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Research Article

Adoption of Coffee Technologies: A Multivariate Probit Model

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Abstract

The sector of agriculture in Ethiopia is a source of livelihood for over 80% population residing in rural areas. It contributes about 50% to the national value of production. The country has huge potential to increase coffee production as it endowed with suitable elevation, temperature, and soil fertility, indigenous quality plantation materials, and sufficient rainfall in coffee growing belts of the country. Adoption of improved coffee varieties and recommended coffee management practice together have a significant effect on annual coffee production. The study was aimed to see the adoption rate and intensity of coffee technologies which are improved coffee Varity and coffee management practice, determinant of adoption of coffee technologies in Jima zone south western Ethiopia. A total of 196 sampled households from three woreda in the zone and 430 plots of 196 farmers household is considered in the survey. The study develops a multivariate probit model econometric model of farmers' choice of combination of coffee technologies. And two primary results were found. First, adoption rate and intensity of Improved coffee variety is greater than adoption of coffee management practice. Secondly adoption of coffee technologies determined by many institutional, resource and other related factor. This implies that policy makers and other stakeholders promoting a combination of technologies can enhance coffee yield through reducing production costs and decreasing coffee vulnerability to disease.

Keywords

Adoption, Coffee Technologies, Multivariate Probit Model

1. Introduction

1.1. Background of the Study

Ethiopia has huge potential to increase coffee production as it endowed with suitable elevation, temperature, and soil fertility, indigenous quality plantation materials, and sufficient rainfall in coffee growing belts of the country. Coffee is a shade-loving tree. It grows well under the large indigenous trees such as the Cordia Abyssinica and the Acacia species, in two regions of the country Oromiya and southern nation nationality and people regional state. In the country smallholder farmers on less than two hectares of land produces and supply Ninety-five percent of Ethiopia's coffee produces, while the remaining five percent grown on modern commercial farms [11, 12].

In Ethiopia, 764863.16 ha of land was allocated for coffee

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production and 494574.36 tones were obtained with average productivity of 0.64 tones ha-1 in 2018/19 Meher Season from which 30% of the total production belongs to South Nation Nationalities and Peoples Regional State (SNNPR). From top 25 coffee producing districts in Ethiopia, Oromia dominates with 18 coffee producing districts and the remaining top coffee producing districts are located in South Nations, Nationalities and Peoples Regional State [7]. Coffee land coverage and dependency of smallholder farmers on coffee is high especially in southwest Ethiopia. [3], found that the share of coffee income from total income in coffee producing districts of Jimma zone is 77%. On other hands, share of land allocated to coffee crop in these areas is more than 69%.

More than 120 Ethiopian Coffee exporters participated in processing and exporting coffee to all destination of the world. Among these export companies 95% are private companies 5% are Coffee growing farmers' cooperative unions and two of them are government enterprises in 2010/11 the top five coffee export destinations for the country are Germany, United stat of America, Saudi Arabia, Belgium and Italy [7]. The country produces almost 200,000 metric tons of coffee every year. 95% of the coffee is produced in the forest area and is claimed to be organic. A major part of the Ethiopian coffee is exported in green coffee beans form, to the Rest of the World.

This study was designed to explore factors limiting adoption of coffee production technologies, constraints related to coffee production, relative benefits of coffee technologies on coffee annual yield among adopters of the improved technologies. The result of the study could be helpful for coffee related biological and physiological researchers, and policy makers.

In general, different packages of coffee production, protection and processing technologies have been promoted to beneficiaries since long period of time. Several institutions were also involved in disseminating these technologies through various extension approaches. However, there is no adequate information on demand for new coffee production and processing technologies and adoption by smallholder farmers in different agro-ecologies of Jimma zone. Moreover, the impacts of the technologies on the coffee annual yield are not adequately addressed and documented for different categories of households. Therefore, this study is focused to fill these gaps and generate information on the status of demand, adoption and impacts of coffee production technologies at smallholder levels.

1.2. Statement of the Problem

Ethiopia has not yet fully exploited its position as the producer of some of the best coffees in the world. Coffee sector is highly dependent on international prices and affected by the structure and workings of the world coffee market. Ethiopia is one of the countries mostly affected by the crisis in world coffee prices [2].

