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Research Article

Agroforestry systems and practices and their adoption in kilombero district, Tanzania

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ABSTRACT

Agroforestry systems and practices are perceived to improve livelihood and sustainable management of natural resources. However, their adoption in various regions differs, with the biophysical conditions and societal characteristics. This study was conducted in Kilombero District to investigate the factors influencing the adoption of different agroforestry systems and practices in agro-ecosystems and farming systems. A Household survey, key informant interviews and focus group discussion was used for data collection in three villages. Descriptive statistics and multinomial logistic regression in SPSS were applied for analysis. Results shows that Igima and Ngajengwa villages had home garden practices dominated, as revealed by 63.3% and 66.7%, respectively, while Mbingu village had mixed intercropping practice with 56.67%. Agrosilvopasture systems were dominant in Igima and Ngajengwa villages with 56.7% and 66.7%, respectively, while in Mbingu village, the dominant system was agrosilviculture with 66.7%. The results from multinomial logistic regression show that show that different explanatory variable was statistical significance as predictors of the adoption of agroforestry systems and practices. Residence type and sex were the most dominant factor influencing the adoption of agroforestry systems. Duration of stay in the village, availability of extension education, residence, and sex were the dominant factor influencing the adoption of agroforestry practices. The most important and statistically significant factors among these were residence type and sex. The study concludes that agroforestry will be more successful if the local priorities which include social-economic need characteristics of the society will be considered in designing systems and practices. The socio-economic need of the community should be addressed in the process of expanding the adoption of agroforestry systems and practices.

Keywords: Agroforestry adoption, Agroforestry systems, Agroforestry practices, Agroforestry kilombero

INTRODUCTION

Agroforestry systems and practices have been used interchangeably in various articles. However, [1] 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. 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 [2]. 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. [3]. [4] pointed out that agroforestry systems and practices gave an

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alternative solution to poor smallholder farmers who would otherwise have a reduction in crop yield.

Eneji, et al. 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 [5,6].

Southern Agricultural Growth Corridor of Tanzania (SAGCOT) is a public-private partnership established in 2010 with the objective of improving agricultural productivity, food security, reducing poverty, and ensuring environmental stability in all the areas that the corridor covers [7]. 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 [8]. In this context, it is vital to identify the socio-economic factors affecting the adoption of agroforestry systems and practices. Identifying the socio-economic factors will ascertain the opportunities for the development of agroforestry systems and practices. Sinclair and Walker reported that quantitative and predictive understanding of agroforestry systems and practices enables easy adoption. Developing strategies and encouraging farmers to plant trees on their farmland can be done only if the characteristics of the farmland and farmers in relation to tree growing exist [9]. This 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 (Figure 1).

