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Farmers' adoption and perceptions of the benefits of intercropping coffee trees with bananas: Evidence from Rwanda

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Farmers' adoption and perceptions of the benefits of intercropping coffee trees with bananas: Evidence from Rwanda

Abstract

Coffee and banana are major cash and food crops for small-scale farmers in Rwanda. Coffee–banana intercropping system has been identified to be less risky for farmers since the chance of simultaneous crop failure is low. In addition, this farming system is highly feasible and sustainable as two crops complement each other in terms of shade and nutrient uptake. This paper aims at examining farmers' perceptions of the benefits of intercropping with coffee trees and bananas and identify factors that determine the adoption decisions. The study used data collected from 296 smallholders producing coffee and banana in Rwanda. The analysis was done using ordered probit regression and binary logistic regression models. The ordered probit regression results show that age, education, land tenure, livestock ownership, and drought stress variables significantly enhance the likelihood of perceiving the benefits of coffee–banana intercropping system. The results from the binary logistic regression model show that age, household size, and drought stress positively affect the adoption decisions for the coffee–banana intercropping system, while gender, group membership, and farm size decrease the likelihood of adoption. Results imply the need for policy to strengthen rural education to promote and create awareness about the benefits of coffee–banana intercropping system.

Keywords: Coffee–banana intercropping; cropping-system; perception analysis; adoption; Rwanda.

1. Introduction

Coffee and banana are the most important cash and food crops for millions of households in Rwanda and the surrounding East African highland countries such as Burundi, Uganda, northwest Tanzania, and eastern Democratic Republic of Congo (DRC). Banana (*Musa spp.*) is the main food and cash crop produced throughout the year and it is estimated to meet more than 10% of the dietary energy requirements in Rwanda, Burundi, and Uganda (Jassogne et al., 2013; van Asten et al., 2011). On the other hand, coffee is a primary cash crop harvested once or twice a year and contributes about 27% of total export revenue (Ngango and Kim, 2019). Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*) are the two most important types of coffee planted in Rwanda. Arabica coffee comprises about 95% of Rwanda's total coffee production and is frequently cultivated at higher altitudes in the Western, Northern, and Southern parts of the country. While Robusta coffee occupies the other leftover 5% where it is cultivated at lower altitudes below 1400 m in the Eastern Province (Ngango and Kim, 2019). The overall area under coffee production in Rwanda was estimated at 35,500 ha in 2019 (FAOSTAT, 2019). Generally, coffee and banana are predominantly grown as monoculture farming systems which mostly depend on inorganic fertilizers and chemicals to enhance the crop yield. However, these monoculture farming systems may cause negative effects on the environment and human health, and they are costly than intercropping systems (Sebatta et al., 2019).

More specifically, coffee and banana intercropping system has been reported by van Asten et al. (2011) to be highly feasible and sustainable in the East African highland region since these two crops complement each other in terms of shade and nutrient uptake (Sebatta et al., 2019). This farming system is not only practiced in the East African highland region, but also across the humid tropics, including Latin America, Asia, and West Africa (van Asten et al., 2015). Although some intercropped systems may have strong competition for resources, the systems are credited with increased total biological productivity per unit area of land (van Asten et al., 2011). Moreover, intercropping coffee with bananas is likely to be less risky for farmers because the chance of simultaneous crop failure or low prices for both crops is low (van Asten et al., 2011). As coffee is a major export crop and farmers in Rwanda depend on bananas for food security and extra income throughout the year, official recommendations from public extension and research bodies suggest that coffee and banana intercropping system will encourage the production of both crops and contribute towards improved food security and increased household income (van Asten et al., 2015). In addition, the International Coffee Organization (ICO) recommended coffee-producing countries adopt farming systems of intercropping coffee with other shade crops to control for the issues of decreases in coffee prices (van Asten et al., 2011).