The productivity of coffee is very less, not more than 6 qt/ha. To improve the productivity of coffee and enhance farmers' on-farm incomes, the national agricultural research system has generated and disseminated more than 30 improved coffee varieties and associated production packages. These technologies were promoted and disseminated to coffee producers through various mechanisms, such as demonstrations, seed distribution and farmer-to-farmer technology exchange mechanisms. Various development actors have also participated in the promotion and dissemination of coffee production technologies since the last decades. Some of the institutes engaged in dissemination of coffee production technologies included Jima Agricultural Research Center, Offices of Agriculture, and another institute.

Coffee diseases cause considerable losses when not treated. According to Cerda et al (2017) [2], 57% yield loss was observed by the infection of disease-causing organisms on coffee crop also reported that the most economically important pathogenic coffee diseases are coffee berry disease (CBD), coffee wilt disease (CWD) and coffee leaf rust (CLR), and physiological disorder like coffee branch die back is caused by pseudomonas syringe and non-pathogenic agents. Similarly, CBD and branch dieback were causing high yield loss of coffee production. In the same way, insect pests such as Anthestia bug and coffee blotch miner are the major ones causing considerable damage. The assessment carried out in Eastern Ethiopia indicated that diseases and insect pests are causing considerable crop losses. CBD is major disease observed while CWD was considered as minor on few farmers' coffee farms. Similarly, major insect pest that affects coffee production in Eastern Ethiopia were coffee stem borer and coffee berry borer. On the other hand, insect pests such as coffee trips, green scale and coffee cushion scale were reported as important coffee production constraints in the country [6].

Low production and productivity, which are mainly associated with poor adoption of recommended coffee technologies, were among the major problems. Adoption of improved technologies is one of the most promising ways to increase productivity and production in Ethiopia [9]. Farmers are facing challenges, including increasingly erratic rainfall, rising temperatures, poor management of coffee trees, fluctuation of coffee prices and degradation of soil, that are adversely affecting their income opportunities the country's coffee production. Coffee production and productivity was used to develop appropriate technology for improvement and inform policy makers to understand the gap. However, the adoption and dissemination of these technologies is constrained by various factors. Different studies have been conducted on adoption of coffee technology in Ethiopia [3, 4, 5, 8]. Most of these researches focus only on factor affecting adoption of coffee variety and few research was conducted on the determinant of adoption of the coffee technologies this research is designed to determine adoption rate of improved coffee vari-

eties and associated packages of technologies. Moreover, the study will explore factors limiting adoption of coffee production technologies.

However, this study will examine the adoption level coffee Varity and agronomic practice also evaluate the impact of coffee variety and coffee agronomic practice and their impact in coffee yield. Thus, this study will fill the existing knowledge gap by assessing adoption and impact of coffee technology and impact on yield in Jimma zone taking with Mana, Gomma and Limu kosa district as a case study.

The findings of the study will help for coffee breeders to understand the key factors which determine farmers' preferences to improved coffee varieties. In their future breeding program, the coffee breeders will consider the influencing factors and merits which the farmers expect to exist on improved coffee varieties. In addition to this, extension service providers will get adequate information on the extent to which technology promotion and extension service provision mechanisms utilized so far worked or not. It will also provide information on the types of technology dissemination mechanisms which were effective in reach out to the farmers. Policy makers will also get information on the social, economic and environmental factors which determined the adoption of coffee production technologies, to identify constraints and opportunities related to coffee production, relative benefits of coffee technologies on coffee annual yield among adopters of the improved technologies. The result of the study could be helpful for coffee related biological and physiological researchers, policy makers and finally for the farmers.

1.3. Description of the Study Area

Jimma is a zone in Oromia State of Ethiopia. Jimma is named after former Kingdom of Jimma, which was absorbed into the former province of Kaffa in 1932. The highest point in this zone is Mount Maigudo (2,386 m). Towns and cities in Jimma include Agaro, Limmu Inariya and Saqqa. The town of Jimma was separated from Jimma Zone and is a special zone now. Based on the 2007 Census conducted by the CSA, this Zone has a total population of 2,486,155, an increase of 26.76% over the 1994 census, of whom 1,250,527 are men and 1,235,628 women; with an area of 15,568.58 square kilometers, Jimma has a population density of 159.69. While 137,668 or 11.31% are urban inhabitants, a further 858 or 0.03% are pastoralists. A total of 521,506 households were counted in this Zone, which results in an average of 4.77 persons to a household, and 500,374 housing units. It has a latitude and longitude of 7°40′N 36°50′E. Prior to the 2007 census.

