East African Journal of Forestry and Agroforestry, Volume 5, Issue 1, 2022
Article DOI: https://doi.org/10.37284/eajfa.5.1.766

East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 5, Issue 1, 2022
Print ISSN: 2707-4315 | Online ISSN: 2707-4323
Title DOI: https://doi.org/10.37284/2707-4323

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

The Extent of Adoption of Agroforestry Systems and Practices and Conservation Implications in Kilombero District, Tanzania

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Article DOI: https://doi.org/10.37284/eajfa.5.1.766

Date Published:

25 July 2022

Keywords:

Agroforestry Adoption, Agroforestry Systems, Agroforestry Practices, Agroforestry, Kilombero.

ABSTRACT

Agroforestry systems and practices are perceived to improve livelihood and sustainable management of natural resources. However, factors influencing their adoption in various regions require further investigation as they differ in biophysical conditions and societal characteristics. This study was conducted in Kilombero district to investigate factors influencing the adoption of different agroforestry systems and practices in agro-ecosystems and farming systems. Household surveys, key informant interviews and focus group discussions were used in data collection. Descriptive statistics and Multinomial Regression Analysis in SPSS were used for data analysis. Results show that Agrosilvopasture and Agrosilviculture systems were the dominant agroforestry systems while the home garden and Mixed Intercropping were the dominant agroforestry practice. There is a potential in agroforestry systems and practices in terms of product diversification and biodiversity conservation though their adoption differed given the influence of different factors. Different factors were statistically significant as predictors of the adoption of agroforestry systems and practices. Resident period, availability of extension education/services, resident type and gender were the dominant factors influencing the adoption of agroforestry systems and practices. Farmers' oriented factors were critical in the adoption of agroforestry systems and practices. The study concludes that the practice of agroforestry will be more successful if the local priorities including socio-economic characteristics of the society are considered in designing systems and practices. Socio-economic characteristics of the communities that factor in conservation priorities should be addressed in the process of expanding the adoption of agroforestry systems and practices. The study recommends that productive systems and practices that contribute to household food and income are better adopted.

Article DOI: https://doi.org/10.37284/eajfa.5.1.766

APA CITATION

Nnko, L. E., Kashaigili, J. J., Monela, G. C., Munishi, P., Lyimo, P. J., & Nyemo, C. (2022). Agroforestry Systems and Practices and Their Adoption in Kilombero District, Tanzania *East African Journal of Forestry and Agroforestry*, *5*(1), 105-117. https://doi.org/10.37284/eajfa.5.1.766

CHICAGO CITATION

Nnko, Lazaro Elibariki, Japhet Joel Kashaigili, Gerald Cladius Monela, Pantaleo Munishi, Paul John Lyimo & and Chilagane Nyemo. 2022. "Agroforestry Systems and Practices and Their Adoption in Kilombero District, Tanzania". *East African Journal of Forestry and Agroforestry* 5 (1), 105-117. https://doi.org/10.37284/eajfa.5.1.766

HARVARD CITATION

Nnko, L. E., Kashaigili, J. J., Monela, G. C., Munishi, P., Lyimo, P. J., & Nyemo, C. (2022), "Agroforestry Systems and Practices and Their Adoption in Kilombero District, Tanzania", *East African Journal of Forestry and Agroforestry*, 5(1), pp. 105-117. doi: 10.37284/eajfa.5.1.766.

IEEE CITATION

L. E., Nnko, J. J., Kashaigili, G. C., Monela, P., Munishi, P. J., Lyimo, & C., Nyemo, "Agroforestry Systems and Practices and Their Adoption in Kilombero District, Tanzania", *EAJFA*, vol. 5, no. 1, pp. 105-117, Jul. 2022.