The decision of farmers to adopt sustainable farming practices such as intercropping systems depends on their awareness, information, and knowledge of these practices (Manda et al., 2016). Thus, investigating farmers' perception and knowledge of the benefits of coffee and banana intercropping system can be useful in identifying the determinants of adoption (Rahman, 2020). However, the literature on farmers' perception and adoption of the coffee and banana intercropping system, particularly in Rwanda, is lacking. In Uganda, Jassogne et al. (2013) investigated the perceptions and outlook of smallholder coffee farmers on the opportunity of the coffee-banana intercropping system. They found that coffee-banana intercropping system provides additional food and income from smallholders' limited land and helps farmers reduce risks related to drought, pest/disease attacks and coffee price volatility. van Asten et al. (2011) examined the agronomic and economic benefits of coffee–banana intercropping system relative to mono-cropped coffee farming system in Uganda. Their findings revealed that the coffee–banana intercropping system was much more beneficial than coffee or banana mono-cropping system. To date, there is no study that has attempted to assess the farmers' perceptions and the determinants of adoption of coffee and banana intercropping system.

The objective of this study is to examine farmers' perception of the benefits of coffee and banana intercropping system and identify the factors influencing the adoption decisions in Rwanda. Therefore, the identification of farmers' perceptions and the determinants of adoption will fill the knowledge gap for policymakers which may also expand further effective development of agricultural policies.

2. Materials and Methods

2.1. Study background and data sources

This study was conducted in the districts of Gakenke and Kamonyi of the northern and southern provinces of Rwanda. As Figure 1 shows Gakenke and Kamonyi districts are among

the largest producers of coffee in Rwanda. Besides, farmers in these districts grow coffee and bananas as intercrop. To conduct the empirical analysis, we used a dataset collected from a farm household survey conducted in August 2021 by the first author and a team of trained enumerators. The sample consists of 296 farm households. A multistage sampling technique was used to select farmers from each district. In the first stage, the two districts were selected based on their coffee–banana production potential. The second stage involved the choice of eight administrative sectors (4 in each district) based on proportionate random sampling. The sectors are deemed to be the lowest administrative units established to coordinate and oversee the execution of extension services across the country. In the third stage, coffee–banana producers were enumerated in each sector and face-to-face interviews were conducted with a set of randomly chosen respondents (i.e., household heads). A total sample of 296 households was randomly selected from the two districts, with the number of households from each selected sector being proportional to the size of the sector. Using a structured questionnaire, these respondents were asked to provide information regarding the socio-economic characteristics, and the use and perceptions of the benefits of coffee–banana intercropping system.

