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REGULAR ARTICLE

DETERMINANTS OF MULTIPLE GROUNDNUT TECHNOLOGY ADOPTION IN EASTERN ETHIOPIA

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ABSTRACT

This research analyses factors that influence the adoption of combination of improved groundnut seed, inorganic fertilizer, and organic fertilizer in eastern Ethiopia using a cross sectional data collected from 300 sample groundnut farming households. Multivariate probit and ordered probit models are used to identify factors affecting adoption of multiple technologies. Tobit model is used to spot the determinants of intensity of adoption of improved seed. The results show a strong correlation between improved seed and inorganic fertilizer adoption, indicating the simultaneous adoption decision of farmers. Age of the household head negatively affects the adoption decision of improved seed while education, groundnut farming experience, extension contact, training and plot size are positive contributors.

Keywords: adoption, technology mix, groundnut, Ethiopia
JEL: I32, Q12, Q18, Q16, Q58

INTRODUCTION

Food insecurity has been the major bother of the Ethiopian people for a very long time. Despite the efforts made by the government and many NGO's, a significant proportion of the Ethiopian population is still living under extreme poverty, under-nutrition, food insecurity and hunger. Most of the poor people live in the rural areas, depending mainly on risk prone agriculture. Due to this fact, focus has been given to the sector by the government for about twenty five years and some encouraging results have been achieved. However, there is still a lot to be done with regards to nutrition security.

Groundnut also known as peanut is a nutritionally dense legume that could contribute to the food and nutrition insecurity of many poor countries (**Ustimenko-Bakumovsky 1983**). It is the fourth most used source of edible oil in the world and a very important source of vegetable protein (**Govindaraj *et al.* 2009; Upadhyaya *et al*. 2010**). Unfortunately, unlike many other countries in Africa, the consumption of groundnuts in Ethiopia is very low especially in non-producing areas. In the cities, in addition to its oil, groundnut butter is the most popular form of consumption followed by a mix of roasted sorghum and groundnuts snack. In East Harerghe, it is consumed as a stew, complement to chat, and snack on the roasted nuts.

Groundnuts have multiple advantages; since they are in the legume family, they contribute to soil fertility, reduce cost of fertilizer, generate income to farm households and increase the nutrition diversity. In addition to this, it doesn't require a lot of moisture to grow, making it an ideal choice for farmers in moisture stressed areas (**Hagos *et al.* 2012**). To bring the benefit of such an important crop to an optimum point, it is vital to improve and disseminate the existing technology, farmers have (**Nega and Sanders 2006; Feleke and Zegeye 2006; Asfaw*et al.* 2012; Teklewold *et al.* 2013 and Getacher *et al.* 2013**).

Although technology adoption is one of the most researched areas in Ethiopia (e.g. **Ahmed 2015; Tura *et al.* 2010; and Getacher *et al.* 2013, Wolka 2014**), most of them emphasized cereals and very few studies have looked at adoption of groundnut technologies. In addition to this, most of the studies focused on the adoption of technologies in isolation by ignoring the fact that farmers adopt multiple technologies as complements, substitutes or supplements to address multiple constraints faced by farmers including weeds, pest and disease infestations, and low soil fertility (**Moyo and Veeman 2004**). This study analyses factors that affect the adoption of multiple Groundnut technologies and the determinants of the intensity of improved groundnut seeds in Eastern Ethiopia.

DATA AND METHODS

Description of the study area

Eastern lowland areas of Ethiopia are known for groundnut production. Particularly Babile, Fedis and Gursum are the major producers of groundnuts for local and commercial consumption (**Chala *et al*. 2012**). Groundnut is planted on 8630, 1250 and 5340ha of land in Babile, Fedis and Gursum areas respectively in 2014.

Babileis classified into *woinadega (altitude 1500-2300m)* and *kola* (*altitude* 500-1500/1800m) agro-climatic zones, covering about 10% and 90% of the total area of the district respectively. Fedis district on the other hand has about 39% of this district in *woinadega* agro-ecology and the remaining 61% in *Kola*. Gursum district is classified into *dega (altitude 2300-3200m), woinadega* and *Kolla* zones, covering about 15%, 35% and 50% of the total area of the district respectively. According to **CSA (2013)** the population of Babile, Fedis and Gursum is 115,229, 183,296 and 135,532 respectively.