MLA CITATION

Nnko, Lazaro Elibariki, Japhet Joel Kashaigili, Gerald Cladius Monela, Pantaleo Munishi, Paul John Lyimo & Chilagane Nyemo "Agroforestry Systems and Practices and Their Adoption in Kilombero District, Tanzania". *East African Journal of Forestry and Agroforestry*, Vol. 5, no. 1, Jul. 2022, pp. 105-117, doi:10.37284/eajfa.5.1.766

INTRODUCTION

Agroforestry systems and practices have been used interchangeably in various articles. However, Nair (1989) pointed out that agroforestry systems are described based on the components (animals, crops, and trees) present in the agroforestry farmland. Agroforestry practices refer to the arrangement of the components present in the agroforestry systems in time and space. Integration of trees on farmland increases socio-economic and environmental benefits for land uses at all levels (ICRAF, 2006). In order to overcome the reduction of arable land, assure food security, and improve livelihoods, it is important to consider the systems and practices since their productivity and management differ (Vincent et al., 2012). Sanchez et al. (1997) revealed that agroforestry systems and practices gave an alternative solution to poor smallholder farmers who would otherwise have a reduction in crop yields. Since agroforestry is now emerging as a promising land-use option and climate-smart agriculture, its productivity depends on the systems and practices that involve components available and their arrangements (Syampungani et al., 2010). Eneji, Irshad, and Inanaga (2004) reported that the aim of agroforestry systems and practices is to optimize the positive outcome in order to obtain a diversified and more sustainable production system from limited resources than other systems of land use. However, the potential benefits of improved livelihoods and long-term environmental management will not be realized unless farmers engage in agroforestry on a large scale (Magugu et al., 2018).

The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) is a public-private partnership established in 2010 with the objective of improving agricultural productivity and food security, reducing poverty, and ensuring environmental stability in all the areas that the corridor covers (Milder et al., 2012). Kilombero District is among the SAGCOT Clusters where various interventions such as conservation farming through agroforestry have been implemented. Though SAGCOT has been supporting different interventions, including capacity building on agroforestry and conservation farming, to benefit ecosystems, biodiversity, and climate, there have been challenges to the adoption of agroforestry systems and practices (Msofe et al., 2018). Sinclair and Walker (1999) reported that a quantitative and predictive understanding of agroforestry systems and practices enables easy

Article DOI: https://doi.org/10.37284/eajfa.5.1.766

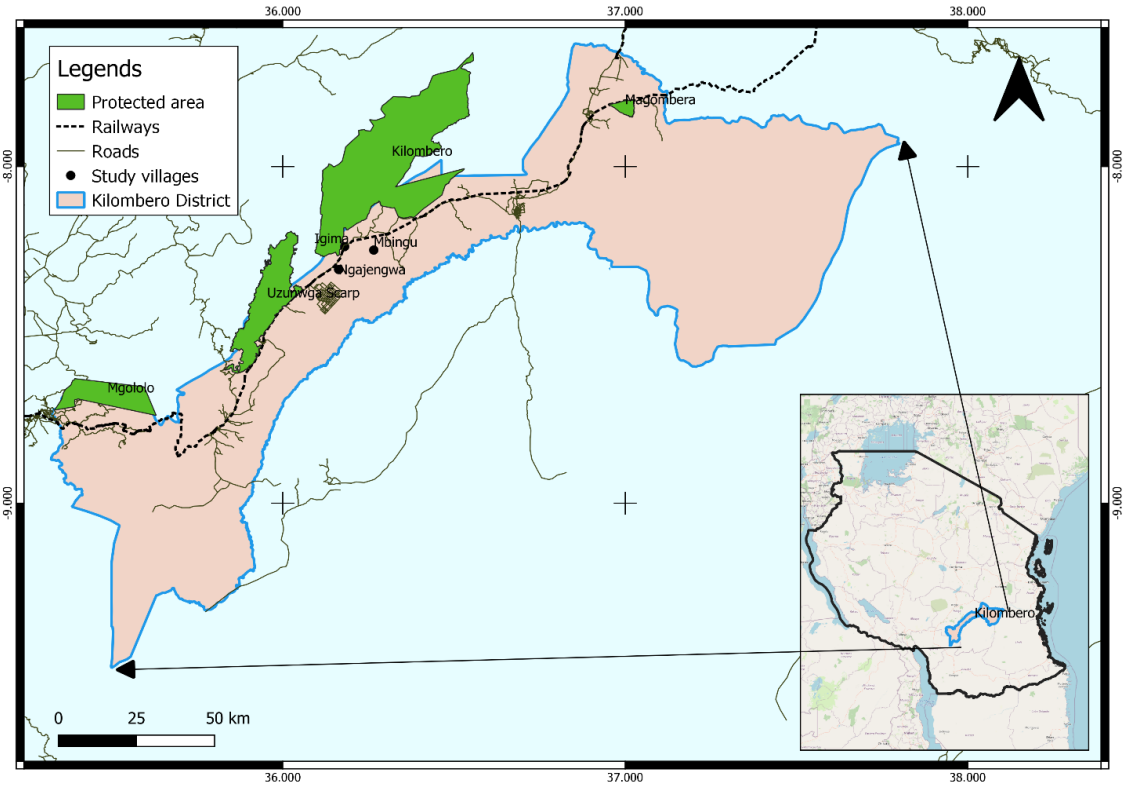
adoption of the two. Developing strategies and encouraging farmers to plant trees on their farmlands can be done only if the characteristics of the farmland and farmers in relation to tree growing exist (Irshand et al., 2011). The factors influencing the adoption of agroforestry differ with biophysical conditions, societal characteristics and conservation needs of relevant areas. This study was conducted in Kilombero district to investigate factors influencing the adoption of different agroforestry systems and practices in agro-ecosystems and farming systems. Identifying the socio-economic factors will ascertain the opportunities for the development of agroforestry systems and practices. In order to identify the agroforestry systems and their adoption, the study had two specific objectives: to identify the agroforestry systems and practices in the study area and to determine the factors influencing the adoption of agroforestry systems and practices.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in Kilombero District, which is located in the Morogoro Region between latitudes of 8°15'0" South and longitudes 36°25'0" East, with elevations ranging from 262 m to 550 m above mean sea level (*Figure 1*). Administratively, the Kilombero District has five divisions, 19 wards, and 46 villages. The district is bordered by Kilosa District in the north, in the southeast by Ulanga District, in the southwest by the Iringa Region, and in the west by the Lindi Region (URT, 2007). According to the 2012 census, the population of Kilombero was 407 880, with 202 789 males and 205 091 females (URT, 2013). This area is currently experiencing a doubling of the human population over the years (Madulu, 2004; Balama et al., 2016). The large migration of farmers due to fertile land and livestock keepers due to the presence of animal fodder is the primary cause of population growth.