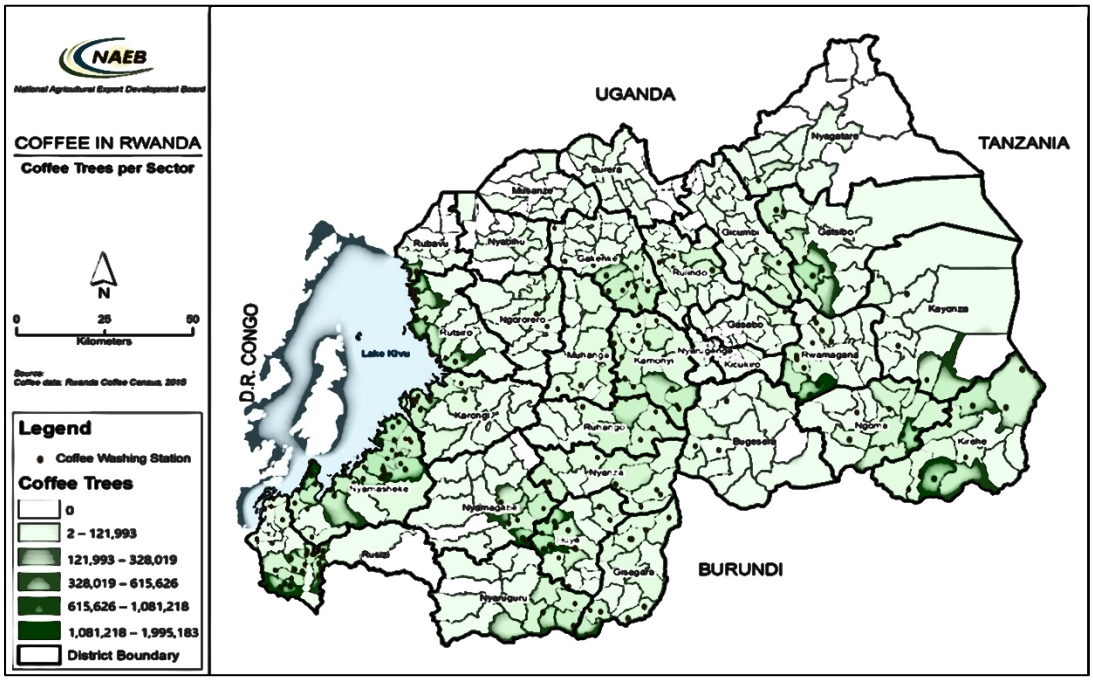

Figure 1. Coffee-growing areas in Rwanda. Source: National Agricultural Export Development Board.

2.2. Specification of econometric model

The assessment of the factors influencing the adoption of coffee–banana intercropping system was done using the logistic regression model. The logit model assumes the adoption of coffee–banana intercropping system to be a dichotomous dependent variable, which takes '1' if adoption was done and '0' otherwise. In other words, the dependent variable Y_i was defined as;

$$Y_i = \begin{cases} 1 & \text{if the farmer has adopted coffee} - \text{banana intercropping system} \\ 0 & \text{if the farmer has not adopted coffee} - \text{banana intercropping system} \end{cases}$$

To examine the farmers' perception of the benefits of coffee–banana intercropping system, we used the ordered probit regression model. In doing so, households were asked to rate the benefits of coffee–banana intercropping system based on a five-point scale, i.e., strongly disagree, disagree, neutral, agree, and strongly agree.

Following Adesina and Zinnah (1993), farmers' adoption decisions on the coffee–banana intercropping system are assumed to be based upon utility maximization. Based on the random utility framework, farmers choose to adopt sustainable agricultural practices if the utility gained from adoption is higher than non-adoption. This utility gain can be expressed as a function of various explanatory variables (X_i) in the following type of latent variable model:

$$Y_i^* = \beta X_i + \varepsilon_i \quad (1)$$

where Y_i^* denotes the dependent variable (adoption), β denotes the vector of the parameter to be estimated, and ε_i is the error term. Some previous studies (Adesina and Zinnah, 1993; Kabir and Rainis, 2015; Ntshangase et al., 2018) have used the binary logit or probit model to examine the factors influencing the adoption of sustainable agricultural practices. However, these binary regression models are not appropriate if the dependent variable has more than two values. Therefore, the ordered probit model is applied to examine farmers' perceptions of the coffee–banana intercropping system. The ordered probit model involves a qualitative dependent variable for which the categories have a natural order or ranking. This model is specified as follows:

$$Y^* = X'\beta + \varepsilon, \text{ where } \varepsilon \widetilde{N}(0,1) \quad (2)$$

Since Y^* is unobservable (latent) in nature, we observe:

$y = 0$ if $y^* \leq 0$

$y = 1$ if $0 < y^* \leq \mu_1$

$y = 2$ if $\mu_1 < y^* \leq \mu_2$

$\vdots$

$y = J$ if $\mu_{J-1} \leq y^*$

where $\mu_1 \ldots \mu_{J-1}$ are the threshold values or cutoff points that can be estimated with β.

Then the probabilities of observing the dependent variable (y) given a set of explanatory variables (x) can be expressed as:

$$\left.\begin{array}{l} Prob(y=0) = \emptyset(-X'\beta) \\ Prob(y=1) = \emptyset(\mu_1 - X'\beta) - \emptyset(-X'\beta), \\ Prob(y=2) = \emptyset(\mu_2 - X'\beta) - \emptyset(\mu_1 - X'\beta), \\ Prob(y=J) = 1 - \emptyset\left(\mu_{J-1} - X'\beta\right) \end{array}\right\}, \quad (3)$$

where $\emptyset$ is the standard normal cumulative distribution function such that the sum of all probabilities is equal to 1. For all the probabilities to be positive, $0 < \mu_1 < \mu_2 < \cdots \mu_{J-1}$.