MATERIALS AND METHODS

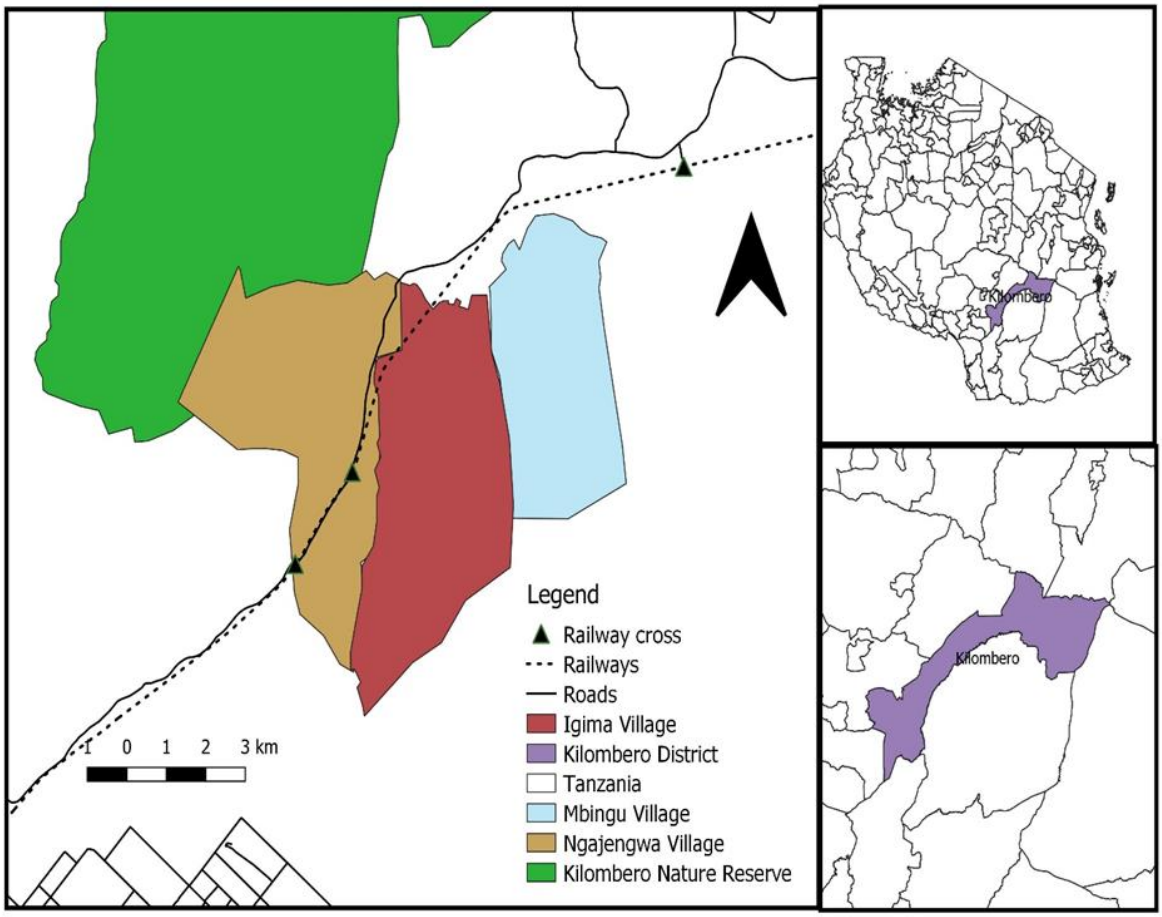

Figure 1. Description of the study area.

The 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 elevation ranging from 262 m to 550 m above mean sea level. Administratively, the Kilombero District has five divisions, 19 wards, and 46 villages. The district is bordered by Kilosa District in the north, the south east by Ulanga District, the south west by the Iringa Region and in the west by the Lindi Region [10]. According to the 2012 census, the population of Kilombero was 407 880, with 202 789 males and 205 091 females [11]. This area is currently experiencing a doubling of the human population over the years [12]. 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.

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 and 1800 mm of rainfall per year, and temperatures range from 26°C to 32°C [13]. Generally, land use is categorized as village land, reserved land, and general land as defined in the Village Land Act 1999 [14].

The main economic activities in the area include cash crop cultivation, food crop cultivation, petty trading, and fishing in the Kilombero River. Overall, cereals from the coast, such as rice, millet, and maize, are widely grown. Also, vegetables such as sweet potatoes, yams, ground-nuts, melons, 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 [15].

METHODS

Sampling procedure

Three villages were purposely selected due to the presence of agroforestry farmers. A random sampling procedure was adopted for selecting households with agroforestry systems and practices. Village registers were used 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 [16,17], Nkonoki Sokoine University of Agriculture, Tanzania thesis for awards of doctor of philosophy).

Sample size determination

Nachimias and Nachimias pointed out that sample size is the most important determinant of any survey estimates. Studies by [18,19], University of Dar es Salaam. Tanzania Dissertation for the award of Doctor of Philosophy and indicated that a sample of 30 units is sufficient, irrespectively of the population size for field work data collection and analysis. Therefore, a total of 90 respondents were sampled from the three villages (Igima, Mbingu and Ngajengwa) for interview. The sample size was considered sufficient to generate the statistical inferences required for making study conclusions.