Figure 1: Map of the Study Area



Article DOI: https://doi.org/10.37284/eajfa.5.1.766

The climate in the study area is marked by wet and dry seasons, which are further categorized into four sub-seasons, the hot wet season from December to March, the cool wet season from April to June, the cool dry season from July to August, and the hot dry season from September to November. The area receives between 1200 mm and 1800 mm of rainfall per year, and temperatures range from 26°C to 32°C (Balama et al., 2016). Generally, land use is categorized as village land, reserved land, and general land as defined in the Village Land Act 1999 (URT, 2017).

The main economic activities in the area include cash crop cultivation, food crop cultivation, petty trading, and fishing in the Kilombero River (URT, 2007). Overall, cereals from the coast, such as rice, millet, and maize, are widely grown. Also, vegetables such, as yams, pumpkins, cucumbers, and many other excellent food crops are grown. Tobacco is grown abundantly, sugar-cane, the castor oil plant, cocoa, and cotton are also cultivated (Bergius et al., 2020).

Sampling Procedure

Three villages were purposely selected based on the existence of agroforestry systems and practices in the farmlands. A random sampling procedure was adopted for selecting households with agroforestry systems and practices using the village registers as a sampling frame. The sampling unit for this study was the individuals chosen from the population as respondents to represent others, and the information obtained was used to describe the characteristics of the entire population, as stated by Bryman (2004) and Nkonoki (2015).

Sample Size Determination

Nachimias and Nachimias (1996) revealed that sample size is the most important determinant of any estimates from a survey. Studies by Bailey (1998); Saunders et al. (2007); Mbeyale (2009) and Mtongani et al. (2014) indicate that a minimum sample of 30 units is sufficient, irrespective of the population size, for fieldwork data collection and analysis. Therefore, a total of 90 respondents (30 from each village) were sampled from the three villages (Igima, Mbingu, and Ngajengwa) for household surveys on the factors influencing the adoption of agroforestry.

Data Collection

A household survey using questionnaires, focus group discussions, and key informant interviews were used to collect data. The questionnaire was the main instrument for collecting data from the farmers practicing agroforestry. Focus Group Discussions (FGD) and Key informant interviews (KII) were involved in order to get an insight into the status of agroforestry in the villages and triangulation of information collected through household interviews. Key informant interviews enabled clarification on particular issues raised during focus group discussions and household interviews. Key informants involved were forest officers from Kilombero Nature Reserve, District Forest officer, and the ward agriculture extension officer.