In addition to groundnuts, farmers in those areas produce cereal crops such as sorghum, maize and oat. They also cultivate pulses and oil seeds such as horse bean, field peas, lentils, groundnut and linseeds. Semi perennial crops, such as chat and coffee are also widely cultivated mainly as cash crops. Those districts are also known for their fruit and vegetable production, Banana, papaya, guava, Anuma, Mango, sugarcane, sweet potato, potato, onion, tomato, carrot, beetroots, are to name some.

Sampling techniques, sample size and type of data

A multi-stage sampling technique is implemented to select respondents. In the first stage, three districts *Babile, Fedis* and *Gursum* are purposively selected based on the intensity of groundnut production. In the second stage, 15 rural *kebeles* are selected from each district proportional to the size of groundnut production. Finally, a total of 300groundnut producing farmers are selected from the *kebeles* by using a simple random sampling technique.

Mainly primary data is used to answer the objectives. However, secondary data are also collected from district offices—primarily to help choose the sample respondents. The primary data are collected by using structured questionnaire and administered by trained enumerators.

Methods

A multivariate probit model is employed to compute the nature of relationship that exists among three technologies and identify factors that affect the adoption of individual technologies. Ordered probit model is used to examine factors affecting adoption of multiple technologies. In order to understand the factors that affect the intensity of improved groundnut seed utilization, Tobit model is employed. Detailed description of the models is presented below.

Multivariate probit model

This model simultaneously models the influence of the set of explanatory variables on each of the different practices while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the adoptions of different practices (**Yu *et al.* 2008; Kassie *et al.* 2009**). Failure to capture unobserved factors and interrelationships among adoption decisions will lead to bias and inefficient estimates (**Greene 2008**).

The observed outcome of technology adoption can be modelled following random utility formulation. Consider the j^{th} household (j= 1,...,N) which is confronting a decision on whether or not to adopt the available productivity enhancing technologies. Let U_0 represent the benefits to the farmer from the traditional production system, and let U_k represent the benefit of adopting the k^{th} productivity enhancing technology: (k = F, S , M) representing choice of inorganic Fertilizer (F), improved seed (S) and application of organic fertilizer(M). The farmer chooses to adopt the k^{th} technology if

$$Y_{jk}^{*} = U_{k}^{*} - U_{0} > 0$$

The net benefit Y_{jk}^{*} that the farmer gains from k^{th} technology is a latent variable determined by observed and unobserved characteristics (Eq. 1).

$$Y_{jk}^{*} = X'_{jk}\beta_{k} + u_{ip} \ (1) \qquad (1)$$

Where X_{jp} represents observed characteristics; u_{jp} represents unobserved characteristics; K denotes the type of technology available and β_k denotes the vector of parameter to be estimated. Using the indicator function, the unobserved preferences in Equation 1 translate into the observed binary outcome equation for each choice as follow the Eq. 2.

$$Y_k = \begin{cases} 1 \text{ if } & Y_{jk}^{*} > 0 \\ 0 & \text{otherwise} \end{cases} \qquad (2)$$

In the MVP model, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity where $(u_F , u_S , u_M) \sim MVN(0, \Omega)$ and the symmetric covariance matrix $\boldsymbol{\Omega}$ is given by:

$$\Omega = \begin{pmatrix} 1 & \rho_{FS} & \rho_{FM} \\ \rho_{SF} & 1 & \rho_{SM} \\ \rho_{MF} & \rho_{MS} & 1 \end{pmatrix}$$

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic components of the different types of technologies **Teklewold *et al.* (2013)**.

Ordered probit model

The MVP model specified above only considers the probability of adoption of technologies, with no distinction made between the number of technologies adopted, for example, those farmers who adopt one technology and those who adopted combination of multiple technologies (**Teklewold *et al.* 2013**). To fill this gap the ordered probit is used to analyse the factors that influence the adoption of a combination of technologies.

