decision to adopt involves simultaneously the decision regarding the intensity of adoption [30], as it does with agricultural technologies. The dependent variable therefore is 0 for non-adopters and varies between 0 and 1 for adopters ([31, 32]). Following Maddala [31] and Gujarati [32], the theoretical model is presented as:

$$Y_i = \beta_i X_i + U_i \text{ if RHS} > 0 \quad (1)$$

=0, otherwise

Where RHS is Right Hand Side

Y_i = observed intensity of adoption of agroforestry practices or technologies

β_i = vector of parameters to be estimated

X_i = vector of explanatory variables

U_i = normally and independently distributed error term

2.4.2. Model Specification

The Tobit model was estimated as;

$$Y_i = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \varepsilon \quad (2)$$

Where;

Y_i = intensity of adoption (proportion of agroforestry technologies applied out of the total number of technologies a farmer was trained in)

β_0 = Intercept

X_1 = Age (Years)

X_2 = Sex of the farmer (1= Male, 0 = Female)

X_3 = Education level (Years of formal schooling)

X_4 = Household size (Number)

X_5 = Farmer's experience (Years)

X_6 = Farm size (Hectares)

X_7 = Market distance from farm (Km)

X_8 = Group membership (1 = Member, 0 = Otherwise)

X_9 = Extension visits (Number)

X_{10} = Access to credit (1= Yes, 0 = Otherwise)

X_{11} = Main occupation (1= Farming, 0 = Otherwise)

X_{12} = Vermines (1= Presence of Vermines, 0 = Otherwise)

X_{13} = Livestock value (Shillings)

ε = Error term

β_{1-13} = Coefficients associated with independent variables

In a Tobit model, the coefficients were not interpreted directly as estimates of the model, but rather as marginal effects of changes in the explanatory variables on the expected value of the dependent variable. Each marginal effect includes both the influence of the explanatory variable on the probability of adoption as well as on the intensity of adoption [33].

2.4.3. Data Analysis

Primary data was entered in SPSS (Statistical Package for Social Scientists) and analyzed using STATA. Descriptive statistics in form of percentages, means and standard deviations were generated to identify socio-economic characteristics of farmers and types of agroforestry technologies adopted and not adopted. Comparison of socio-economic characteristics was made using chi-square and t-test statistics for categorical and continuous variables, respectively. To determine the intensity of adoption and factors influencing enhancement of adoption of agroforestry technologies, the Tobit model parameter estimates were used.

3. Results and Discussion

3.1. Socio-Economic Characteristics of Agroforestry Technologies Adopters and Non-adopters

Table 1 presents descriptive statistics of the socio-economic characteristics of adoptors and non-adoptors of agroforestry technologies in Busia District in the eastern agro-ecological zone of Uganda. Agroforestry adoptors were on average older (42 years) than non-adoptors and the difference was significant. Generally, farmers in the study area were relatively old and actively involved in farming. This is an advantage to enhance adoption of agroforestry technologies. The mean household size of adoptors was comparatively larger with 7 members as compared to non-adoptors with 5 members. The significant relationship between household size and adoption level of agroforestry implies that farmers with a higher number of household members were more likely to adopt agroforestry technologies compared to those with fewer members.

The average number of household members actively involved in farming was higher for adoptors. This means that households with a big number of members actively involved in farming were more likely to adopt agroforestry because of abundant labor supply provided by such members. On the other hand, households with fewer numbers of members involved in farming are less likely to adopt agroforestry because of labor shortages. The mean number of adult males and females was significantly different between adoptors and non-adoptors. Similarly, the mean number of male children was significantly different between the two groups of farmers. However, there was no significant difference in the average number of female children between adoptors and non-adoptors' households. Agroforestry adoptors held comparatively larger farms (2.847 ha) compared to non-adoptors (1.916 ha). This implies that farmers with larger farms were more likely to adopt agroforestry compared to those with smaller farms. This is consistent with the findings of Onweremadu and Mathews-Njoku [34] who reported that farmers with larger farms were positively associated with the decision to adopt maize production technologies in Nigeria. In addition, the education level of household heads in terms of years of formal schooling was higher for adoptors (7.291 years) compared to (5.395 years) for non-adopters. The significant relationship between the level of education and adoption implies that educated farmers adopted more than the less or non-educated ones. This is because education enhances the ability to derive, decode and evaluate useful information for agricultural production [35, 36].

