American Journal of Rural Development, 2023, Vol. 11, No. 1, 15-20
Available online at http://pubs.sciepub.com/ajrd/11/1/3
Published by Science and Education Publishing
DOI:10.12691/ajrd-11-1-3

Farmers' Adoption and Perceptions of Coffee and Banana Intercropping System in Rwanda

Jules Ngango*

Department of Economics, College of Business and Economics, University of Rwanda
*Corresponding author: ngajules2@gmail.com

Received September 04, 2023; Revised October 05, 2023; Accepted October 12, 2023

Abstract This paper examined farmers' perceptions of the benefits of intercropping with coffee trees and bananas and identified factors that determine the adoption decisions. The study used cross-sectional data collected from 364 farmers producing coffee and bananas in Rwanda. The analysis was done using descriptive statistics, chi-square test, ordered probit regression model, and binary logistic regression model. The Chi-square test indicates significant differences in farmers' perceptions about the benefits of coffee–banana intercropping system among adopters and non-adopters of the coffee-banana intercropping system. Adopters of the coffee-banana intercropping system have a significant marginally higher perception of the benefits of this cropping system. 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 the coffee–banana intercropping system.

Keywords: *Coffee–banana intercropping, perceptions, farming system adoption, smallholder farmers, Rwanda*

Cite This Article: Jules Ngango, "Farmers' Adoption and Perceptions of Coffee and Banana Intercropping System in Rwanda." American Journal of Rural Development, vol. 11, no. 1 (2023): 15-20. doi: 10.12691/ajrd-11-1-3.

1. Introduction

The agriculture sector in Rwanda and most parts of sub-Saharan Africa (SSA) is the most important economic activity employing more than 60% of the working population [1,2]. In particular, coffee and bananas 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 [3,4]. On the other hand, coffee is a primary cash crop harvested once or twice a year and contributes about 27% of total export revenue [5]. 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. On the other hand, Robusta coffee occupies the other leftover 5% where it is cultivated at lower altitudes below 1400 m in the Eastern Province [5]. The overall area under coffee production in Rwanda was estimated at 35,500 ha in 2022 [6]. Generally, coffee and bananas are predominantly grown in 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 costlier than intercropping systems [7].

More specifically, the coffee and banana intercropping system has been reported by [4] 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 [7]. 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 [8]. Although some intercropped systems may have strong competition for resources, the systems are credited with increased total biological productivity per unit area of land [4]. 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 [4]. Furthermore, [9] noted that intercropping coffee with shade plants is considered as a climate-smart agricultural practice due to the fact that reasonable shade cultivation improves the regulation of light, heat, water, soil, fertilizer, and other factors affecting crop growth, hence, providing a suitable growth environment for coffee.

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 the coffee and banana intercropping system will encourage the production of both crops and contribute towards improved food security and increased household income [8]. In addition, the International Coffee Organization (ICO) recommended that coffee-producing countries adopt farming systems of intercropping coffee with other shade crops to control for the issues of decreases in coffee prices [4].

The decision of farmers to adopt sustainable farming practices such as intercropping systems depends on their awareness, information, and knowledge of these practices [10]. Thus, investigating farmers' perceptions and knowledge of the benefits of coffee and banana intercropping systems can be useful in identifying the determinants of adoption [11]. However, the literature on farmers' perception and adoption of the coffee and banana intercropping system, particularly in Rwanda, is limited. In Uganda, [3] investigated the perceptions and outlook of smallholder coffee farmers on the opportunity of the coffee-banana intercropping system. They found that the 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. Similarly, [4] examined the agronomic and economic benefits of the coffee–banana intercropping system relative to the mono-cropped coffee farming system in Uganda. Their findings revealed that the coffee–banana intercropping system was much more beneficial than the coffee or banana mono-cropping system. This study examined farmers' perception of the benefits of coffee and banana intercropping system and identify the factors influencing the adoption decisions in Rwanda.

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. Farmers in these districts grow coffee and bananas as intercrop. A cross-sectional study was conducted in August 2021 and a multistage sampling procedure 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 364 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.