This portion could have been treated as a count variable using a Poisson regression model. However, the underlying assumption of Poisson regression that states all events have the same probability of occurrence is violated as the probability of adopting the first technology could differ from the probability of adopting a second or third practice, given that in the latter case the farmer has already gained some experience with adoption of a technology. Therefore, the number of technologies adopted by farmers is considered as an ordinal variable and an ordered probit model in the estimation.

Tobit model

Data on agricultural technology adoption patterns in developing countries are complicated by the existence of zero observations on the dependent variable. Regression analysis using ordinary least squares (OLS) for such data is known to lead to biased and inconsistent parameter estimates given the censored, nature of the data (**Greene 2003; Kennedy 2003**). The standard Tobit model (**Tobin 1958**) was originally developed to accommodate this problem. The standard Tobit model is specified in Eq. 3.

$$
\begin{aligned}
&y_i^* = x_i'\beta + u_i \\
&u_i \sim N(0,\sigma^2) \qquad i = 1,..,n \\
&y_i = y_i^* \qquad \text{if } y_i^* > 0 \\
&y_i = 0 \qquad \text{otherwise}
\end{aligned} \tag{3}
$$

where x_i are a vector of explanatory variables corresponding to the i^{th} household, y_i, are observed intensity of technology adopted by the i^{th} household and y_i^* is an unobserved continuous latent variable assumed to determine the value of y_i. The latent variable is only observed if it is greater than or equal to zero. Standard estimators for these types of models are based on maximum likelihood estimation (MLE). The likelihood function of the Tobit model can be written as (**Tobin 1958**) (Eq.4).

$$L(\beta,\sigma^2) = \prod_0 \left[1 - \Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] \prod_1 \left[\sigma^{-1}\phi\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \tag{4}$$

The regression coefficients of the Tobit regression model cannot be interpreted like traditional regression coefficients that give the magnitude of the marginal effects of change in the explanatory variables on the expected value of the dependent variable. In a Tobit model, each marginal effect includes both the influence of explanatory variables on the probability of dependent variable to fall in the uncensored part of the distribution and on the expected value of the dependent variable conditional on it being larger than the lower bound. From the likelihood function of this model stated in Equation (4), **Gould *et al.* (1989)** showed the equations of three marginal effects as follows:

The effect of a given explanatory variable on the probability of Y is:

$$\frac{\partial F(Z)}{\partial X_i} = f(Z)\frac{\beta_i}{\sigma}$$

The marginal effect of an explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(Z)\beta_i$$

Where $\frac{\beta_i X_i}{\sigma}$ is denoted by Z

The change in the amount of Y with respect to a change in explanatory variable among individuals who are adopting the technology:

$$\frac{\partial E(Y_i / Y_i^* > 0)}{\partial X_i} = \beta_i \left[1 - Z\frac{f(Z)}{F(Z)} - \left(\frac{f(Z)}{F(Z)}\right)^2\right]$$

Whereas: F (z) is the cumulative normal distribution of Z, f(z) is the value of the derivative of the normal curve at a given point (i.e., unit normal density), Z is the z-score for the area under normal curve, β is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term.

RESULTS AND DISCUSSION

Characteristics of Sample Respondents

Characteristics of the sample are displayed in the Table 1. Of the total sample households, about 85% are male-headed. Age of the total sample respondents ranges from 17 to 80 years with mean of about 38 years. 64.8% of the sample household heads have not attained formal schooling. The average groundnut farming experience is 17 years. The average adult equivalent of the sampled household's is5.47. The mean annual farm income is 9518.41ETB. And 18% of respondents are engaged in non/off fame activities such as petty trade, remittance, pension, wage and rent from assets. On average, respondents own 3.437 units of livestock measured by the tropical livestock unit (TLU), calculated according to Storck, et al. (1991). The size of land owned ranges from 0.5 to 24 *qoxi* with an average size of 7.744 *qoxi*.

As far as institutional variables are concerned, 55% of the respondents are member of agricultural (input or marketing) cooperatives. Nearly 40% of respondents have social responsibility such as security guard (*Militia*), member of local administration and religious or traditional leadership. Except five percent of the respondents, all of them indicate that they get extension service though the frequency differs. Frequency of extension contact ranges from zero to 288 days with the mean of 66.309 days per year and 85% of the respondents perceived that the extension service they receive is sufficient. Out of the total respondents, 63.5% got training specific to groundnut production. The sample respondents are on average 5.22 and 1.3 km far from market and farmers training center respectively.