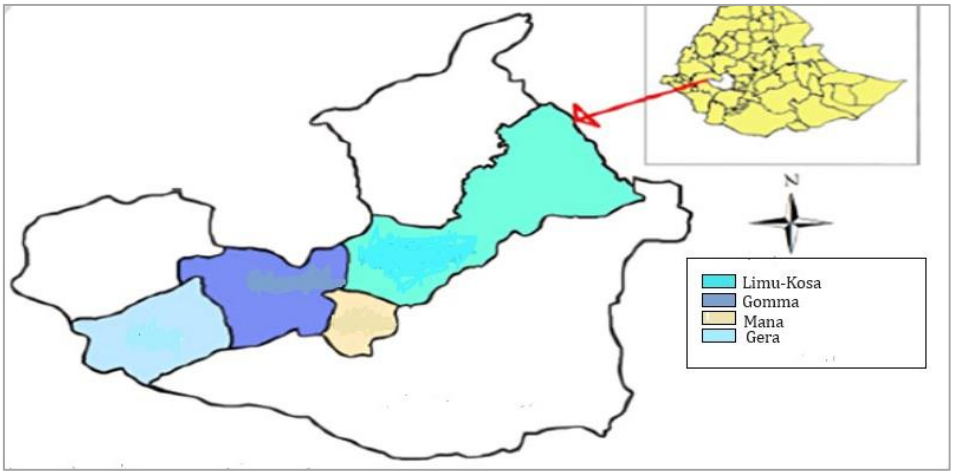

Figure 1. *Map of the Study Area.*

2. Methods of Data Collection

The study was based on the cross-sectional data set. It was collected using both qualitative and quantitative data collection tools. The quantitative data collection tool was used to collect data from representative households through administrating an independent structure questionnaire (both close and open-ended questionnaire) to the producer personal interview. Before the Formal data collection structured questionnaires were pretested on the ground and modified accordingly. As far as the qualitative data collection tools are concerned, they were key informant interview, individual in-depth interview and focus group discussion. FGD was made with coffee producers. Key informant was purposively selected and interviewed who works in the area related to coffee production.

2.1. Sampling Techniques

Both primary and secondary data was collected and used to investigate the problems. Primary data like farmers specif-

ic characteristics resource factor and other data collected service provided by the experts and other were collected from the respondents by using interview with questionnaire and the survey were held by using designed CSPro software and secondary data were collected from different information sources like experts in the zone and district, previous studies and others.

2.2. Sample Size

The dataset used for this study is based on a farm household survey conducted in Ethiopia during October–December 2022 by the Ethiopian Institute of Agricultural Research (EIAR). A multistage sampling procedure was employed to select peasant district from the zone. First, based on their coffee production potential, three or four kebele from each district were selected then based on proportionate random sampling after selecting a potential district by a simple probability sampling techniques 12 to 16 household in each kebele were selected.

2.3. Data Analysis

Econometric Analysis

Agricultural research has generated packages of coffee production technologies, including: improved coffee varieties, recommended spacing, Stumping and pot seedling practices. These technologies were promoted and disseminated to beneficiaries through various channels of extension services. Hence, this have created an opportunity for smallholder farmers to make a decision and choose available coffee production technologies. Among the various improved coffee varieties, the farmers may decide to choose either one or more to get more yield and to minimize coffee vulnerability to diseases considering the possibility of simultaneous choice of outlets and the potential correlations among the choices multivariate probit model is believed to be appropriate and will be employed in this study. The model simultaneously sets out the influence of a set of explanatory variables on choice of coffee technology, while allowing for the potential correlations between unobserved disturbances as well as the relationship between the coffee technologies.

