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ADOPTION OF AGROFORESTRY TECHNOLOGIES AND THE WELFARE OF ARABICA COFFEE FARMERS IN BUKHURA PARISH, BUDUDA DISTRICT, EASTERN UGANDA

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ABSTRACT

Due to the declining productivity of coffee farms in many regions, there has always been a growing interest in agroforestry technologies as a way to improve the fertility of the soil, increase crop diversity, and provide other income sources to farmers. Much as there had been successful cases of agroforestry adoption in the study area, there was still limited evidence on the impact of these technologies on coffee farmer's welfare. A study was conducted to assess the socio economic factors influencing the adoption of agroforestry practices and the welfare of the coffee farmers in Bukhura parish, Bumasheti Sub County, Bududa district. The findings REVEALED that the majority (80%) of the farmers practiced agroforestry in their gardens, of which they grew shade-providing trees such as *Ficusnatalensis* in coffee gardens is an important practice for the wellbeing of the coffee. The regression results indicate that the use of agroforestry techniques had a significant positive impact on the income generated from the coffee by the farmers. However, other factors; distance from the nearest coffee market and form of coffee sold also had a significant impact on the income generated from the coffee. The results also showed that access to credit, access to extension services and farming experience were found to have significant influence on the adoption of agroforestry practices among the coffee farmers in the study area. The key conclusions from the study are that credit facilities and extension services are key issues in promoting agroforestry among coffee farmers, and there is need to encourage coffee farmers to practice agroforestry since it had a positively significant impact on their incomes.

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1. INTRODUCTION

Globally, the top three world coffee producing countries are Brazil, Vietnam and Colombia. Brazil produced over 2.6 million metric tons of coffee, followed by Vietnam at 1.6 million metric tons and then Colombia at 0.7 million metric tons. Coffee consumption has greatly been increasing over the past decade in accordance with the international coffee organization (Basamba et al., 2016). In 2020, world coffee consumption stood at around 166 million bags, with the United States being the leading consumer. Coffee is one of the most traded commodities in the world and is also a major source of employment (Bongers et al., 2015). The coffee industry provides employment for millions of people in processing, roasting and retail.

Uganda is one of the top coffee-producing countries in Africa (Nguyen et al., 2020). In fact it is the leading coffee exporting country on the African continent where about 500,000 (Nkamleu & Manyong, 2005) farm households with less than 1 ha of land rely on coffee as their major cash crop. Accordingly to, Coffee is a major cash crop for many small holder farmers in Uganda second to crude which is the mostly traded providing employment and income for millions of people. However coffee productivity faces a number of limitations, for example, climate change, soil degradation and declining productivity (Bongers et al., 2015).

Agroforestry technologies can make significant contribution towards addressing high levels of poverty and associated land degradation in the east and central Africa region. This requires to be supported by improved access to markets and stronger association that can help facilitate economies of scale. Agroforestry is an essential component for developing sustainable agricultural systems, especially in tropical countries of the world with a multiple objectives like maximizing productivity, creating jobs and income in rural areas, and safeguarding sustainability. Trees are introduced into agricultural production systems to decrease soil erosion, maintain soil moisture, and produce useful products such as fuelwood, nuts, fruits, and building materials for the rural household and commercial markets. Agroforestry techniques need to be promoted among rural farmers in developing countries by demonstrating the benefits of various options (Siriri and Bekunda, 2001).

Agroforestry technologies present a promising solution to these challenges, as they offer a multifaceted approach for sustainable agriculture that integrates trees, crops, and livestock in a complementary and mutually beneficial way (Waldron et al., 2017). The adoption of agroforestry systems by coffee farmers has been promoted as a way to improve soil fertility, increase biodiversity, and provide additional income streams and the reducing productivity (Castle et al., 2021). Despite the potential benefits of agroforestry adoption, there is limited empirical evidence

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on the impact of these technologies on the welfare of coffee farmers (Jose, 2009). 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 (Basamba et al., 2016) A few studies have reported positive effects of agroforestry adoption, including increased income, improved food security, and enhanced environmental sustainability (Glover et al., 2014), while others have shown mixed results, with some farmers facing challenges in implementing the systems. Therefore, there was need for further research to assess the relationship between agroforestry adoption and the welfare of coffee farmers and identify the mechanisms that underlie these effects.