3. Results and Discussion

3.1. Summary statistics

A summary of the socio-economic, institutional, and farm-level characteristics of the sampled households used in this study is shown in Table 1. The summary statistics given in Table 1

indicate that the average age of household heads in the study area is about 51 years, the level of education is approximately 6 years, and about 57% of the households are headed by males. The average household size is approximately 5 members and it nearly the same as the national average household size which is 4.8 according to the Fifth Integrated Household Living Survey (EICV5). The proportion of farmers who are members of cooperatives is 72% and the frequency of contacts with extension agents is roughly 30 times per year. The average farm size under cultivation is 0.55ha while the average livestock owned by farmers is about 0.8 TLUs.

Table 1. Definition of variables and summary statistics.

Variable	Description	Mean	Std. Dev.
Age	Head of household age (years)	51.43	16.97
Gender	1 if the head of household head is male, 0 otherwise	0.57	0.45
Education	Number of years of formal education	5.98	3.02
Household size	Total household size (number of persons)	5.14	2.33
Extension services	The frequency of extension contacts per year	29.75	18.68
Group membership	1 if the farmer is a member of a community group of farmers, 0 otherwise	0.72	0.40
Land tenure	1 if the land is owned by a farmer, 0 if rented	0.76	0.39
Credit access	1 if a farmer has access to credit, 0 otherwise	0.43	0.45
Farm size	Farmland under production (ha)	0.55	0.43
Livestock ownership	Amount of livestock owned in tropical livestock units (TLU)	0.80	0.68
Location dummy	1 if the farmer is located in Gakenke district, 0 in Kamonyi district	0.56	0.51
Drought stress	1 if drought occurred on the farm	0.34	0.29
Number of Observations		296	

Note: TLU across various categories of livestock are computed as: 0.7 for cows, 0.45 for heifers, 0.1 for goats, 0.1 for sheep, 0.01 for chickens, and 0.2 for pigs (Ngango and Hong, 2021).

3.2. Empirical results

Table 2 presents the results of the farmers' perception of the benefits of coffee–banana intercropping system. As Table 2 shows, about 67% of the farmers agreed that intercropping coffee with bananas would provide additional food and income from smallholders' limited land, while approximately 17% of the farmers disagreed with this statement. Farmers' perceptions on the benefits of coffee–banana intercropping system can also be indicated by the fact that about 74% and 70% of the farmers agreed that banana provides shading and in situ mulching materials for coffee, respectively. In aggregate, 65.6% of farmers in the sample agree that coffee–banana intercropping system is advantageous because it can improve the labor use efficiency. Around 43% of households in the study area stated that the shade

provided by bananas result into thicker cherries. Approximately 41% of the respondents perceive the coffee–banana intercropping system as a beneficial farming system because they can easily get animal feeds from banana stems.

Table 2. Farmers' perception of benefits of coffee–banana intercropping system: Summary statistics.

Benefits	Farmers' perception (%)				
	SA	A	N	D	SD
Cash and food from the same piece of land/increased income	26.3 (78)	40.9 (121)	16.2 (48)	8.9 (26)	7.7 (23)
Banana provides shading for coffee	29.0 (86)	45.3 (134)	11.82 (35)	8.8 (26)	5.1 (15)
Banana provides in situ mulching material for coffee	20.9 (62)	48.7 (144)	13.9 (41)	10.8 (32)	5.7 (17)
Coffee under shade gives thicker cherries	15.2 (45)	27.7 (82)	33.4 (99)	13.2 (39)	10.5 (31)
Improved labor use efficiency	30.8 (91)	34.8 (103)	18.9 (56)	9.8 (29)	5.7 (17)
Feed animals with banana stems	17.6 (52)	23.0 (68)	23.6 (70)	24.0 (71)	11.8 (35)

SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; figures in parentheses indicate frequencies.

Table 3 investigated the determinants of perception on coffee–banana intercropping system. In this regard, the ordered probit regression results show that variables such as age, education, land tenure, livestock ownership, and drought stress significantly increase the likelihood of perceiving the benefits of a coffee–banana intercropping system. However, farm size decreases the likelihood of perceiving the benefits of a coffee–banana intercropping system.

Table 3. Factors affecting the farmers' perception of the benefits of coffee–banana intercropping system: ordered probit regression estimates.