The selection of coffee technology *k* by farmer *i* is Y_{ki}^{A} defined as the choice of farmer i to adopt coffee technology k ($Y_{ki}^{A} = 1$) or not ($Y_{ki}^{A} = 0$) is expressed as follows

$$Y_{ki}^{A} = \begin{cases} 1 \; if \; \beta kiXki + \varepsilon i^{A} \geq 0 \\ 0 \; if \; \beta kiXki + \varepsilon i^{A} < 0 \end{cases} \quad (1)$$

Where β_{ki} is a vector of estimators, εi^{A} a vector of error terms under the assumption of normal distribution, Y_{ki}^{A} Dependent variable for adoption of coffee technology simultaneously and X_{ki} combined effect of the explanatory variables. Therefore, econometric models of determinants of adoption of coffee technology of farmer will be specified as

$$\text{Coffee variety i} = X_1\beta_1 + \varepsilon^{v}$$

$$\text{Coffee mgt practice i} = X_2\beta_2 + \varepsilon^{m}$$

Where, coffee variety *i*, coffee proper management practice as per recommended *i*, are binary variables taking values 1 if farmer i selects coffee variety, management practice properly and 0 otherwise; X_1 to X_2 are vector of the same set of explanatory variables x for each outlet; β_1 to β_2 a vector of parameters to be estimated for each outlet and ε disturbance term for each outlet.

In multivariate probit model, the use of several coffee technologies simultaneously is possible and the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity and ρ_{ki} represents the correlation between endogenous variables [1] given by

$$\begin{pmatrix} \varepsilon^{v} \\ \varepsilon^{m} \end{pmatrix} \qquad N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}\begin{pmatrix} 1 & \rho_{12} \\ \rho_{21} & 1 \end{pmatrix}\right] \quad (2)$$

$$E(\varepsilon/X) = 0$$

$$var(\varepsilon/X) = 1$$

$$cov(\varepsilon/X) = \rho$$

Fitting the multivariate probit model involves estimating the values of β1 β2 and p. To do so, the likelihood of the model has to be maximized. This likelihood is ρ_12.

3. Result and Discussion

3.1. Adoption Rate of Coffee Technologies

Rogers, E. M. et al. [10] defined the rate of adoption as "the relative speed with which an innovation is adopted by members of a social system" (p. 221). For instance, the number of individuals who adopted the innovation for a period of time can be measured as the rate of adoption of the innovation. The perceived attributes of an innovation are significant predictors of the rate of adoption. Rogers reported that 49-87% of the variance in the rate of adoption of innovations is explained by these five attributes. In addition to these attributes, the innovation-decision type (optional, collective, or authority), communication channels (mass media or interpersonal channels), social system (norms or network interconnectedness), and change agents may increase the predictability of the rate of adoption of innovations. For instance, personal and optional innovations usually are adopted faster than the innovations involving an organizational or collective innovation-decision. However, for Rogers, relative advantage is the strongest predictor of the rate of adoption of an innovation.

As seen in the graph below the adoption rate of coffee

technologies was very low for the management practice only 28% of the sampled household was slash 3 times a year and for improved coffee variety 52% of the sampled household adopt an improve coffee variety.

3.2. Adoption Intensity of Coffee Technologies

According to [10] the innovation-diffusion is "an uncertainty reduction process" (p. 232), and he proposes attributes of innovations that help to decrease uncertainty about the innovation. Attributes of innovations includes five characteristics of innovations relative advantage, compatibility, complexity, trialability and observability. [10] stated that "individuals' perceptions of these characteristics predict the rate of adoption of innovations" (p. 219).

As investigated in this research the adoption intensity of the zone was shown in the figure 4 below as shown in the graph out of 329.64ha of land around 205.13ha of land which was around 62% of the total land was covered by an improved coffee variety. The types of the coffee Variety which was used by the farmers due to different variety attributes is shown in the pie below according to this 44% of the farmers didn't know the name of the variety even though the variety is improved 13% of the farmers know the name of they used 74110 which is released in 1974 Gregorian calendar the prefix 74 before the name of the variety stands for the released year the variety 74110 is a preferable improved variety which is chosen due to the relative advantage which means according to center profile of Jima agricultural research center it give 9-10 qt of coffee in hectare of land which is greater than the local variety 3qt/ha. The other 32% of the farmers uses a local coffee Varity due to different reason like inaccessibility of seedling, lack of information and other factors the other 11% of the farmers use 7440 (0.22%), 7464 (1.12%), 7487 (1.34%), 74140 (1.56%), 74158 (1.11), 74165 (0.67%) catimor-J19 (0.67%), Gawe (0.89%), mansibu (0.89%), merdachero (0.44%), yachi (0.44%), 74112 (0.44%), angefa (0.44%) and wush wush (0.44%), varieties.