Coffee cultivation plays a pivotal role in the livelihoods of millions of farmers worldwide, particularly in developing countries. However, the over use of monoculture approach in coffee farming often led to several challenges including environmental degradation, economic instability and social inequities. Due to the declining productivity of coffee farms in many regions, there has always been a growing interest in agroforestry technologies as a way to improve the fertility of the soil, increase crop diversity, and provide other income sources to farmers. Much as there had been successful cases of agroforestry adoption by a few farmers in Bumasheti sub county, Bududa district, there was still limited evidence on the impact of these technologies on coffee farmer's welfare. The study, therefore, aimed at evaluating the adoption of agroforestry technologies and the welfare of coffee farmers by investigating the multifaceted dimensions of agroforestry adoption, including the social, economic, and environmental aspects, this aimed at providing a comprehensive understanding of the potential benefits and factors that determine integrating trees into coffee farming systems. The study also explored the factors to agroforestry adoption and the effect of agroforestry on the welfare of coffee farmers. The findings of this study contributed to the existing literature on the impact of agroforestry technologies on the livelihoods of coffee farmers.

2. METHODS

The study employed a descriptive longitudinal approach. Longitudinal studies are simple in design and are aimed at finding out the prevalence of a phenomenon, problem, attitude or issue by engaging a longitudinal study of the population. This obtains an overall picture as it stands at the time of the study. Longitudinal usually involve tracking the same people and so the difference observed in those people are less likely to be the results of cultural differences across generations. This design was chosen because it generates reliable data and is relatively cheap and easier to administer. The target population for this study was all the coffee farmers in Bukhura

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Parish, Bumasheti Sub County, Bududa District. This focused more on the coffee farmers that have embraced agroforestry and the relationship to their welfare.

The household survey and in-depth studies were conducted in Bukhura Parish located in Bumasheti Sub County which is one of the five sub counties in Bududa district. Bududa district is bordered by Manafwa district to the north, Mbale district to the northeast, Sironko district to the East, Namisindwa District to the southeast, Butaleja district to the south and Pallisa District to the southwest. Bududa is approximately 42km from Mbale city by road. The time varies depending on the route taken and the state of the road used at that time. The geographical coordinates of Bududa are 1°00'60.00''N, 34°19'60.00''E. The district has a land area of 250.8km² with a population of 271,100. The annual rainfall ranges between 312.72-477.07mm. The average temperature ranges between 58°F to 86°F annually.

Qualitative and quantitative data was generated from the field based on the questionnaire was collected through conducting Rapid Rural Appraisal (RRA) between June to December 2022. The key informants and particularly those farmers involved in pepper intercropping, were consulted to collect information on cultivation, production, income, and marketing of hot pepper. Some of the information was obtained during field observation as well. Data collected through questionnaires, Interview guide, were entered into the computer, coded, cleaned, and analyzed using SPSS V23 for quantitative analysis. The statistics focused on the measures of central tendencies (percentages) and relational statistics to measure the direction. Quantitative data was described using descriptive statistical techniques that included the use of tables, graphs and pie charts, these assisted in drawing inferences and establish the extent to which the independent variables have significance and implications. Descriptive statistics were used to analyze the data collected on the above objective. They included mean, percentages, standard deviations, frequency tables and statistical figures such as pie charts were used to clearly illustrate the different agroforestry practices among the coffee farmers in Bukhura Parish, Bumashetisubcounty.

A log linear regression analysis model was used to achieve this specific objective. A natural log was used in order to transform the skewed data on farmers' revenue into a normally distributed dataset to ease comparison. The dependent variable was the log income (lnY) of the coffee farmers and independent variables being all the pre-assumed factors having an effect on income generated by coffee farmers. The linear regression model that was used is given as;

$$LnY = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + A \quad \text{.....(1)}$$

Where; LnY = Natural log revenue/ income generated by coffee farmers; β0 = y-intercept (constant); X1 = Use of agroforestry practices (dummy variable); X2 = Farmers' group.

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(Through groups can have better access to market than their counterparts); X3 = distance to the nearby coffee market. Farmers who are in remote and distant areas usually receive low prices.; X4 = Access to credit by smallholder coffee farmers (this will influence farmers' revenues generated from coffee since farmers with access to credit can adopt to modern technologies and X5 = form of coffee sold by small holder coffee farmers. For any value-adding activity done by any farmer increases their potential of receiving higher revenues.

A = stands for Erroneous constant.

And, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ **:** Are the regression coefficients of the independent variables.