Data Analysis

Information from focus group discussions and key informant interviews was analysed using content analysis, whereby raw data was broken down to generate meaningful units of information in regards to agroforestry systems and practices and factors influencing their adoption. Information from the household survey was coded and assigned variables in the Statistical Package for Social Science (SPSS). Descriptive statistics such as percentages and frequencies were used to profile the agroforestry systems and practices. Multinomial logistic regression was used to identify factors determining the choice of adopting agroforestry systems and practices. This model is suitable for determining adoption when the dependent variables have more than two categories (Ojo et al., 2013; Obadim et al., 2020).

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Let πj denotes the multinomial of an observation falling in the j^{th} category to find the relationship between the probability and the p - explanatory variables

$$X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots X_p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

The multiple logistic regression is given by:

$$\log\left[\frac{\pi_j(x_1)}{\pi_k x_1}\right] = a_{oi} + \beta_{1j}x_{1j} + \beta_{2j}x_{2j} + \cdots \ldots\ldots\ldots\ldots\ldots \beta_{pj}x_{pj} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(2)}$$

Where J= 1, 2…… (k - 1), I = 1, 2…...p

k stands for the number of response or dependent categories whereas for this study dependent categories for agroforestry systems were agrosilvopasture, agrosilviculture, and silvopasture. For agroforestry practices, dependent categories were home garden, mixed intercropping, parkland, and boundary planting.

P = Number of explanatory variables included in the model.

When estimating the model, the coefficient of the reference group is normalized to zero (Rahij & Fakayode, 2009; Ojo et al., 2013). This is because the probability of the choice must sum up to unity. Hence, for the choice of three categories (agrosilvopasture, agrosilviculture, and silvopasture), only two sets of parameters were identified and estimated. For four categories (home garden, mixed intercropping, parkland, and boundary), only three distinct sets of parameters were identified and estimated. In this study, the reference category for agroforestry systems was agrosilvopasture, and for agroforestry practices, the reference category was home garden. The natural logarithm for the odds ratio for equations 1 and 2 gives the estimation equation below.

$$log\pi_j(x_i) = \frac{\exp\left(a_{0i}+\beta_{1j}x_{1i}+\beta_{2j}x_{1i}+\cdots\ldots\ldots\ldots+\beta_{pj}x_{pi}\right)}{1+\sum_{j-1}^{k-1}\exp\left(a_{0i}+\beta_{1j}x_{1i}+\beta_{2j}x_{1i}+\cdots\ldots\ldots\ldots+\beta_{pj}x_{pi}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

J= 1, 2, ……… k – 1 the model parameter is estimated by the method of multinomial logit.

The independent variable included

X_1: Farming experience (Years),

X_2: House hold income (Tanzania shillings),

X_3: Resident period (years),

X_4: Resident type (1 native 2 other wise),

X_5: Education level,

X_6: Extension services,

X_7: House hold size,

X_8 Gender (1 male 2 other wise).

These independent variables were selected on the basis of the social-economic context of the study area and other agroforestry adoption studies conducted in different tropical counties (Rahij & Fakayode 2009; Ojo et al., 2013; Obadimu et al., 2020).

RESULTS

Agroforestry Systems and Practices in Kilombero

A total of three agroforestry systems identified were agrosilvopasture, agrosilviculture, and silvopasture systems. The agrosilvopasture system was most dominant in Igima and Ngajengwa villages, being practiced accounting for 56.6% and 67.7% of the study population. Agrosilviculture system was the dominant system in Mbingu village, accounting for 66.7% of the study population (*Figure 2*). Four agroforestry practices identified were home garden, parkland, boundary planting, and mixed

Article DOI: https://doi.org/10.37284/eajfa.5.1.766

intercropping. Home gardens was most dominant in Igima and Ngajengwa accounting for 63.3% and 66.7% of the study population respectively, while mixed intercropping was more prominent in Mbingu village accounting for 56.7% of the respondents (*Figure 3*).