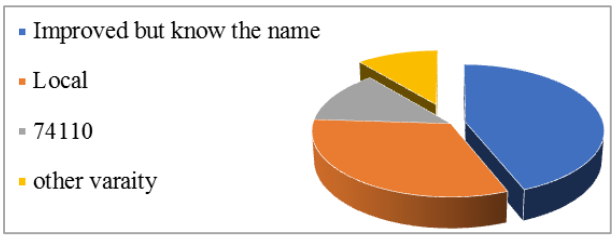

Figure 2. *Types of local and improved seedling the farmers use.*

Farmers have different source of seedling like government, cooperatives, research centers, NGO and other seedling providers the figure 3 below shows the farmers primary source of seedling in production of coffee. As seen in the graph below the farmers' major seedling source was the government agricultural extension center and the next high source of the farmers source was the farmers own propagation and cooperatives NGOs and other source like research centers provide a minor amount for the farmers.

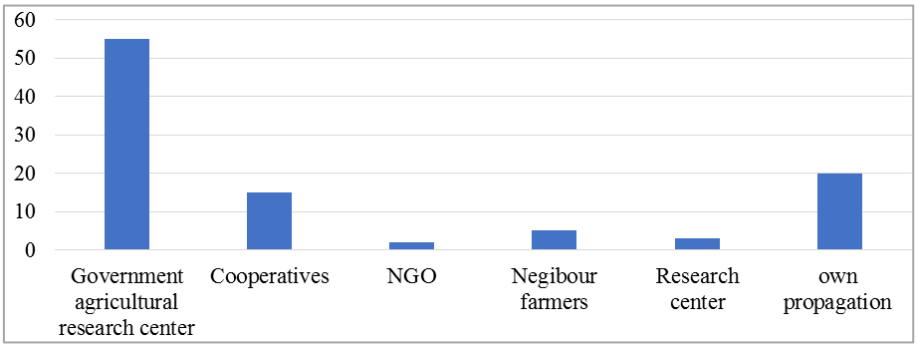

Figure 3. *Farmers seedling source.*

Proper management practice throughout the year is the other innovation that is recommended for productive coffee growing because it minimized the coffee competing plants and will allow the coffee to get resource easily but the process of slashing have high cost it may take 2 or 3 days for 1 hectare of land with 10 peoples and 80-birr wage rate due to this the farmers face budget constraints and can't handle it for management practices per year more than 60% of the farmers slash their coffee land 2 times per year only 27 percent of the farmers slash 3times per year, which is 89ha out of total land.

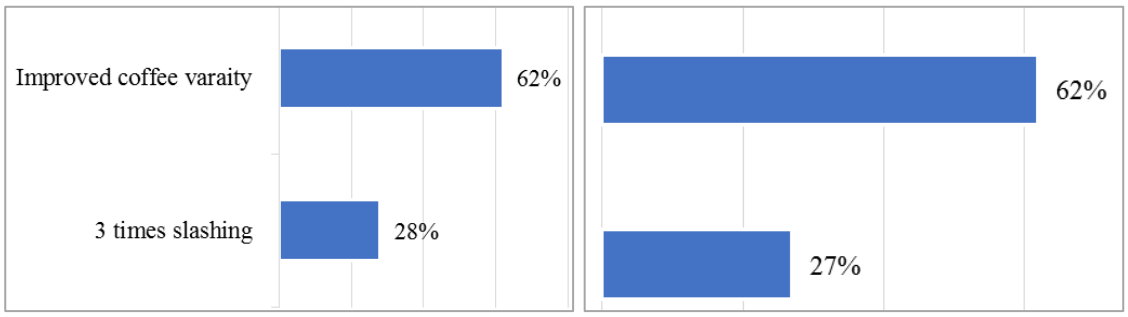

Figure 4. Adoption rate and adoption intensity in the zone.