Data collection

A house hold survey, a focus group discussion, and a key informant interview were used to collect data. The Questionnaire was the main instrument for collecting data from the agroforestry farmers on agroforestry practices and determinant factors for adoption. Focus group discussion enabled to get an insight on status of agroforestry in the villages. Key informant interviews enabled us to get clarification on particular issues raised during focus group discussion and household interviews. Key informants involved were a forest officer from Kilombero Nature Reserve, District Forest Officer and a Ward agriculture extension officer.

Data analysis

Information from focus group discussions and key informant interviews was analyzed using content analysis; whereby raw data was broken down to generate meaningful units of information. 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 of the respondents. In addition, 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 [20-22].

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

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

The multiple logistic regressions are given by:

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

Where J= 1, 2…… (k - 1), I = 1, 2…..p

K stands for number of response or dependent categories where for this study dependent categories for agroforestry systems are agrosilvopasture, agrosilviculture and silvopasture. For agroforestry practices dependent categories are home garden, mixed intercropping, parkland and boundary.

P = Number of explanatory variables included in the model.

When estimating the model, the coefficient of the reference group is normalized to zero [23]. 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 odd ratio for equation 1 and 2 gives the estimation equation below.

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

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 duration of stay in the village (years), X_4 residence type (1 native 2 other wise), X_5 education level, X_6 extension services, X_7 house hold size, X_8 sex (1 male 2 other wise). These independent variables were selected on basis of other agroforestry adoption studies conducted in different

tropical counties.

RESULTS

Agroforestry systems and practices in Kilombero

A total of three agroforestry systems were found in this study which are agrosilvopasture, agrosilviculture and silvopasture systems. The agrosilvopasture system was highly practiced in Igima and Ngajengwa villages, with 56.6% and 67.7%. In Mbingu village, the most dominant system was the agrosilviculture system with 66.7% (Figure 2). Four agroforestry practices were identified in the study area. The practices found were home garden, parkland, and boundary and mixed intercropping. Home garden was highly practiced in Igima and Ngajengwa with 63.3% and 66.7% respectively, while mixed intercropping was highly practiced in Mbingu villages with 56.7% (Figure 3).

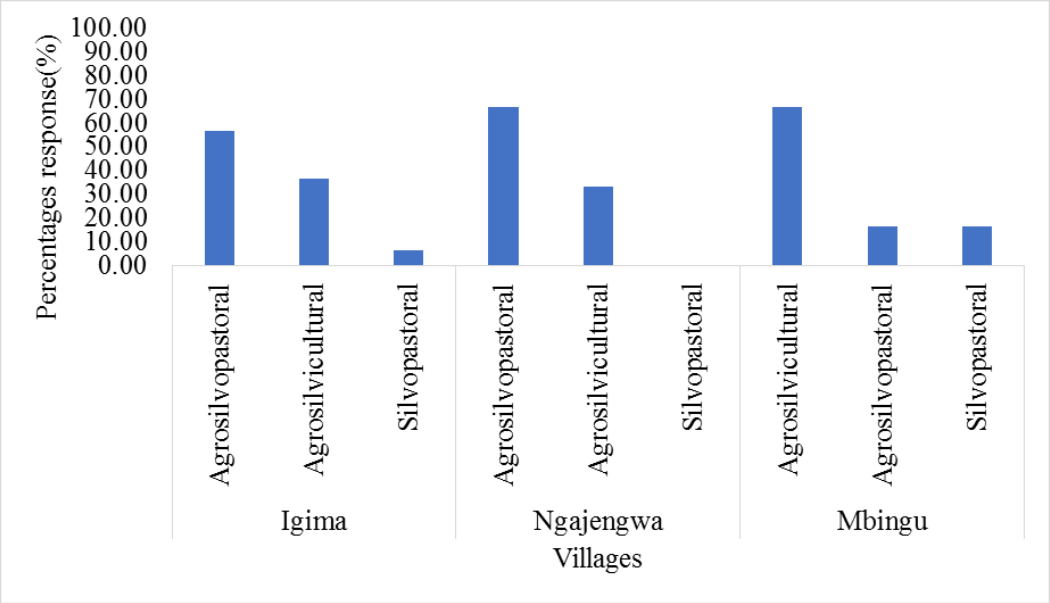

Figure 2. Agroforestry systems in Kilombero District.