Similarly, the average education level of spouses for adoptors (4.873) was higher compared to that of non-adoptors (5.395). The education level of spouse is important in adoption decisions because in the absence of household heads, spouses make all important decisions and provide all the necessary support for the family [37]. Both general farming experience and experience in agroforestry were significantly related to enhanced adoption of agroforestry.

Adoptors had more experience in general farming and agroforestry practices compared to non-adoptors. These results are similar to those of Okoedo-Okojie and Onemolease [38] on the adoption of improved yam storage technologies in Nigeria. The results further indicated that the market distance for adoptors (7.076 km) was less than that of non-adoptors (11.017 km) on average. This shows that the nearer the market from the farm, the more it becomes easier for the products to reach the market, hence high adoption. In terms of extension services, agroforestry adoptors received more extension visits (0.473 visits) on average as compared to non-adoptors (0.047 visits). This indicates that the more visits by the extension agents to the farmers, the more aware they become of the agroforestry practices, hence enhanced adoption. This compares well with the findings of Njoku *et al.* [39] on the acceptability of improved crop production practices among rural women in Aguata agricultural zone of Anambra State, Nigeria.

Table 1. *Descriptive statistics of the socio-economic characteristics of adoptors and non-adoptors of agroforestry technologies in the eastern agro-ecological zone of Uganda.*

Variable (mean)	Adoptors (n=110)	Non-adoptors (n=43)	t-value	p-value
Age (years)	42.382 (13.401)	37.488 (7.582)	-2.255	0.026
Household size (number)	7.273 (3.749)	5.558 (1.820)	-2.865	0.005
Male adults (number)	1.345 (0.971)	1.060 (0.507)	-1.767	0.079
Female adults (number)	1.464 (1.123)	1.130 (0.774)	-1.737	0.084
Male children (number)	2.482 (1.948)	1.581 (1.118)	-2.850	0.005
Female children (number)	2.009 (1.553)	1.767 (1.411)	-0.887	0.377
Household members involved in farming (number)	3.473 (2.337)	2.767 (1.493)	-1.836	0.068
Household members not involved in farming (number)	3.782 (2.849)	4.023 (1.883)	0.513	0.609
Education level of household head (years)	7.291 (3.820)	5.395 (3.303)	-2.861	0.005
Education level of spouse (years)	4.873 (3.912)	2.279 (4.090)	-3.639	0.000
Distance to trading centre (km)	7.076 (5.564)	11.017 (5.693)	3.913	0.000
Farm size (ha)	2.847 (2.419)	1.916 (1.132)	-2.416	0.017
General farming experience (years)	12.327 (11.008)	8.512 (5.457)	-2.168	0.031
Agroforestry experience (years)	3.664 (3.005)	0.279 (1.297)	-7.118	0.000
Extension visits (number)	0.473 (0.502)	0.047 (0.213)	-5.378	0.000

Table 2. *Descriptive statistics of categorical variables of agroforestry adoptors and non-adoptors.*

Variable (%)	Adoptors (n=110)	Non-adoptors (n=43)	χ^2-value	p-value
Sex				
Male	82.7	79.1	0.277	0.599
Female	17.3	20.9		
Marital status				
Married	84.5	79.1	11.987	0.002
Single	11.8	2.3		
Widowed	3.6	18.6		
Education level				
No formal education	9.1	23.3	10.788	0.013
Primary	50.9	60.5		
Secondary	37.3	16.3		
Tertiary	2.7	0		
Major occupation				
Farming	92.7	100.0	3.300	0.192
Trading	4	0		
Civil service	4	0		
Group membership				
Yes	60.9	23.3	17.533	0.000
No	39.1	76.7		
Access to credit				
Yes	17.3	2.3	6.078	0.014
No	82.7	97.7		
Access to extension				
Yes	47.3	4.7	24.591	0.000
No	52.7	95.3		

Table 2 presents descriptive statistics of categorical variables of agroforestry adoptors and non adoptors in Busia District. The results indicated that there were more male than female farmers adopting (82.7%) and not adopting (79.1%) agroforestry technologies in Busia District. This is because men tend to have better access to land, labor and other resources than women [40]. The percentage of married household heads was higher (84.5%) among farmers who had adopted agroforestry compared to those who had not and the difference was significant. A significant relationship between marital status and adoption of agroforestry implies that as more farmers got married, the more they were involved in adopting agroforestry. This is because, as a farmer marries, his household size increases, resulting into additional food requirements [41]. Food is usually the most basic need in every household and the use of agroforestry technology to enhance crop yields and improve livestock productivity is usually opted for [12].