Variable	Coefficient	Std. error
Age	0.147*	0.098
Gender	0.043	0.051
Education	0.241**	0.134
Extension services	–0.065	0.187
Land tenure	0.468***	0.125
Farm size	−0.610***	0.373
Livestock ownership	0.152*	0.088
Location dummy	0.032	0.175
Drought stress	0.549***	0.114
/cut 1 (μ_1)	1.916***	0.572
/cut 2 (μ_2)	2.209**	1.138

/cut 3 (μ_3)	2.174***	0.992
/cut 4 (μ_4)	2.414***	0.998
Log likelihood	–253.602	
LR Chi-Square	48.367***	
Pseudo R^2	0.281	
Number of observations	296	

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regarding the determinants of adoption of coffee–banana intercropping system, the results from the maximum likelihood estimation of the binary logistic regression model are presented in Table 4. The results indicate that older farmers are more likely to adopt this farming system of intercropping coffee with bananas compared to younger farmers. A plausible explanation could be that older farmers are exposed to more information related to farming practices due to their political and social connections. This finding is consistent with the study of Amare et al., (2012) on intercropping maize and pigeon pea. Male farm household heads are less likely to adopt the coffee–banana intercropping system. Households with a large number of family members have a higher likelihood of adoption than those with few family members. Farmers who are members of community groups and/or cooperatives are less likely to adopt the coffee–banana intercropping system. A plausible explanation for this finding is that many farmers' cooperatives encourage their members to practice a mono-cropping system (Ngango & Kim, 2019).

Table 4. Determinants of adoption of coffee–banana intercropping system: binary logistic regression estimates.

Variable	Coefficient	Std. error
Age	0.214**	0.107
Gender	–0.377*	0.006
Education	0.073	0.091
Household size	0.154**	0.085
Extension services	0.515	0.568
Group membership	−0.439***	0.074
Land tenure	−0.630	0.744
Credit access	−0.576	0.188
Farm size	−0.243**	0.119
Livestock ownership	0.169	1.103
Location dummy	0.081	0.097
Drought stress	0.324***	0.065
Constant	−1.755**	0.021
Number of observations	296	

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Farm size is also a significant factor that determines the adoption of coffee–banana intercropping system. Our results in Table 4 show that farm size negatively affects adoption

decisions. This finding is consistent with the study of Teklewold et al. (2013). However, Ngango and Hong (2021) did not find similar results as their study indicated that farm size positively affects adoption decisions. Farms that have experienced drought stress are more likely to adopt the farming system of intercropping coffee with bananas than their counterparts that did not experience drought stress.

4. Conclusions and Implications

This paper used farm-level data collected from smallholder farmers producing coffee and banana in Gakenke and Kamonyi districts of the northern and southern provinces of Rwanda. The study analyzed the farmers' perception of the coffee and banana intercropping system and the determinants of adoption decisions. The farmers' perception of the coffee–banana intercropping system was estimated using an ordered probit regression model. On the other hand, we used the binary logistic regression model to examine the determinants of adoption of the coffee–banana intercropping system.

We examined farmers' perceptions of the coffee and banana intercropping system. The findings indicate that roughly 67% of the farmers agreed that intercropping coffee with bananas would provide additional food and income from smallholders' limited land. Moreover, in terms of farmers' perceptions of the benefits of coffee–banana intercropping system, 74% and 70% of the farmers agreed that banana provides shading and in situ mulching materials for coffee, respectively. The ordered probit regression results reveal that age, education, land tenure, livestock ownership, and drought stress variables significantly enhance the likelihood of perceiving the benefits of a coffee–banana intercropping system. With regard to the determinants of adoption of coffee–banana intercropping system, the results from the binary logistic regression model show that age, household size, and drought stress are the variables that significantly and positively affect the adoption decisions for the coffee–banana intercropping system. On the other hand, gender, group membership, and farm size decrease the likelihood of adopting the coffee–banana intercropping system. Our results imply the need for stakeholders along the coffee value chain to focus on the development of education programs in rural areas as well as awareness campaigns to remove barriers to acquiring information as one of the strategies to improve the adoption of coffee–banana intercropping system.

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