The study used a structured questionnaire involving personal interviews with farmers located in Gakenke and Kamonyi districts who adopted the coffee and bananas intercropping system and those who did not adopt it. The respondents were asked to provide information regarding the socio-economic, institutional, and farm-related characteristics such as age, gender, education, household size, extension services, group membership, land tenure, credit access, farm size, livestock ownership, location dummy, drought stress. Moreover, the structured questionnaire was designed to obtain the information concerning the farmers' adoption and perceptions of the benefits of coffee–banana intercropping system.

2.2. Analytical framework

2.2.1. Chi-square test

The study used the Chi-square (χ^2) test to examine and compare the farmers' perceptions about the role of intercropping coffee trees with bananas among adopters and non-adopters of coffee-banana intercropping system.

2.2.2 Specification of the logistic regression 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;

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

Typically, we assume that the decision of a farmer to adopt the coffee–banana intercropping system depends on the 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.

2.2.3. Specification of the Ordered Probit Regression Model

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. Some previous studies [12,13] have used the binary logit or

probit model to examine the factors influencing the farmers' adoption and perceptions 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:

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

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

$$y = 0 \text{ if } y^* \le 0$$

$$y = 1 \text{ if } 0 < y^* \le \mu_1$$

$$y = 2 \text{ if } \mu_1 < y^* \le \mu_2$$

$$\vdots$$

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

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:

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

where $\varnothing$ 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, $0 < \mu_1 < \mu_2 < \ldots \mu_{J-1}$.

3. Results and Discussion

3.1. Descriptive Analysis

About 57% of the households are headed by males. The average household size was approximately 5 members and it is 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 were members of cooperatives was 72% and the frequency of contact with extension agents was about 30 times per year. The average farm size under cultivation was 0.55ha while the average livestock owned by farmers was 0.8 TLUs. Concerning the access to credit, about 43% in the study area had access to credit. The summary statistics also indicate that approximately 34% of the farmers experienced drought in their farms in the last agricultural season.

Table 2 presents the results as it is with this particular item, of the farmers' perception of the benefits of coffee–banana intercropping system. As Table 2 shows, about 73.9% of the farmers agreed that intercropping coffee with bananas would provide additional food and income on smallholders' limited land, while approximately 26.1% of the farmers did not agree to that. The results also indicate that approximately 78% and 84.2% of the farmers agreed that banana provides shading and in situ mulching materials for coffee, respectively, while 22% did not agree that banana provides shading for coffee. Only 15.8% did not agree that banana provides in situ mulching material for coffee. In aggregate, 59.9% of farmers in the sample agree that coffee–banana intercropping system is advantageous because it can improve labor use efficiency. Around 58.2% of households in the study area stated that the shade provided by bananas results into thicker cherries. Approximately 81% of the respondents perceive the coffee–banana intercropping system as a beneficial farming system because they can easily get animal feed from banana stems.

Table 1. Respondents' socioeconomic institutional, and farm-level characteristics

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	Number 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 in the last agricultural season	0.34	0.29
Number of Observations		364	

Note: TLU across various categories of livestock is 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 [14].

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

Benefits	Farmers' perception (%)			
	Strongly agree	Agree	Disagree	Strongly disagree
Cash and food on the same piece of land/increased income	28.3	45.6	17.0	9.1
Banana provides shading for coffee	37.1	40.9	15.1	6.9
Banana provides in situ mulching material for coffee	40.4	43.8	8.5	7.3
Coffee under shade gives thicker cherries	20.0	38.2	11.3	30.5
Improved labor use efficiency	19.8	40.1	29.9	10.2
Feed animals with banana stems	37.6	43.4	14.3	4.7

Table 3. Chi-square test of whether adopters and non-adopters have different perceptions toward the benefits of the coffee–banana intercropping system