Although there was a significant difference between formal education of agroforestry adoptors and non-adoptors, education was largely limited to primary level for both categories of farmers. The major occupation of most household heads among agroforestry adoptors and non-adoptors was mainly farming. In addition, a large proportion of agroforestry adoptors (60.9%) belonged to farmer groups. This is because such groups increase information acquisition through interaction of members, thus enhancing adoption. The descriptive results in Table 2 also showed that more agroforestry adoptors had accessed credit facilities than non-adoptors. As reported by Chukwuji and Ogisi [42], access to credit is a very important factor in the adoption of agricultural technologies.

In terms of access to extension services, agroforestry adoptors had more access to extension services compared to non-adoptors. Contacts with extension agents expose farmers to availability of information which stimulates adoption.

3.2. Level of Adoption of Various Agroforestry Technologies

Seven major agroforestry technologies have been disseminated to farmers in Busia District over the past 10 years to conserve the environment and improve agricultural productivity [18, 43]. These include row planting (alley cropping), boundary planting, scattered trees (dispersed trees), home gardens, improved fallows, woodlots and taungya system. Results on the level of adoption of various agroforestry technologies by farmers are presented in Figure 1. They show that out of the seven agroforestry technologies disseminated, farmers adopted only four technologies which are boundary planting (33.6%), followed by scattered tree planting (32.8%), row planting (29.5%) and homestead gardening (4.1%) which was the lowest adopted agroforestry technology. Similarly, Eyasu [44] identified scattered trees on crop fields and homestead tree planting as traditionally practiced in many parts of Africa.

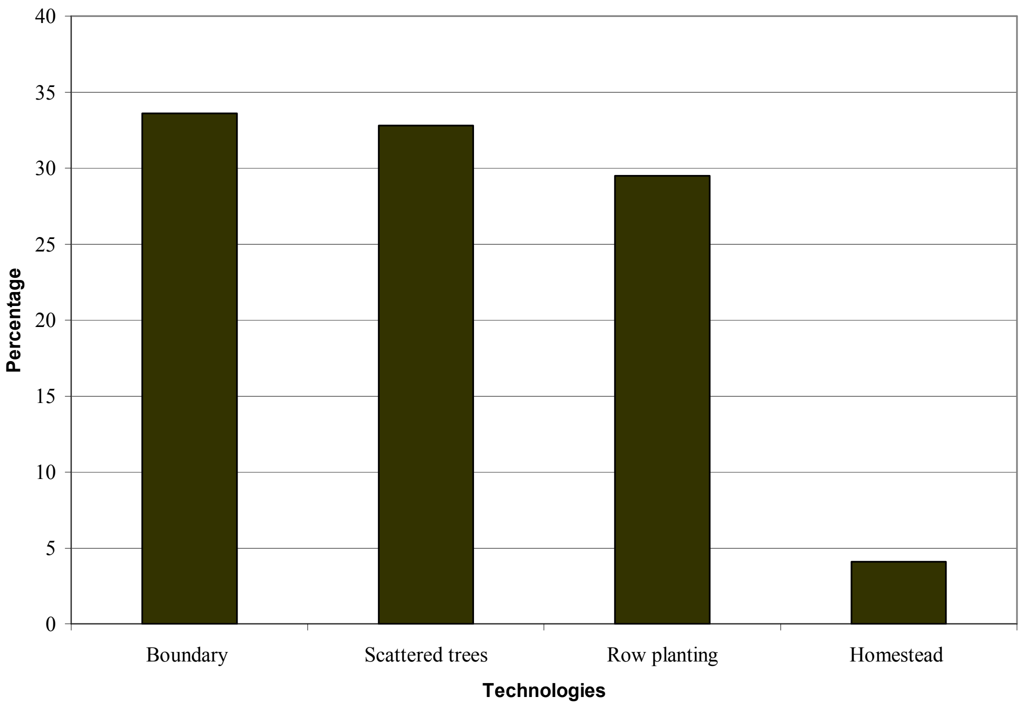

Fig. 1. *Adoption level of various agroforestry technologies promoted in the eastern Uganda agro-ecological zone.*