Figure 2: Dominant Agroforestry Systems in Kilombero District Tanzania

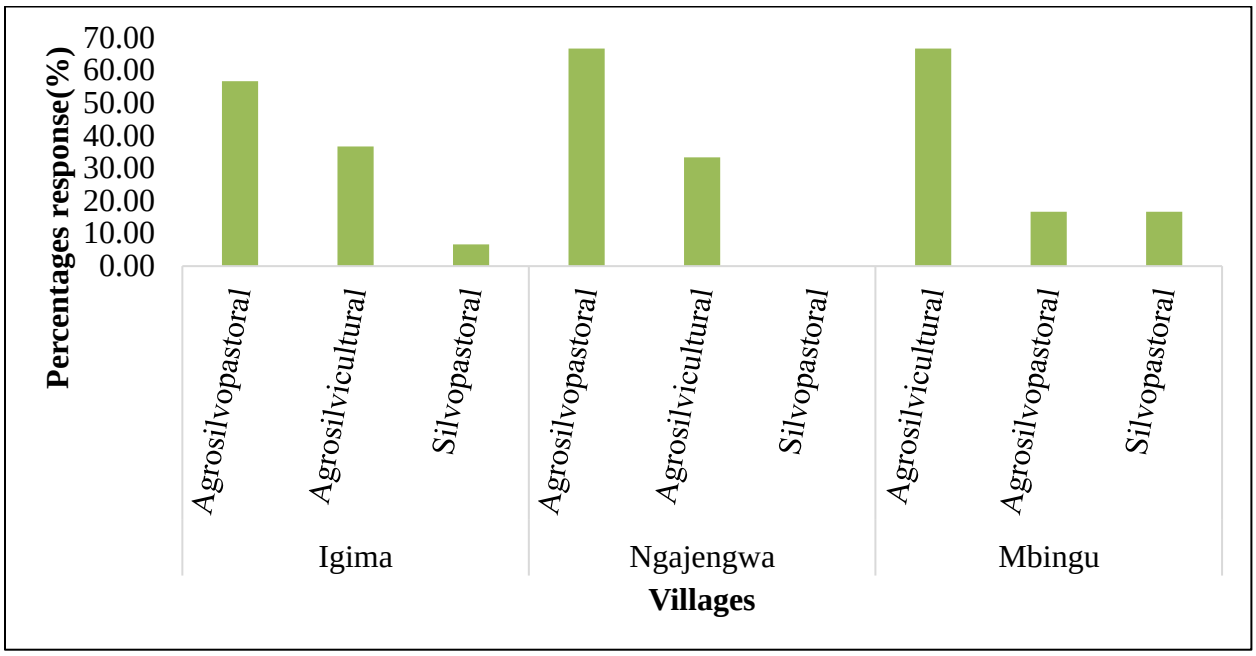
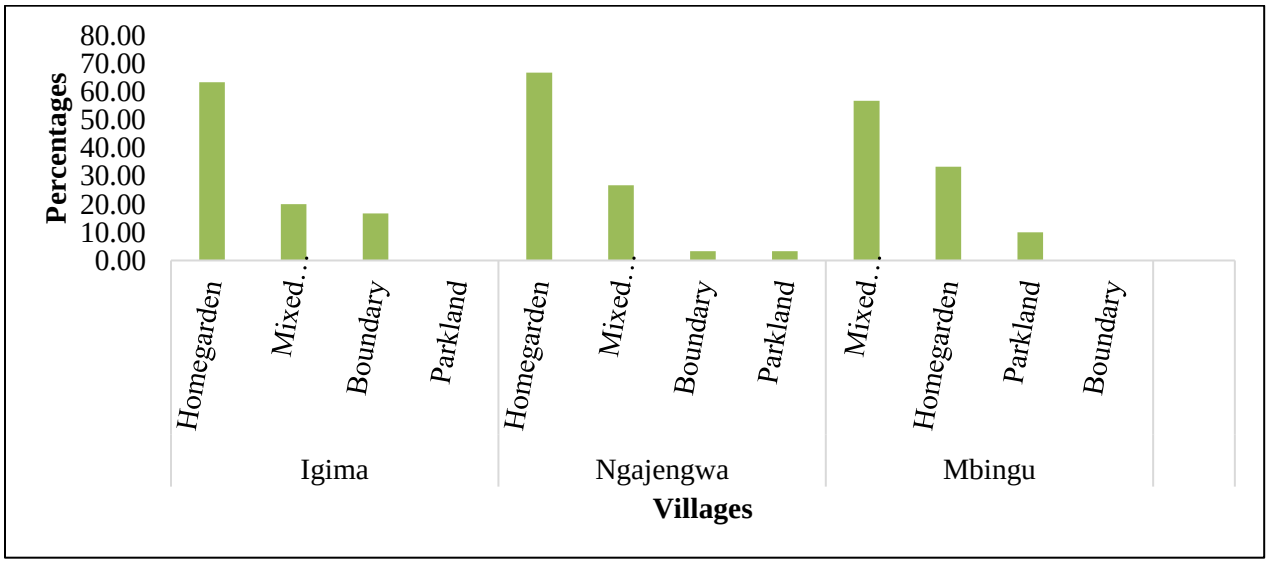