The adoption of agroforestry practices by coffee farmers largely depends on a number of socio-economic factors which may be directly or indirectly come into play. In this case, a multiple linear regression analysis model was employed. The dependent variable was the use of agroforestry practices (dummy) by the farmers and the independent variables being the factors drive the farmers to using those agroforestry practices. The linear regression model in this case was given as below;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + A \quad \text{.....(ii)}$$

Where; Y = the use of agroforestry (dummy); X_1 = Age of the farmer. (Years); X_2 = Education level.

X_3 =land size; X_4 = access to extension services; X_5 = access to credit; X_6 = house head (1= Male, 0=Female); X_7 = Group membership (1= Member, 0= not member); X_8 = household size; X_9 = land ownership; X_{10} = access to information; β_1 To β_{10} are the regression coefficients to be estimated and *e* is the error term; and A = Constant term.

3. RESULTS

3.1 Demographic Characteristics of the Respondents

Table 1: Bio-data of the respondent coffee farmers

Characteristics	Frequency	percentage(%)
Sex		
Male	85	70
Female	15	30

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Education		
primary	8	16
Secondary	31	62
Higher education	11	22
Access to credit		
Yes	40	80
Land ownership		
Owned	37	74
Hired	13	26
Group members		
Yes	35	70
Access to extension		
Yes	38	76

Parameter	mean	Standard deviation
Age(years)	48	13.48
Experience(years)	3.6	0.84
farm size(acres)	1.9	0.61
Distance to market(km)	2.75	1.6

The results showed that 76% (majority) of the coffee farmers in Bumashetisub county had access to extension services. From these they acquire knowledge on agroforestry techniques, especially planting trees to provide shade for the coffee. The adequacy of extension services is due to high coffee production potential in the region that calls for more development in the crop.

The results showed that the average age of the farmers in Bumashetisub county is 48 years. This had a standard deviation of 14, indicating that there was a big deviation from 48 years which means there were many farmers below and above the mean age. 48 years being the mean age shows that the majority of the farmers are middle aged, which is the most productive age of men. On average each coffee farmer had an experience of approximately 3.6 years in coffee farming. This explains why the majority of the farmers did agroforestry; they have been in the enterprise for quite long to know its advantages. Table 2 shows findings on the farm size owned/hired by the coffee farmers in Bumashetisubcounty. It indicates that on average every farmer operates on

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approximately 2 acres of land. This is generally small land area which gives a chance to majority small holders coffee farmers to practice agroforestry in the fields.

The distance to the nearest coffee market is generally small with an average of 2.75km with a standard deviation of 1.60. This indicates that the majority of the coffee farmers have access to market which motivates them to put more energy in making sure their coffee is in good health o as to earn much from it. They do this by ensuring shade for the coffee through agroforestry.

Results in Table 3 represent findings on agroforestry practices among coffee farmers in Bumashetisub county. The Table results show that out of the farmers covered, 80% carried out agroforestry in their coffee farms/gardens. Out of these that carried out agroforestry, the majority (62.50%) grew shade providing trees in their coffee gardens. Using tree species such as *Calliandara Calothyrsus* and "Omutumba" the farmers provided shade for the coffee protecting them from severe sunshine that could lead to reduced yields. The trees also protect the coffee from strong winds that could break the heavy coffee trees.

Table 2: Agroforestry practices among coffee farmers

Parameter	Percentage
Practice Agroforestry	
Yes	80%
Agroforestry practice employed	
Shade grown trees	62.50%
Alley cropping	10%
Nitrogen fixing trees	27.50%

3.2 Determining factors influencing the adoption agroforestry practices by coffee farmers.

Results in Table 4 presents that, R-squared was 0.8229 which implies that 82.3% variation in the adoption of agroforestry practices (dependable variable) is explained by the independent variable included in the market. Results from the presented that, the age of the farmer as a variable had a negative coefficient of 0.120658, and the coefficients for the level of education were 0.120658 for secondary and 0.094828 for tertiary education. The size of the farm under coffee production had a negative coefficient of 0.04538 while the coefficient of the access to credit by the farmer for a yes response was 0.754983 and significant at 1% level of significance. Access to extension services (yes response) had a coefficient of 0.326879 and it was significant at 5 % level of significance. Land ownership (private category) had 0.104874 as the coefficient but not significant. The coefficient for group membership, farming experience were 0.45856 and 0.145534 respectively.

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According to results in Table 4, access to credit by the farmer had a coefficient of 0.754983 and significant at 1% level which implied that access to credit by a farmer increases the level of adoption of the agroforestry practices by 75%, provided other factors are held constant. This can be explained on the fact that, access to credit by a farmer will increase his/her financial resources which are always important in purchasing good varieties of trees (leguminous trees) and also in the process of controlling the pests and diseases that are often associated with those shady trees commonly intercropped with coffee. This finding of the study was in line with the findings of a study by (Desmiwati et al., 2021) in which the researcher reported that, credit access had a significant influence on the adoption and implementation of agroforestry technologies.