3.3. Diseases and Pests' Farmers Face

In the zone the farmers face different diseases and pests that affect the production of coffee as seen in the figure below coffee berry and coffee wilt diseases are among the diseases that the farmers face highly in addition to those diseases root rot were 9.4% of the farmers problem. In addition to the disease the farmers affected by different kinds of weeds these weeds include broad leave weed a problem for 45% of the farmers' grassy weed a problem for 21.8% of the farmers and a parasitic weed is among the weed that affect farmers field and had a strass on the farmers. The level of stress due to those disease and weed in the farmers land was different but the level of strass due to weed were very high for more than half of the farmers.

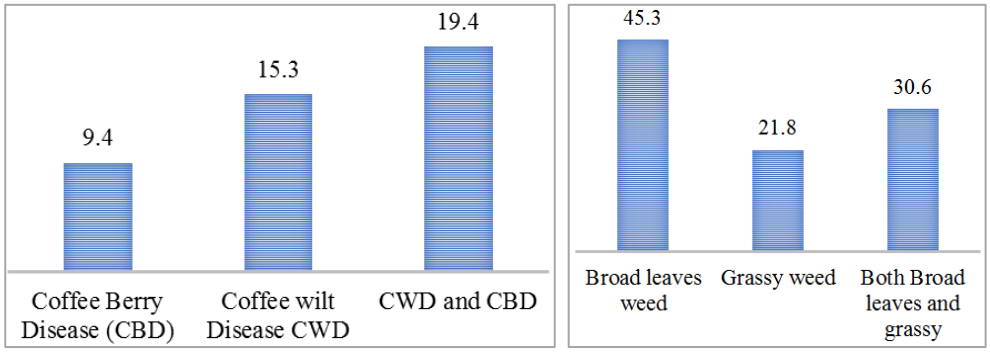

Figure 5. Coffee diseases and weed shown in the farmer's plot.

The level of stress the farmers face in their field due to those disease pests for more than 51% of the farmers were high. The major control measures the farmers uses to disease were cultural methods like uprooting, fumigation burn and replacing the coffee with other variety were the main major to controlling mechanisms but 49% of the farmers did nothing to control the diseases this may due to the fact that lack of knowledge about the spread of diseases. In relation to weed the level of stress the farmers face was high for more than 70% of the farmers as seen in the graph above broad leaves weed are the major cause of stress the farmers face in their coffee land the types of control measure the farmers uses to control those weeds were slashing regularly and digging of their land a minor farmer uses a chemical to control weeds. Only 2% of the farmers uses a chemical to minimize the stress in their coffee land the main problem in using chemical to control the disease and weed are those chemicals are lowering the test of organic coffee and limit its competitiveness to the international market.

3.4. Major Constraints That Limit Famers Adoption of Coffee Technologies

Beside the importance of coffee technologies there were a number of constraints the farmers faces to Adopte coffee technologies from the sampled survey the result show that for the adoption of improved coffee variety the constraints were the reason related to limited supply of improved coffee variety it accounts for 38.71% of the farmers challenges to adopt it in addition to the supply challenges lack of capital and need inputs was the second constraints the farmers faces it is about 19.45% of the farmers problem 24.98% was lack of information and knowledge on seedling propagation and the importance of improved seedling for the 15.94% farmers land shortage was the problem. For the second technology which is weeding three times a year the major problem for the farmers to adopt those new technology was the problem because now adays the per diam payment for the laborer is 80birr/day.

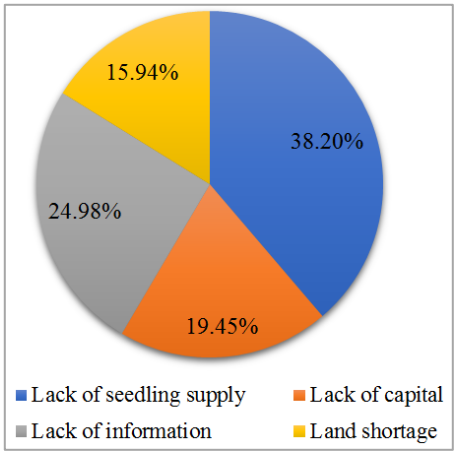

Figure 6. *Constraints related to adoption of improved coffee variety.*

From the FGD data the result showed that nowadays planting coffee is not a profitable business. As they mentioned regarding to the favorable agroecology the environments had to other plant like chat and other fruit many farmers start replace coffee with other perennial crops like chat this is due to 3 major reason there are the low price of coffee in the market, weak linkage of coffee value chain actors in coffee and selfish broker the second reason is now adays planting chat is more profitable and have a good market access and lastly the disease and pests as seen above in figure 6 above is high in coffee land due to those fact the farmers are compel to replace coffee with chat.