Figure 3: Dominant Agroforestry Practices in Kilombero District Tanzania



Adoption of Agroforestry Systems

Multinomial logistic regression analysis indicated that male and native residents had a statistically significant difference in the adoption of agrosilviculture when compared with agrosilvopasture ($P < 0.05$). Native residents negatively influenced the adoption of agrosilviculture and the rate of adoption decreased

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at an odds ratio of 0.14. On the other hand, males were found less likely to adopt agrosilviculture at an odds ratio of 0.344 (*Table 1*). Other variables had no statistically significant influence on the adoption of silvopasture agroforestry system (*Table 2*).

Table 1: Determinant of adoption of Agrosilviculture in Kilombero District Tanzania

Parameter Estimates				
Agrosilviculture system	**B**	**Std. Error**	**Sig.**	**Exp(B)**
Farming experience	-0.048	0.03	0.115	0.953
Household income	0	0	0.313	1
Resident period	0.05	0.026	0.059	1.051
Household size	-0.066	0.117	0.574	0.937
Education	-0.108	0.256	0.675	0.898
Extension services	0.84	0.563	0.136	2.316
Resident type (Native)	-1.963	0.729	0.007*	0.14
Gender (Male)	-1.068	0.528	0.043*	0.344

*The reference category is: Agrosilvopasture. * P<0.05*

Table 2: Determinant of adoption of Silvopasture in Kilombero District Tanzania

Parameter Estimates				
Silvopasture systems	**B**	**Std. Error**	**Sig.**	**Exp(B)**
Farming experience	-0.009	0.048	0.843	0.991
Household income	0	0	0.965	1
Resident period	0.074	0.043	0.083	1.077
Household size	0.288	0.289	0.319	1.333
Education	0.692	0.405	0.087	1.998
Extension services (Yes)	-0.546	1.155	0.636	0.579
Resident type (Native)	-1.364	1.214	0.261	0.256
Gender (Male)	-0.521	1.031	0.614	0.594

*The reference category is: Agrosilvopasture. * P<0.05*

Adoption of Agroforestry Practices

The study revealed that the duration of stay in the village, resident type, extension education, and gender were the factors that were statistically significant in influencing the adoption of different agroforestry practices (P <0.05). Resident period and extension services had a positive influence while resident type and gender had a negative influence on the adoption of mixed intercropping. A unit increase in the resident period in a village leads to increased adoption of mixed intercropping at an odds ratio of 1.064 while the availability of extension education, information, and awareness by farmers increased the adoption of mixed intercropping at an odds ratio of 4.052 (*Table 3*). Native residents were unlikely to influence the adoption of mixed intercropping by an odds ratio of 0.068 while male adoption of intercropping was unlikely by an odds ratio of 0.167 (*Table 3*). Boundary planting and parkland agroforestry practices were not significantly influenced by any of the explanatory variables (*Table 4 and Table 5*).

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Table 3: Determinant of adoption of Mixed Intercropping Agroforestry Practices in Kilombero District Tanzania

Parameter Estimates				
Mixed intercropping	**B**	**Std. Error**	**Sig.**	**Exp(B)**
Farming experience	-0.048	0.036	0.175	0.953
Household income	0	0	0.303	1
Resident period	0.062	0.031	0.041*	1.064
Household size	-0.139	0.14	0.32	0.87
Education	-0.44	0.301	0.144	0.644
Extension services	1.399	0.675	0.038*	4.052
Resident type (Native)	-2.684	0.908	0.003*	0.068
Gender (Male)	-1.79	0.65	0.006*	0.167