Table 3 shows that (33.9%) of the farmers adopted boundary planting to mainly fence and protect their farm boundaries from possible land encroachers. Row planting (alley cropping) was adopted mainly for soil conservation (22.3%) and land shortage (6.6%). Similarly, soil conservation (33.1%) was the major reason for the adoption of scattered tree planting agroforestry technology. In addition, homestead planting (4.1%) was adopted to provide shade around homesteads. Farmers in Busia District use *Persea americana, Artocapus heterophylus* and *Eucalyptus species* in boundary planting. For scattered tree and row planting, farmers apply *Markharmia lutea, Maesopsis eminii, Grivellia robusta, Calliandra calothyrsus, Leucaena leucocephola* and *Sesbania sesban. Mangifera indica* and *Artocapus heterophylus* are planted around homesteads for shade and fruits. Agroforestry systems have attracted considerable attention as an attractive and sustainable pathway to improve soil fertility [13, 45]. Previous studies have also indicated the adoption of alley cropping for soil fertility management reasons. For example in Nigeria, most farmers (82%) indicated that soil fertility improvement was the major reason for the adoption of alley cropping technology [46].

***Table 3.** Reasons for adopting agroforestry.*

Technologies	Major reason (s) for adoption	Frequency* (n=121)	Percentage (%)
Boundary planting	Fencing and Demarcating land	41	33.9
Scattered tree planting	Soil conservation	40	33.1
Row planting or alley cropping	Soil conservation	27	22.3
	Land shortage	8	6.6
Homestead planting	Shade	5	4.1

*Multiple responses

3.2.1. Tree Species Adopted

Results in Table 4 indicate the most common tree species adopted by farmers and their uses. The most common were *Persea americana* (15.9%), *Eucalyptus species* (13.8%), *Maesopsis eminii* (12.3%), *Markharmia lutea* (12.3%), *Artocapus heterophylus* (11.3%), *Mangifera indica* (10.8%) and *Milicia excelsa* (6.7%). Similarly, previous agroforestry adoption studies have also indicated fodder trees (*Leucaena* and *Calliandra*), fruit trees (*Mangifera indica*, *Persea americana* and citrus) and timber trees (*Grevillea*) as commonly grown tree species in many parts of Africa [47]. Tree species adopted by farmers in Busia have multiple uses such as fencing or demarcating land boundaries timber, firewood, fruits, fodder, shade, soil fertility and provision of poles (Table 4).

***Table 4.** Common tree species adopted by farmers.*

Common name	Scientific name	Percentage*	Major uses
Ovacado	*Persea americana*	15.9	Fencing or demarcating land, fruits, shade
Kalitunsi	*Eucalyptus species*	13.8	Demarcating land, poles, timber, firewood
Musizi	*Maesopsis eminii*	12.3	Soil conservation, fencing, timber, poles
Musambya	*Markharmia lutea*	12.3	Soil conservation, Poles, firewood
Ffene	*Artocapus heterophylus*	11.3	Fencing, fruits, shade, fodder, firewood
Muyembe	*Mangifera indica*	10.8	Fencing, fruits, shade, wind breaking
Muvule	*Milicia excelsa*	6.7	Timber, shade, firewood
Greveria	*Grivellia robusta*	4.6	Soil conservation, poles, timber, fencing
Omusolya	*Makhamia spp*	4.1	Fodder
Calliandra	*Calliandra calothyrsus*	3.6	Soil fertility, fodder, firewood
Mudwele	*Mellia azadrachiea*	2.5	Firewood
Leucaena	*Leucaena leucocephola*	1	Soil fertility, fodder, poles
Sesbania	*Sesbania sesban*	1	Soil fertility, fodder, firewood
Mutuba	*Ficus natalensis*	0.5	Fencing, fodder, shade, soil conservation

*Multiple responses

3.2.2. Crops Grown with Trees

Agroforestry maximizes positive interactions between trees and crops [48, 49]. Table 5 indicates the various crops mixed with different tree species in Busia District as maize (26.8%), cassava (26.6%), sorghum (10.3%), millet (9.9%), sweet potatoes (7.9%), coffee (6.7%), cotton (5.8%), beans (4.6%), bananas (1.0%) and groundnuts (0.4%). However, maize and cassava are the main crops integrated with the common tree species to produce high yields. Maize, millet, beans, sorghum, sweet potatoes and bananas are mainly intercropped with *Markharmia lutea*, *Maesopsis eminii, Grivellia robusta, Mangifera indica* and *Eucalyptus species*. *Ficus natalensis* and *Leucaena leucocephola* are mixed with bananas, coffee and cotton.