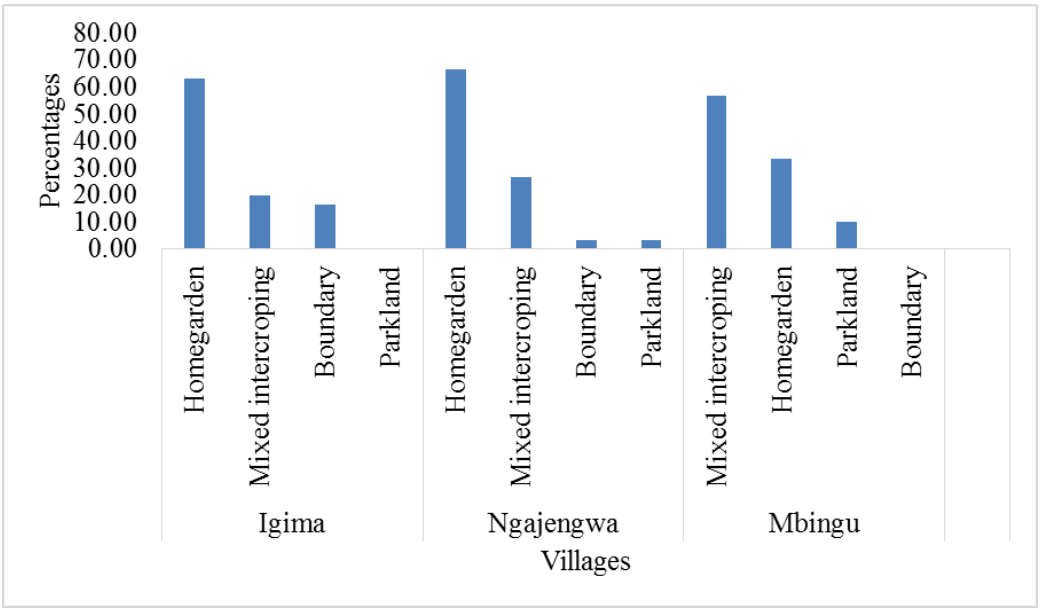

Figure 3. Agroforestry practices in Kilombero.

Adoption of agroforestry systems

Multinomial logistic regression analysis indicated that male and native residences had a statistically significant difference in the adoption of agrosilviculture with reference to agrosilvopasture ($P < 0.05$). Native residences negatively influenced the adoption of agrosilviculture with reference to agrosilvopasture, and the rate of adoption decreased at an odd ratio of 0.14. On the other hand, males were found less likely to adopt agrosilviculture with reference to agrosilvopasture, at an odd ratio of 0.344 (Table 1). Furthermore, other variables had no statistic significant difference in the adoption of silvopasture with reference to agrosilvopasture. Table 2 is illustrative.

Table 1. Determinant of adoption of agrosilviculture with reference to agrosilvopasture.

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
Time to stay	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=Yes	0.84	0.563	0.136	2.316
Residence (Native)	-1.963	0.729	0.007*	0.14
Sex (Male)	-1.068	0.528	0.043*	0.344
The reference category is: Agrosilvopastore. *P<0.05				

Table 2. Determinant of adoption of silvopasture with reference to agrosilvopasture.

Parameter estimates silvopastural systems	B	Std. error	Sig.	Exp (B)
Farming experience	-0.009	0.048	0.843	0.991
Household income	0	0	0.965	1
Time to stay	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
Residence (Native)	-1.364	1.214	0.261	0.256
Sex (Male)	-0.521	1.031	0.614	0.594
The reference category is: Agrosilvopastoral. *P<0.05				

Adoption of agroforestry practices

On the other hand, results from multinomial logistic regression show that the duration of stay in the village, residence type, extension education, and sex (P <0.05) were the factors that influenced the adoption of agroforestry practices with a statistically significant difference. A unit increase in the duration of stay in a village leads to increased adoption of mixed intercropping at an odd ratio of 1.064 (Table 3). Furthermore, the availability of extension education, information, and awareness to farmers increased the adoption of agroforestry practices at an odd ratio of 4.052 (Table 3). Native residences less likely to influenced the adoption of mixed intercropping with reference to home gardens. This indicates that native residences are likely to adopt home garden practices at an odd ratio of 0.068 (Table 3). Furthermore, males were less likely found to adopt mixed intercropping with reference to home gardens at an odd ratio of 0.167 (Table 3). Boundary and parkland agroforestry practices were influenced by explanatory variables, but there was no statistically significant difference with reference to the home garden (Table 4 and Table 5).