Access to extension services also had a significant relationship with the level of adoption of the agroforestry practices by farmers with a coefficient of 0.326874. This implies that, having access to extension services by farmers will boost the level of adoption of agroforestry practices by 32.7% as other factors remain constant. This is because, many extension services, farmers are educated on the benefits of agroforestry practices and also farming knowledge and skills on their coffee plantations. In addition, through extension services, farmers get advised on the best tree varieties suitable for being intercropped with coffee.

Table 3: Multiple linear regression analysis results on the factors influencing the adoption of agroforestry practices in coffee production.

Adoption of agroforestry practices (%).	**Coefficient**	**standard error**	**P>(t).**
Age of the farmer.	-0.00294	0.00353	0.409
Education level			
2. Secondary	0.120658	0.08204	0.149
3. Tertiary	0.094828	0.10577	0.375
Farm size	-0.04538	0.06427	0.484
Access to credit by the farmer (yes).	0.754983	0.11509	0.000***
Access to extension services (yes).	0.326879	0.22596	0.015**

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Land ownership (Private).	0.104874	0.23362	0.656
Group membership (yes).	0.045856	0.10357	0.660
Farming experience of the farmer.	0.145534	0.07408	0.056*
constant.	-0.04412	0.13806	0.751

R- Squared = 0.8229. *, ** and *** are significant at 10%, 5% and 1% levels of significance respectively.

Lastly, farming experience of the farmer had a significant relationship with the adoption of agroforestry practices with a coefficient of 0.145534. This coefficient implies that, keeping other factors constant, an increase in the faming experience by one year will increase the adoption of agroforestry practices by 14.6%. This can be explained by the fact that, gaining more experience in coffee growing by a farmer will equip them with more knowledge practical knowledge of boosting the productivity of coffee plantations. Intercropping shady trees with coffee play a very crucial role in preventing dehydration of coffee plants during long periods of draught. Therefore, agroforestry will enable a farmer to realize better yields through the production cycles. The results of the study on this variable were in accordance with the results reported by (Janka & Nigatu, 2020) in the study in which the researchers reported that, the number of years spent in coffee growing are crucial in determining the rate of adoption and implementation of the agroforestry practices by the smallholder coffee farmers.

3.3 Determining the effect of Agroforestry practices on the income of coffee farmers.

The results in Table 4 showed that, R-squared is 0.8586 which implied that 86% of the variations in the dependent variable (Log Revenue) is explained by the independent variables included in the model. Practicing agroforestry practices as a variable had a positive coefficient of 0.34 which implied that there is a positive relationship between the adoption of agroforestry practices and the revenue earned by coffee farmers in Bukhura Parish, Bumasheti sub-county and the coefficient was significant at 5% level of significance. The results further presented that, the group membership had a positive coefficient of 0.05 which indicated a positive relationship between the revenue earned by the coffee farmers and the group membership. Access to credit by farmers also had a positive coefficient of 0.05 and this showed a direct relationship between the income earned by coffee farmers and the access to credit. The coefficient of the distance to the nearby coffee market as a variable was obtained as negative 0.03797 and it was significant at 10% level which indicated a negative influence of the distance to the coffee market and the farmers' income. The coefficients of the forms of coffee sold by the farmers were positive

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0.79904 and 0.11 for black cherries and coffee parchments respectively. This indicated a positive influence of the value-added forms of coffee to the revenue realized by the farmers.

According to the results in Table 4, the coefficient of the practicing agroforestry by the farmer was positive 0.34 and significantly influencing the coffee farmers' revenue. This coefficient implied that, adopting and practicing agroforestry by a farmer increases farmer's revenue earned from coffee by 34.4% while other factors are kept constant. This can be explained on the fact that, having both trees and coffee plants on the same piece of land at the same time serves a very important role in coffee growing. These trees mainly the shady trees provide shade to coffee plants hence protecting them from drying up during the dry seasons. In addition, some trees that are usually intercropped with coffee are legumes (e.g., *Calliandara Calothyrsus*), implying that they are capable of adding nitrogen to the soil hence boosting the performance of the coffee plants. The increase in farmers' revenue comes as a result of increased yields hence increased volumes of sale made by coffee farmers. The findings reported by this study are in line with the findings of the study by (Valencia et al., 2015) in which the researcher reported that the relationship between the farmers' revenue and the level of agroforestry adoption was positive and significant.