Variables		Number of households			
	Adoption of coffee–banana intercrop	Agree	Disagree	χ^2	p-value
Q1. Coffee–banana intercrop provides cash and food on the same piece of land, hence an increased income	Yes	226	21	8.150	0.007
	No	43	74		
Q2. Banana provides shading for coffee	Yes	143	40	1.117	0.352
	No	141	40		
Q3. Banana provides in situ mulching material for coffee	Yes	275	6	4.036	0.041
	No	31	52		
Q4. Coffee under shade gives thicker cherries	Yes	161	65	2.982	0.064
	No	51	87		
Q5. Coffee–banana intercropping system improves the labor use efficiency	Yes	190	19	8.865	0.003
	No	28	127		
Q6. Coffee–banana intercropping system helps farmers to get animal feed from banana stems	Yes	146	35	0.738	0.461
	No	149	34		

3.2. Chi-Square Test (χ^2) Analysis for Comparisons of Farmers' Perceptions About the Benefits of the Coffee–Banana Intercropping System Among Adopters and Non-Adopters

The chi-square test shows that four questions among the six questions that were designed in the structured questionnaire to capture the farmers' perceptions about the benefits of the coffee–banana intercropping system, exhibit a significant difference in responses between adopters and non-adopters. In particular, with regard to the first question which is related to increased income and food, Table 3 shows that a significantly higher proportion of adopters agreed that coffee–banana intercropping system provides cash and food on the same piece of land, hence an increased income ($\chi^2 = 8.150$, $p = 0.007$). Regarding the questions related to the perceptions of farmers toward the benefits of providing in situ mulching material and thicker coffee cherries, a significant difference was found in farmers' responses, implying that adopters of coffee–banana intercropping system have a significantly better perception of the benefits of this cropping system.

3.3. Determinants of Perception of Coffee-Banana Intercropping System

This study modeled the factors that determine farmers' perception of the benefits of coffee–banana intercropping system using the ordered probit regression model. The estimates of the ordered probit regression model are reported in Table 4. The 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. This finding corroborates the findings of [15] and [16], who acknowledged the significance of socio-demographic and farm characteristics in influencing farmers' perceptions of coffee intercropping systems in Burundi and Uganda. However, the results reveal that farm size decreases the likelihood of perceiving the benefits of a coffee–banana intercropping system.

3.4. Determinants of adoption of coffee-banana intercropping system

Table 5 indicates 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 [17] 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 [5].

Farm size is also a significant factor that determines the adoption of coffee–banana intercropping system. Our results in Table 5 show that farm size negatively affects adoption decisions. This finding is consistent with the study of [18]. However, [14] 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.

Table 4. Factors affecting the farmers' perception of the benefits of coffee–banana intercropping system

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	364	

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

Table 5. Determinants of adoption of coffee–banana intercropping system

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	364	

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

4. Conclusions and Recommendations

The findings indicate that roughly 73.9% of the farmers agreed that intercropping coffee with bananas would provide additional food and income on the smallholders' limited land. Moreover, 78% and 84.2% of the farmers agreed that banana provides shading and in situ mulching materials for coffee, respectively. 58.2% of the respondents stated that the shade provided by bananas offers thicker coffee cherries, while 81% of the respondents perceive the coffee–banana intercropping system as a beneficial farming system that helps to get animal feeds from banana stems. The Chi-square test revealed a significant difference in farmers' perceptions about the benefits of intercropping coffee trees with bananas among adopters and non-adopters of coffee-banana intercropping system. Particularly, the results indicated that a significantly higher proportion of adopters agreed that coffee–banana intercropping system has the benefits of providing cash and food on the same piece of land, in situ mulching material, thicker coffee cherries, and an improved labor use efficiency. These findings imply that adopters of coffee–banana intercropping system have a significantly good perception of the benefits of this cropping system.

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.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the National Agricultural Export Development Board (NAEB) in data collection.

Statement of Competing Interests

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M. Amare, P. Parvathi, and T. T. Nguyen, "Micro insights on the pathways to agricultural transformation: Comparative evidence from Southeast Asia and Sub-Saharan Africa," *Can. J. Agric. Econ. Can. d'agroeconomie*, vol. 71, no. 1, pp. 69–87, Mar. 2023.