4. Conclusion: Determinant of Adoption of Coffee Technologies

1) *Experience household head in coffee farming:* The total experiences of the farmer specially related to coffee farm experience is expected to affect the decision of adopting modern agricultural technology positively as shown in the table below. It is measured by number of years of the farm household head and hence continuous variable.
2) *Gender:* Most agricultural input decisions in Ethiopia are influenced by decision of the male household heads. Hence it is expected to affect the adoption decision of farm households. It is a dummy variable taking 1 for male and 0 for female (male=1 and female= 0, for this study) as shown in the table below female headed household are more likely to manage their coffee field.
3) *Education level of the household head:* It is well expected that farmers with more education are aware of more information, and be more efficient in evaluating and interpreting information about innovations than those with less education. Thus, it is hypothesized that producers with more education are more likely to be adopter coffee management practice than farmers with less education. It is measured by number of years of schooling of the head of the households and hence a continuous variable.
4) *Total farm income:* Total farm income represents the amount of income the farmers earn in the year. It is the amount of income (in Birr) generated from both off farm and on farm activity. These include petty trading, charcoal selling, firewood selling and livestock and crop production. It is expected that the availability of annual household income is positively related with adoption decision both improved coffee Varity and coffee management practice.
5) *Asset owned:* It is continuous variable which is expected to affect the decision of the farm households positively. This is because as the asset becomes larger the household gets more money and materials and equipment to practice the new technology of production. As shown in the table below asset ownership affects farmers decision on adoption of improved coffee Varity.
6) *Extension service*: Extension service will help the farm households to understand the importance of the modern technology and enhance the accuracy of implementation of the technology packages. More frequent DA visits, using different extension teaching methods like attending demonstrations and field day can help the farmers to adopt a new technology. If the farmers get better extension services, they are expected to adopt seed production technologies than others. In this study this variable was treated as a dummy variable. That is if the farmers get extension service it is a continuous variable which is measured the total number of days the extension worker contact with the household head.
7) *Membership to cooperatives:* Farmers may obtain information from different source and may learn also from cooperative. Cooperatives in rural part of the country are mainly source of seedling, credit and other resources. It is dummy variable measured as 1 if farmers are member to cooperatives and 0 otherwise.

Table 1. *A Multivariate Analysis Result of Adoption of Coffee Technologies.*

	Coffee Varity		**Coffee Management Practice**	
	Coef.	**Std.Err.**	**Coef**	**Std Err**
Age of HH head	-0.009	0.008	0.007	0.008

	Coffee Varity		Coffee Management Practice	
	Coef.	Std.Err.	Coef	Std Err
Sex of HH head	-0.571	0.437	-1.014*	0.592
Number of Family size	0.007	0.050	0.058	0.050
Experience in coffee farming	0.036***	0.009	0.032***	0.011
Education level of HH head	0.016	0.019	0.055***	0.026
Total livestock owned	0.001	0.006	0.006	0.006
Total Asset owned	0.000***	0.000	0.000	0.000
Total land owned	0.119	0.091	0.081	0.064
Annual HH income	0.000**	0.000	0.000***	0.000
Walking distance to MKT	-0.098**	0.040	-0.052	0.044
Walking distance to FTC	-0.025**	0.010	-0.005	0.008
Number of Extension contact	0.042***	0.013	0.024***	0.009
Credit utilization	0.274	0.244	-0.020	0.232
Membership to cooperative	0.490*	0.213	0.489**	0.216
_cons	-6.340	2.292	-11.692	2.322
/atrho21	1.082	0.165	6.560	0.000
rho21	0.794	0.061	13.020	0.000

Conflicts of Interest

The Autor declares no conflict of interest.

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