Concerning the plot characteristics, about 79% the plot are found in *kola* agro ecology zone. The mean size of the plot was 3.249 *qoxi*. The plots are on average 0.109 km away from the where the respondents live. Ninety-eight percent of the plots considered for this study are owned and operated by the respondents and the remaining are ether rented in on shared in. About 70% of the plots are perceived to be fertile.

Adoption of Multiple Technologies: Multivariate Probit Dependent Variables

The dependent variables considered in this model are inorganic fertilizer (F), organic fertilizer (M) and improved groundnut seeds (S). Though groundnut can fix nitrogen from the air with the help of *Rhizobium* in the root nodules (**Somasegaran and Hoben 2012**), it takes about 25-30 days to develop root nodules (**Singhand and Oswalt 1995**). Therefore, nitrogen is required in the early stages for plant growth. Phosphorus is also the most important nutrient that affects the yield and quality of leguminous crops including groundnut (**Patel *et al.* 1990**). Therefore, both phosphorus and nitrogen application is necessary for sustainable groundnut production. Of the total groundnut plots considered for this study, inorganic fertilizer is adopted on 71%.

The other technology considered is organic fertilizer. The benefit of organic fertilizer in increasing groundnut yields has been indicated in the work of **Prasad *et al.* (2002).** Of the total groundnut plots, 55% of them adopted organic fertilizer (compost, animal waste or manure). Bulkiness of organic fertilizer to transport, lack of livestock to prepare it and lack of awareness were the reasons indicated by the farmers for not adopting this technology.

The seed used for production will determine the ultimate yield that will be obtained at the end. Therefore, improved seed adoption of groundnut producers were also considered in this study. Though adoption of improved seed in crucial as compared to inorganic fertilizer for groundnut farming since it can fix nitrogen from the air, the rate of adoption of inorganic fertilizer is twice as much as adoption rate of improved seed. Accordingly, out of the total plots considered for this study, improved seed was adopted on 35% of them. Financial constraint, lack of technical knowledge and accessibility of the improved seed were among the reasons indicated by the respondents for not adopting this technology. The conditional and unconditional probabilities of adoption of those technologies are presented in Table 2.

Relationship between technologies

The likelihood ratio test [chi^2 (3) = 24.9438, P= 0.0000)] of the null hypothesis that the covariance of the error terms across equations are not correlated is rejected. This is supported by the correlation between error terms of the adoption equations reported in Table 3.

The estimated correlation coefficients are statistically significant in two of the three pair cases, which justify the use of MVP model for this study. In addition to supporting the use of the MVP, it also shows the interdependence of technologies where the probability of adopting a technology is conditional on whether a technology in the subset has been adopted or not. This cross-technology correlation information have important policy implications since policy changes which affect one technology can have spillover effects to other the technology.

Table 1: Data; a variable selection

Variable	Mean	Std. Dev.	Min	Max
Household Head Characteristics				
Male headed household	0.847	0.360	0	1
Age of the household head	37.844	11.769	17	80
Literacy of the head (dummy)	0.352	0.478	0	1
Farming experience	20.033	10.429	2	60
Groundnut farming experience	17.169	9.908	2	45
Socioeconomic Characteristics				
Size of land owned	7.744	4.403	0.5	24
Livestock size (TLU)	3.437	5.462	0	88.9
Participation in off/non-farm	0.179	0.384	0	1
Off/non-farm income	3401.831	35157.	0	600000
Income from livestock	1370.419	4046.7	0	36000
Family size in adult equivalent	5.473	2.311	1.75	16
Institutional Characteristics				
Cooperative membership	0.551	0.498	0	1
Social responsibility	0.392	0.489	0	1
Access to Extension	0.950	0.219	0	1
Frequency of extension contact	66.309	78.927	0	288
Sufficiency of extension service	0.850	0.357	0	1
Information exchange	0.910	0.286	0	1
Training regarding groundnut	0.635	0.482	0	1
Market information	0.817	0.412	0	3
Distance to market	5.293	6.962	0.01	39
Distance to coop	1.974	2.593	0.01	17
Distance to FTC	1.300	1.421	0.01	10
Groundnut Plot Characteristics				
Plot size	3.249	1.793	0.5	12
Ecology (1 = *kola*)	0.748	0.435	0	1
Plot to home distance	0.109	0.142	0.01	1
owned by Household Head	0.980	0.141	0	1
Good fertility	0.698	0.460	0	1
Medium fertility	0.272	0.446	0	1
Plain Slope	0.813	0.391	0	1
Average Slope	0.147	0.355	0	1