*The reference category is: Home Garden. * P<0.05*

Table 4: Determinant of adoption of the Boundary Planting Agroforestry Practices in Kilombero District Tanzania

Parameter Estimates				
Boundary Planting	**B**	**Std. Error**	**Sig.**	**Exp(B)**
Farming experience	-0.064	0.053	0.229	0.938
Household income	0	0	0.125	1
Resident period	-0.086	0.069	0.213	0.917
Household size	-0.123	0.376	0.744	0.884
Education	0.474	0.655	0.469	1.607
Extension services	0.715	1.388	0.606	2.045
Resident type	2.951	2.495	0.237	19.134
Gender (Male)	3.004	2.128	0.158	20.164

*The reference category is: Home Garden. * P<0.05*

Table 5: Determinant of adoption of Parkland Agroforestry Practices in Kilombero District Tanzania

Parameter Estimates				
Parklands	**B**	**Std. Error**	**Sig.**	**Exp(B)**
Farming experience	-0.18	0.138	0.192	0.835
Household income	0	0	0.077	1
Resident period	0.141	0.093	0.13	1.151
Household size	0.018	0.256	0.944	1.018
Education	-18.36	0	.	1.06E-08
Extension services (Yes)	3.027	1.759	0.085	20.64
Resident (Native)	-24.553	0	.	2.18E-11
Gender (Male)	-0.722	1.7	0.671	0.486

*The reference category is: Home Garden. * P<0.05*

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DISCUSSION

Agroforestry Systems and Practices in Kilombero

Agrosilvopasture agroforestry system and home garden practices were more prominent in two out of the three villages involved in this study. This implied that the components involved were mostly trees, herbaceous crops, and/or animals. Respondents revealed that the availability of animal fodder and small grazing areas has attracted many farmers to engage in home garden practices. Furthermore, home garden practices and agrosilvopasture had higher adoption because they produce supplementary staple crops and also serve as a source of income for many families. The home garden provides a diversity of crops and livestock, which enables the year-round production of different products and reduces production risk. A study conducted by Maroyi (2009) shows that goods obtained from home garden practices are all consumed at home and cannot be sold to other relatives, so they are offered for free to strengthen the relationships in the village and can only be sold when the household has a surplus. Farmers also revealed that agro-silvopasture systems optimize the production per unit area while ensuring a sustained yield over time. Growing trees on farms while integrating with livestock also helps to increase income, and produce more food, resulting in food security and protecting the environment, according to key informants. A study by Saleh (2016) indicates that agrosilvopasture contributes significantly to soil improvement through the supply of green manure and about 67% of tree species used in the agrosilvopasture system were *Theobroma cacao*, *Mangifera indica*, and *Tectona grandis*, which provide animal fodder, shade, fruits, timber, and are used as a source of food for households. In contrast, 73% of the tree species encountered in home gardens matched those found in agrosilvopasture.

In Mbingu village, mixed intercropping was the most dominant agroforestry practice, and this was due to the suitability of land for Cocoa growing and the shortage of reserved area for grazing compared to the other two villages. Focus group discussion, revealed that mixed intercropping provides diversification of crops, especially cash crops like cocoa, which in turn provides income to households. Also, results from focus group discussion, revealed that the presence of specific enabling environment such as markets for goods and services produced from the agroforestry systems/practices contribute to adoption. For example, in Mbingu village the presence of Cocoa Kamili Company in the village has influenced mixed intercropping and agrosilviculture of cocoa with trees and other crops due to market availability for Cocoa. Antriyandarti, Ferichani, and Ani. (2013) revealed that agrosilviculture dominates the land suitable for the intercropping. Most of the trees intercropped were *Theobroma cacao* and fruit trees such as *Cocos nucifera* and *Mangifera indica*. Robiglio Guillaume and Paolo (2013) showed that the integration of Cocoa with other trees and food crops has been an easily manageable strategy because of its components. Sonwa (2004) found that farmers in Southern Cameroon usually use fruit plants to diversify the cocoa plantation. It was also revealed through FGD that silvopasture is difficult to implement due to the shortage of grazing land and climate variability. Other respondents pointed out that operational costs are very high and there is a poor market structure for livestock products. Caradona, Ramirez, Morales, and Sanchez (2014) pointed out that livestock production depends on climate factors therefore, changes in the climate have an enormous impact on production.