Table 3. Determinant of adoption of mixed intercropping with reference to home garden practices.

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
Time to stay	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 (Yes)	1.399	0.675	0.038*	4.052
Residence (Native)	-2.684	0.908	0.003*	0.068
Sex (Male)	-1.79	0.65	0.006*	0.167
The reference category is: Home garden. *P<0.05				

Table 4. Determinant of adoption of boundary with reference to home garden practices.

Parameter estimates boundary practice	**B**	**Std. error**	**Sig.**	**Exp (B)**
Farming experience	-0.064	0.053	0.229	0.938
Household income	0	0	0.125	1
Time to stay	-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 (Yes)	0.715	1.388	0.606	2.045
Residence (Native)	2.951	2.495	0.237	19.134
Sex (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 with reference to home garden practices.

Parameter estimates parkland practice	**B**	**Std. error**	**Sig.**	**Exp (B)**
Farming experience	-0.18	0.138	0.192	0.835
Household income	0	0	0.077	1
Time to stay	0.141	0.093	0.13	1.151
Household size	0.018	0.256	0.944	1.018
Education	-18.36	0	.	1.06 E-08
Extension services (Yes)	3.027	1.759	0.085	20.64
Residence (Native)	-24.553	0	.	2.18 E-11
Sex (Male)	-0.722	1.7	0.671	0.486
The reference category is: Home garden. *P<0.05				

DISCUSSION

Agroforestry systems and practices in Kilombero

Through observation and interviews, two villages were found with more home garden practices and an agrosilvopastoral system, leading to the conclusion that the components involved were trees, herbaceous crops, and/or animals at a high percentage. During interviews, respondents said 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 were highly practiced 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 [24] 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 urge that agrosilvopasture 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, produce more food, resulting in food security, and protect the environment, according to a key informant. A study by [25] indicates that agrosilvopasture contributes significantly to soil improvement through the supply of green manure to the soil. 66.73% 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. On the other hand, 73.17% of the tree species encountered in home gardens were similar to those found in

agrosilvopasture.

In Mingus village, mixed intercropping was the most dominant agroforestry practice, and this was due to suitable land for cocoa growing as well as a lack of reserved area for grazing compared to the other two villages. Also, in the focus group discussion, respondents revealed that mixed intercropping provides diversification of crops, especially cash crops like cocoa, which in turn provides income to households. Also, during focus group discussion, respondents in Mingus village revealed that the presence of Cocoa Kamili Company in the village has influenced mixed intercropping and agrosilviculture of cocoa with trees and other crops. Since mixed intercropping dominates in Mingus Village, the components included were trees and herbaceous crops, which are termed agrosilviculture. A study conducted by Antriyandarti, et al. indicated that agrosilviculture dominates the land suitable for vegetation. Most of the trees intercropped were *Theobroma cacao* and fruit trees such as *Cocos nucifera* and *Mangifera indica* Robiglio, et al. pointed out that the integration of cocoa trees, other trees, and food crops have been an easily manageable strategy because it is easier to manage cocoa and tree species. Another survey by Sonwa found that farmers in Southern Cameroon usually use fruit plants to diversify the cocoa plantation [26-28].

Silvopasture was observed by a few farmers, and it is not commonly practiced by farmers in the study area. During focus group discussion, it was revealed that silvopasture is difficult to implement due to a shortage of grazing land and climate variability. Other respondents pointed out that operation costs are very high and there is a poor market structure for livestock products. Caradona, et al. pointed out that livestock production depends on climate factors; therefore, changes in the climate have an enormous impact on production [29-36].

Adoption of agroforestry systems in Kilombero.