Results in Table 4 further presented that, the distance to the nearby coffee market also had negative coefficient of 0.04 and had a significant effect on the revenue. The coefficient implied that, an increase in the distance to the nearby coffee market by one kilometer while other factors are kept constant will increase the farmers' income by 4%. This can be explained on the basis that, the prices received by the farmers tend to vary the variation in the distances from their households to the nearby coffee markets. This is because farmers are usually price takers and traders tend to offer lower prices to far distant farmers, while putting into consideration the transaction costs (transportation costs) which may eventually lower their margins. Since revenue is the product of Yields (kgs) and price, a lower price offered to a farmer will directly reduce farmer's income earned from coffee.

The coefficients of the forms of coffee sold by the farmers were positive 0.79 and 0.11 for black cherries and coffee parchments respectively and significant at 1% level. These results showed that, any value adding activity engaged in by a farmer will have a positive influence on the income earned. This is because dry black coffee and coffee parchments fetch quite higher prices than the fresh red cherries. Therefore, farmers with same coffee yields marketing under similar market conditions can still earn different incomes due to the difference in the form of coffee being sold. These results are supported by the results in the study by (Basamba et. al., 2014) in which the researcher stated that, value-adding activities on coffee have significant impacts on the revenues realized by small holder coffee farmers.

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Table 4: Log linear regression analysis results for the effect of agroforestry practices onincome generated from coffee.

Log revenue	Coefficient	Standard error.	P>(t)
Practicing agroforestry practices(yes)	0.34407	0.156951	0.034**
Group membership (Yes).	0.04847	0.077952	0.537
Access to credit. (Yes)	0.04952	0.157634	0.755
Distance to the nearby coffee market.	-0.03797	0.018798	0.050*
Form of coffee sold by a farmer.			
Dry cherries.	0.79904	0.067582	0.000***
Coffee parchments.	0.11010	0.094545	0.000***
Constant.	13.95168	0.090045	0.000

R- Squared = 0.8586. *, ** and *** are significant at 10%, 5% and 1% levels of significances.

4. CONCLUSION

The main objective of this study was to examined the factors influencing the adoption of agroforestry practices among coffee farmers in Bumashetisubcounty. The study established that the majority (80%) of the farmers practiced agroforestry in their gardens, of which the majority (62.5%) grew shade providing trees amongst their coffee. This indicates that growing trees such as *Ficusnatalensis* in coffee gardens is an important practice for the wellbeing of the coffee. The multiple linear regression results indicate that the use of agroforestry techniques had a significant positive impact on the income generated from the coffee by the farmers. This was because agroforestry protects the coffee from severe weather conditions hence securing good harvest. However, other factors; distance from the nearest coffee market and form of coffee sold (red cherries, dry cherries and coffee parchments) also had a significant impact on the income generated from the coffee. Furthermore, the multiple linear regression results show that access to credit, access to extension services and farming experience were found to have significant influence on the adoption of agroforestry practices among the coffee farmers in Bumasheti Subcounty. The study concluded that credit facilities and extension services are key issues in

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promoting agroforestry among coffee farmers, since it was found to have a significant impact on the income generated from coffee.

5. RECOMMENDATIONS

The key policy recommendations are that the coffee farmers should engage in adoption of agroforestry practices since they showed positive significant influence on the revenue generated from coffee. Secondly, its recommended that policy makers to widen and extend coffee markets close to farmers and widen the provision of credit services to smallholder coffee farmer in order to minimize the negative effect of distance to nearby coffee markets. Coffee farmers should adopt value adding activities such as drying coffee cherries, primary processing into parchments since these forms of coffee had positive significant influence on the revenue earned from coffee. The provision of extension services to coffee farmers should be strengthened by policy makers since its effect on revenue was positive and significant. This will help them improve on their earnings and farming practices as well and create jobs for other unemployed people for example transporting coffee to the markets. The government should regulate the market for the coffee such that the coffee farmers can benefit from their farming activities not to be cheated by intermediaries. Trainings should also be organized for farmers to improve on their production methods and knowledge/skills trainings will help them to be exposed to many different people who can help them make their farming activities profitable.

Compliance with ethical standards

Conflict of Interest

The authors declare that there is no known scientific, employment of funding conflict of interest with this paper.

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Disclosure of conflict of interest

The authors confirm and declare that there are no known conflict(s) of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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