Adoption of Agroforestry Systems in Kilombero

The results indicated that there was a negative correlation between native residents and the adoption of agrosilviculture systems, indicating that native residents were more likely to adopt agrosilvopasture than agrosilviculture. It was

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revealed that agrosilvopasture is better than agrosilviculture as it allows the diversification of all three components. In addition, it was learned that non-natives were less likely to be engaged in agrosilviculture systems because many of them are migrants, spending short periods of time and migrating to another area. Thus, the permanency of agrosilviculture may not be suitable for this group. A study by Obeng and Weber (2014) reported that non-native farmers were less likely to adopt agrosilvopasture due to their shorter horizons of residence. Gender was another factor that showed a statistically significant influence on the adoption of agrosilviculture compared to agrosilvopasture. In this study, males were less likely to adopt agrosilviculture than agrosilvopasture. It was observed that with the presence of trees and crop integration, livestock was also important, especially for income when crops failed. Similar results have been observed in Malawi by Thangata and Alavalapati (2003) and in Kenya by Sanchez (2002), who indicated that female farm-headed houses did not adapt to agroforestry system compared to male-headed houses because most males prefer trees as the long-term source of income. According to Oino and Mugure (2013), male land ownership allows them to be final decision maker on land use systems such as the type of agroforestry system to be practiced for the benefit of households though females are always involved during the planning of land use, but they cannot change the last decision made by males. Similar results have been observed by Merce (2004), who shows that women are more involved practically in agroforestry systems than men, but they cannot make final decisions on the utilization of the land and agroforestry products.

Adoption of Agroforestry Practices

The findings revealed that native residents were poor adopters of mixed intercropping. A study by Irshad, Khan, Inoue, Ashraf and Sher (2011) showed that native residents have a high chance of succeeding in the implementation of home garden practices as it takes time to establish a permanent settlement. This result is similar to a study by Magugu et al. (2015) who revealed that native residents are in a good position to attain land tenure and secure enough land for agroforestry since it is a long-term investment. The resident period in the village had a positive correlation with the adoption of mixed intercropping compared to home gardens. This indicated that as the resident period in the village increased, farmers were becoming more interested in adopting mixed intercropping than home gardens. These results are similar to a study by Liniger et al. (2011) who found that the duration of stay/farmer period influenced crop diversification, hence shifting from practicing agroforestry near the home to the farmland. Farmers who had access to extension education were more likely to use mixed intercropping over home gardens as it was argued that there was no proper arrangement of crops and trees in home gardens practices, which made practice less productive. The availability of extension services had a positive influence on the adoption of intercropping. A study by Chija (2013) showed that extension education is the most critical factor that enhances farmers' adoption of particular agroforestry practices in consideration of the products and production. On the other hand, males were found less likely to adopt mixed intercropping compared to home gardens. Men preferred home gardens because most of the components in the home garden supplement the household's food and income hence satisfying one of the male's roles of ensuring food security for households. Fruit trees were the primary source of food in the study area, especially during drought. The fruit trees found in the study area were *Mangifera indica*, *Percea americana*, and *Cocos nucifera.* A similar study on the home garden by Mengistu (2008) confirmed that fruit trees in the home garden have a significant role in the family during environmental crises such as drought.

CONCLUSION

Article DOI: https://doi.org/10.37284/eajfa.5.1.766

There is a potential in agroforestry systems and practices in terms of product diversification and biodiversity conservation though their adoption differed given the influence of different factors. Productive systems and practices that contribute to household food and income are better adopted. Farmers' oriented factors are critical in the adoption of agroforestry systems and practices. The major factors that influence adoption include resident period, extension services, resident type and gender. The practice of agroforestry will be more successful if the local priorities including socio-economic characteristics of the society are considered in designing systems and practices. Socio-economic characteristics of the communities that factor in conservation priorities should be addressed in the process of expanding the adoption of agroforestry systems and practices.

ACKNOWLEDGMENT

The authors are immensely grateful to Development Corridors Partnership (DCP) Project for funding this study. Sincere appreciation to the Government of Tanzania for sharing pearls of wisdom with us during the course of this research. Great thanks to Profs, E. F Nzunda from the Sokoine University of Agriculture and Neil Burgess from WCMC for their comments on earlier versions of the manuscript, although any errors are our own and should not tarnish the reputations of these esteemed professionals.

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