[2] V. Nsengimana, J. de Dieu Nsenganeza, T. Hagenimana, and W. Dekoninck, "Impact of chemical fertilizers on diversity and abundance of soil-litter arthropod communities in coffee and banana plantations in southern Rwanda," *Curr. Res. Environ. Sustain.*, vol. 5, p. 100215, 2023.

[3] L. Jassogne, P. J. A. van Asten, I. Wanyama, and P. V Baret, "Perceptions and outlook on intercropping coffee with banana as an opportunity for smallholder coffee farmers in Uganda," *Int. J. Agric. Sustain.*, vol. 11, no. 2, pp. 144–158, May 2013.

[4] P. J. A. van Asten, L. W. I. Wairegi, D. Mukasa, and N. O. Uringi, "Agronomic and economic benefits of coffee-banana intercropping in Uganda's smallholder farming systems," *Agric. Syst.*, vol. 104, no. 4, pp. 326–334, 2011.

[5] J. Ngango and G. S. Kim, "Assessment of Technical Efficiency and Its Potential Determinants among Small-Scale Coffee Farmers in Rwanda," *Agriculture*, vol. 9, no. 7. p. 161, 2019.

[6] FAOSTAT, "Food and Agriculture Organization of the United Nations.," 2022. https://www.fao.org/faostat/en/#data/QCL

[7] C. Sebatta *et al.*, "Pathways to sustainable intensification of the coffee-banana agroecosystems in the Mt. Elgon region," *Cogent Food Agric.*, vol. 5, no. 1, p. 1611051, Jan. 2019.

[8] P. J. A. van Asten, D. Ochola, L. W. I. Wairegi, A. Nibasumba, L. T. P. Jassogne, and D. Mukasa, "Coffee-Banana Intercropping: Implementation guidance for policymakers and investors. Climate-Smart Agriculture Practice Brief. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).," 2015.

[9] K. Hao *et al.*, "Optimizing shade cultivation method and irrigation amount to improve photosynthetic characteristics, bean yield, and quality of coffee in a subtropical monsoon climate," *Front. Plant Sci.*, vol. 13, 2022.

[10] J. Manda, A. D. Alene, C. Gardebroek, M. Kassie, and G. Tembo, "Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia," *J. Agric. Econ.*, vol. 67, no. 1, pp. 130–153, 2016.

[11] S. Rahman, "Farmers ' perceptions of integrated pest management (IPM) and determinants of adoption in vegetable production in Bangladesh," *Int. J. Pest Manag.*, 2020.

[12] M. H. Kabir and R. Rainis, "Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an approach to sustainable agricultural development," *Environ. Dev. Sustain.*, vol. 17, pp. 1413–1429, 2015.

[13] N. L. Ntshangase, B. Muroyiwa, and M. Sibanda, "Farmers ' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke , KwaZulu-Natal Province," *Sustainability*, vol. 10, p. 555, 2018.

[14] J. Ngango and S.-J. Hong, "Speed of adoption of intensive agricultural practices in Rwanda: A duration analysis," *Agrekon*, vol. 60, no. 1, pp. 43–56, 2021.

[15] S. Ndihokubwayo *et al.*, "Farmers' Perception of Coffee Agroforestry Systems in an Area Targeted for Organic Certification in Burundi," *East African J. For. Agrofor.*, vol. 3, no. 1, pp. 40–53, 2021.

[16] S. Mpiira, M. Kipsat, P. Mose, F. Kalyango, W. Tushemereirwe, and C. Staver, "Farm diversification benefits and technology choice: A case of the coffee-banana farming system in Central Uganda," *African J. Agric. Res.*, vol. 19, no. 1, pp. 48–60, 2023.

[17] M. Amare, S. Asfaw, and B. Shiferaw, "Welfare impacts of maize–pigeonpea intensification in Tanzania," *Agric. Econ.*, vol. 43, no. 1, pp. 27–43, 2012.

[18] H. Teklewold, M. Kassie, B. Shiferaw, and G. Köhlin, "Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor," *Ecol. Econ.*, vol. 93, pp. 85–93, 2013.

© The Author(s) 2023. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).