***Table 5.** Common crops integrated with tree species.*

Crops	Frequency* (n=504)	Percentage (%)
Maize	135	26.8
Cassava	134	26.6
Sorghum	52	10.3
Millet	50	9.9
Sweet potatoes	40	7.9
Coffee	34	6.7
Cotton	29	5.8
Beans	23	4.6
Bananas	5	1.0
Groundnuts	2	0.4

*Multiple responses

A previous study by Sileshi and Mafongoya [50] also concluded that maize grown under *Leucaena leucocephola,* *Gliricidia sepium, Acacia anguistissima* and *Sesbania sesban* produced higher yields as compared with conventionally tilled and fully fertilized monoculture maize. Argel *et al.* [51] also reported the enormous potential of *Leucaena leucocephola* in contributing to more sustainable crop practices among indigenous farmers in Mexico and Central America.

3.2.3. Livestock Combined with Trees

Agroforestry systems in Busia District in the eastern Ugandan Agro-ecological zone are integrated with livestock, particularly goats (38.3%), birds (30.8%), cattle (18.7%) and sheep (1.9%) (Table 6). *Calliandra, Leucaena* and *Sesbania* are the most commonly used types of fodder trees in feeding livestock in the study area. Farmers mainly feed their cattle and sheep on *Leucaena*. Goats are reared with *Ficus natalensis, Leucaena, Artocapus heterophylus* and *Sesbania sesban*. Pigs are commonly fed the leaves of *Leucaena leucocephola* and rotten fruits from *Artocapus heterophylus* and *Persea americana*. Livestock has been successfully integrated into tree crops in the humid tropics of Cote d'Ivoire and Ghana [52, 53]. Trees and shrubs are therefore increasingly recognized as important components of animal feeding, especially as suppliers of protein [12].

Table 6. *Common livestock reared in agroforestry systems of Busia District.*

Livestock	Frequency* (n=107)	Percentage
Goats	41	38.3
Birds	33	30.8
Pigs	20	18.7
Cattle	11	10.3
Sheep	2	1.9

*Multiple responses

3.3. Factors Influencing the Level of Enhancement of Adoption of Agroforestry Technologies

The results of Tobit models 1 and 2 are presented in Table 7. Of the thirteen variables included in the model, 9 were significant in influencing the enhancement of adoption of agroforestry technologies in the eastern Uganda agro-ecological zone. These were sex, age, household size, education level, distance to the market, group membership, access to credit, number of extension visits and presence of vermines. Model 1 included major occupation and in Model 2 it was dropped.

Sex, age, household size, education level, distance to the market, group membership, access to credit, number of extension visits and presence of vermines were consistently significant in the two models while major occupation, land size and livestock value were not.

Sex of the farmer was significant at 5% level of statistical significance with a positive sign in both models, implying that men were more likely to adopt agroforestry technologies compared to women. The traditional power structure and control over household productive resources such as land favors men. This also affects decisions of labor acquisition and allocation. Furthermore, women in Sub-Saharan Africa have greater difficulty than men in obtaining labor needed for land preparation and other farm activities [54, 55]. Agroforestry technologies are complex and different from other agricultural technologies because of high demands of labor and other input requirements [56, 57, 58]. Thus, even if women farmers were willing to adopt agroforestry, the need for more labor would probably discourage them.

Table 7. *Tobit model estimates of the determinants of enhancement of adoption of agroforestry technologies.*

Model 1			
Variable	**dy/dx**	**z**	**p-value**
Sex	0.075	2.14	0.032**
Age	0.003	2.48	0.013**
Household size	0.009	2	0.046**
Education level	0.009	2.54	0.011**
Major occupation	0.05	0.77	0.444
Distance to market	-0.008	-2.9	0.004***
Land size	0.004	0.61	0.543
Group membership	0.091	3.03	0.002***
Access to credit	0.078	1.94	0.052*
Extension visits	0.009	2.18	0.029**
Presence of Vermines	-0.075	-2.47	0.014**
Livestock value	-9.46E-08	-1.4	0.161
Model 2			
Variable	**dy/dx**	**z**	**p-value**
Sex	0.078	2.24	0.025**
Age	0.003	2.48	0.013**
Household size	0.009	1.98	0.048**
Education level	0.009	2.45	0.014**
Distance to market	-0.007	-2.84	0.004***
Land size	0.004	0.67	0.501
Group membership	0.09	3.01	0.003***
Access to credit	0.069	1.81	0.071*
Extension visits	0.009	2.25	0.024**
Presence of Vermines	-0.075	-2.47	0.014**
Livestock value	-9.35E-08	-1.38	0.166