The results indicated that there was a negative correlation between native residences and the adoption of agrosilviculture systems, with reference to agrosilvopasture systems, indicating that native residences were more likely to adopt agrosilvopasture than agrosilviculture. During the survey, respondents pointed out that agrosilvopasture are better than agrosilviculture as it allows the diversification of all three components. In addition, during focus group discussion, respondents pointed out that non-natives are less likely to engage in agrosilviculture systems because many of them spend a short time and then move to an area. A study by Obeng and Weber reported that non-native farmers are less likely to adopt agrosilvopasture due to their shorter horizons. Gender was another factor which showed the statistical significance difference in the adoption of agrosilviculture with reference to agrosilvopasture. In this study, males were less likely to adopt agrosilviculture, with reference to agrosilvopasture. Respondents pointed out that with the presence of trees and crop integration, livestock is also important, especially for income contribution when there is crop failure. Similar results have been observed in Malawi by Thangata and Alavalapati and in Kenya by Sanchez, who indicated that female farm headed houses did not adapt to the agroforestry system compared to male farm headed houses because most males prefer trees as the long-term major source of income. Also, during the focus group discussion, a few spouses were available to respond on behalf of the rest. The woman pointed out that men are always the heads of households; as a result, they make decisions on household affairs, such as controlling resource allocation and general land use management. According to Oino and Mugure, male land ownership has put them at the forefront of decision making on land use systems such as the type of agroforestry system to be practiced for the benefit of households. On the other hand, during focus group discussion, males pointed out that females are always involved during the planning of land use, but they cannot change the last decision made by males, and poultry were found to belong to females and livestock to males. Similar results have been observed by Merce who indicates 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 residences had a negative correlation with the adoption of mixed intercropping with reference to the home garden. This indicates that native residences are more likely to adopt home gardens compared to mixed intercropping. A study by Irshad, et al. pointed out that native residences 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. who pointed out that native residences are in a good position to attain land tenure and secure enough land for agroforestry since it is a long-term investment.

Duration of stay in the village had a positive correlation with the adoption of mixed intercropping with reference to the home garden. This indicates that as the duration of stay in the village increases, farmers become more interested in adopting mixed intercropping than home gardens. This result is similar to a study by Liniger, et al. who pointed out that the duration of stay influences crop diversification, hence shifting from practicing agroforestry near the home to the farm land. Farmers with access to extension education were likely to adopt mixed intercropping over the home garden. During the survey, farmers practicing mixed intercropping argued that in their home gardens there was no proper arrangement of crops and trees, which made them less productive. Similarly, a study by Chija indicates that extension education is the most critical factor that enhances farmers' adoption of particular agroforestry practices in consideration of the product and production. On the other hand, males were found less likely to adopt mixed intercropping with reference to their home garden. During the survey, it was noted that the majority of the households were headed by males, and one of the roles of males is to ensure food security. In that respect, men preferred home gardens because most of the components in the home garden supplement the household's food and income. In the study area, fruit trees were the primary source of food, 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 confirmed that fruit trees in the home garden have a significant role in the family during environmental crises such as drought.

CONCLUSION

From this study, it is revealed that potential exists in agroforestry systems and practices in terms of product

diversification and biodiversity conservation. However, systems and practices were practiced at different levels in the study area. This indicates that farmers have different preferences in establishing agroforestry systems and practices for different purposes, but the major purposes observed were for domestic use. In order to achieve the development of agroforestry systems and practices, smallholder farmers must develop intensive management to yield a quality product from components of priority to meet market demand. Farmer's oriented factors are critical in the adoption of agroforestry systems and practices. Though the model did not provide statistically significant support to accept the influence of most of the explanatory variables on farmer's decisions to adopt agroforestry systems and practices. But the key factors discussed provide an empirical overview of the factors that should be given attention in the adoption of agroforestry practices and systems. Therefore, the study recommends that all the independent variables outlined must be addressed in order to expand adoption of different systems and practices. This study recommends that different stakeholders be involved in implementing the agro forest projects, and these findings should be disseminated to enhance adoption. Furthermore, these findings may be replicated in other parts of tropical countries to improve the adoption of agroforestry systems and practices.

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