*, **, *** Significant at 10%, 5% and 1% respectively

Buyinza and Wambede [59] also reported higher probability of adoption of mixed inter-cropping of Crotalaria and Maize among men in Kabale District of Uganda. They attributed the lower agroforestry adoption among women to lack of control over land due to largely patrilineal inheritance systems. These results are also consistent with those of other researchers such as Jera and Ajayi [60] who reported that men and women were equally likely to adopt tree-based fodder technology if they were given similar opportunities and incentives. Lagat *et al.* [61] also indicated that gender was not significant in influencing adoption of water harvesting technologies since both males and females were sensitive to water issues and were actively involved in the implementation of banana trench technologies.

In both models, age was significant at 5% level of statistical significance and the sign consistent with the expectation that it influences adoption of agroforestry positively. Results indicate that an increase in farmer's age by one year would increase the probability of adopting agroforestry by 0.3%. In the study area, respondents were relatively older, with an average age of 41 years and thus willing to take up new farming innovations and bear risks. These results tally with those of Adesiina and Baidu-Forson [62] who indicated that age positively influenced the adoption of sorghum in Burkina Faso. Since the results show that age increases the level of adoption, young farmers are less likely to adopt agroforestry technologies.

Household size was also significant at 5% level of statistical significance with a positive coefficient, implying that farmers with large numbers of people in the household were more likely to adopt agroforestry technologies. Results indicate that as the number of active people in the household increases by one person, there will be an increase of 0.9% in the probability of adopting agroforestry. This could be due to the availability of labour supply for farming activities associated with large family sizes. In the study area, the average number of household size adopting agroforestry technologies was comparatively higher than the non-adopters (Table 1). Household size has been reported to encourage adoption and application of agricultural technologies by other scholars as well [39, 56].

The positive and significant coefficient on the education level of the farmer implies that educated farmers were more likely to adopt agroforestry technologies because education improves the understanding of technologies and access to information, thus enhancing adoption. When all other factors are held constant, increasing farmer's education by one year increases the probability that a farmer would adopt agroforestry by 1%. Similarly, Doss and Morris [54] indicated that education was a significant determinant of adoption of modern varieties of maize in Ghana. Recently, Buyinza and Wambede [59] reported that better educated farmers tended to use improved fallow technology in improving the chemical and physical properties of soil in Kabale District of Uganda.

Consistent with other studies [12, 63, 64], distance to the market had a negative and significant impact on adoption of agroforestry technologies. This implies that the further the market from the farm, the more remote the farmer is located and it becomes difficult for the products to reach the market, hence the low level of adoption. Secondly, households located close to the market centre are more able to adopt a new technology because they have better access to input stockists and may incur less transaction costs. Therefore, the longer the distance to the market, the lower the market access and so is the likelihood to adopt agroforestry practices.

Land size is a characteristic of the farm which has continued to receive attention from agricultural researchers [65]. Land size was hypothesized to influence adoption of agroforestry technologies positively as the larger the farm, the higher the probability of adopting agroforestry as reported by Doss and Morris [54]. However, there was no significant relationship between land size and the adoption of agroforestry technologies. This is because certain agroforestry technologies can be adopted even without larger land sizes; for example, homestead and boundary planting. Similarly, Mugisa-Mutetikka [66] also showed that land size was not a significant factor in the adoption of new bean varieties in Uganda.

As hypothesized, membership in farmer association was positive and significant at 1% level of statistical significance, implying that farmers within associations or organized groups were more likely to adopt agroforestry than those who did not belong to any group. This is because farmer associations promote sharing of information and experiences about the new technologies, which influences adoption behavior of individual farmers as well as the whole group. A positive impact of farmer associations on adoption behavior was also reported by other scholars [64, 67].

Results indicated that access to credit was positive and significant at 10% level of statistical significance. Significant positive effects of access to credit were also reported by Feleke and Zegeye [68] and Paudel and Matsuoka [69]. Access to credit enhances farmers' ability to adopt technologies that require initial investments in form of seeds, fertilizers and machinery.

There was a positive and significant relationship between extension contact and adoption of agroforestry technologies at 5% level of statistical significance in both models. When all other factors are held constant, an additional extension visit increases the probability of adopting agroforestry by 0.9%. Access to extension education exposes farmers to agroforestry information which stimulates adoption. Extension contact is a key variable in developing a favorable attitude among farmers towards the technology. This study supports the findings of Omoregbee [70], Ghadim and Pannell [71]; Boahene et al. [72] and Adesina *et al.* [73] that farmers with higher extension contact are more likely to adopt agroforestry technology.

Presence of vermines was negative and significant at 5% level of statistical significance in both models. Vermines are termites and mole rats which attack tree roots and branches, thus destroying several tree species on farms. An increase in the number of vermines reduces the probability of adopting agroforestry by 7%. Previous studies have also indicated similar constraints in the adoption of agroforestry. For example, Hasan et al. [74] reported that diseases, insects, bats and squirrels were the major constraints in the adoption of jackfruit-pineapple agroforestry in Bangladesh. The study found out that farmers were unable to take any control measures due to lack of knowledge as well as high prices of chemicals. Rao et al. [75] also argued that agroforestry trees were normally attacked by a wide spectrum of insects at all stages of their growth. Similarly, Kiwuso *et al.* [22] and Nyeko and Nakabonge [76] reported devastating impacts of termites in agroforestry systems in the tropics.

4. Conclusions

The Tobit model that was used in this study demonstrated a combination of socio-economic factors that affect enhancement of adoption of agroforestry technologies in the Eastern Uganda agro-ecological zone. These include sex, education level, distance to the market, age, household size, access to credit, group membership, extension visits and presence of vermines. Policies aimed at improving the quality and coverage of these variables are likely to increase adoption of agroforestry technologies in this area.

Membership in farmer groups was a significant factor in agroforestry adoption. To increase the likelihood of adopting agroforestry technologies by smallholder farmers in the tropics, policy makers should put emphasis in mobilizing farmers to join groups. Farmers in their respective groups will also have better access to credit because most financial institutions prefer providing credit to farmers in groups than individual farmers in order to minimize administrative costs and defaulting. In addition, farmer associations could evolve into marketing cooperatives that would provide an opportunity to farmers to learn how to aggregate their products, grade them and access competitive agroforestry markets.

Row planting (alley cropping), boundary planting, scattered trees (dispersed trees), home gardens, improved fallows, woodlots and taungya system are the seven major agroforestry technologies that were disseminated to farmers in the eastern Uganda agro-ecological zone over the past years with the aim of conserving the environment and improving agricultural productivity. Only boundary planting, scattered tree planting, row planting and homestead gardening were adopted.

Access to extension services was found to be an important factor in the enhancement of adoption of agroforestry technologies in the Ugandan eastern agro-ecological zone. At policy level, this implies that improving the quality and coverage of extension services is of vital importance in the adoption of agroforestry technologies. In providing effective extension services, extension agents are expected to conduct frequent meetings with farmers within their jurisdiction. Also, the development of extension activities must be based on, and take into account, the socio-economic status of the farmers, the biophysical aspects of the technology and more importantly, the needs of farmers.

However, vermines still remain a major threat to the adoption of agroforestry technologies in eastern Uganda. This is because vermines destroy trees on farms, thus reducing adoption as indicated in the Tobit model results. Policies aimed at training farmers in effective management of termites and mole rats would increase adoption of various agroforestry technologies.

Acknowledgements

We sincerely acknowledge the generous financial support we received from the National Agricultural Research Organization of the government of Uganda (NARO) that made the work easier. We also appreciate the support of the College of Agricultural and Environmental Sciences, Makerere University, more especially the Principal Professor Bernard Bashaasha. We are grateful to the Head of the Department of Agricultural Production, Professor Dennis Mpairwe, Makerere University, for giving ample time to the main author to accomplish this study. Mr. Albert Muhumuza, the College of Agricultural and Environmental Sciences Computer Systems Administrator is recognized for his tireless efforts to assist whenever computers gave us headache. We thank you all for making this scientific output what it is.

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