Notes: TLU and adult equivalents are calculated according to Storck, et al. (1991)
Source: Own estimation result (2016)

Table 2. Conditional and unconditional probabilities of adoption of technologies

	Improved Seed	Inorganic Fertilizer	Organic Fertilizer
$P(Y_k = 1)$	0.35	0.71	0.55
$P(Y_k = 1\|Y_S= 1)$	1.00	0.86	0.95
$P(Y_k = 1\|Y_F= 1)$	0.42	1.00	0.64
$P(Y_k = 1\|Y_M= 1)$	0.35	0.82	1.00
$P(Y_k = 1\|Y_S= 1, Y_M= 1)$	1.00	0.97	1.00
$P(Y_k = 1\|Y_F= 1, Y_M= 1)$	0.41	1.00	1.00
$P(Y_k = 1\|Y_S= 1, Y_F= 1)$	1.00	1.00	0.62

Note: Yk is a binary variable representing the adoption status with respect to practice k (k = improved seed (S), inorganic fertilizer (F) and organic fertilizer (M))
Source: Own estimation result (2016)

Improved groundnut seed is found to have a positive relation with adoption of inorganic fertilizer and this correlation between the two technologies is the highest (38%). This relationship is in line with findings of **Ahmed (2015) and Teklewold *et al.* (2013)**. Organic fertilizer is also related with inorganic fertilizer positively. This finding is also in line with the finding of **Marenya and Barrett (2007). Whalen and Chang (2001)** also reported that application of inorganic fertilizer in combination with manure enhanced the effectiveness of inorganic fertilizers resulting in higher yields.

The simulated maximum likelihood estimation result also shows that the likelihood of households to adopt improved seed, inorganic fertilizer and organic fertilizer were 35.3%, 71.8%, and 52.4% respectively. It also shows that the joint probability of using all technologies was 18.1% and the joint probability of failure to adopt all technologies was 15.9%.

Table 3: Correlation matrix of the technologies from the MVP model

	Improved seed	Inorganic Fertilizer	Organic fertilizer
Rho2	0.383(0.101)***		
Rho3	-0.039(0.098)	0.34(0.097)***	
Predicted probability	0.353	0.718	0.524
Joint probability (success)			0.181
Joint probability (failure)			0.159

Source: Own estimation result (2016)
*** Significant at 1% probability level, respectively

Factors Affecting the Adoption of Technologies

Though farmers adopt a combination of technologies, there are also significant factors that could determine their decision to choose a particular technology. This section has identified those variables using MVP. The MVP model fits the data reasonably well. The Wald test [$\chi^2(54) = 185.46$, p = 0.000) of the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. As it is presented in Table 4, the MVP model estimates differ considerably across the equations, representing the appropriateness of differentiating between technologies. This was also formally tested by estimating a constrained specification with all slope coefficients forced to be equal. The likelihood ratio test statistic of the null hypothesis of equal-slope coefficients is rejected, reflecting the heterogeneity in adoption of technologies and, subsequently, supporting a separate analysis of each rather than aggregating them as a single dependent variable.

The MVP model result indicated that sex of the household head has a positive relationship with adoption of organic fertilizer in favour of male. This is plausible, as women may not adopt technologies that require more time and labour such as application of organic fertilizer, which is bulky to transport, since they are the one who are responsible for the many domestic activities. This result is in line with the argument of **Doss and Morris (2001).**

The result of the study also indicated that educational level of the household head has a positive effect on the adoption of both improved seed and inorganic fertilizer. Educated farmers have more exposure to the external environment and accumulated knowledge through formal learning, which enhances their ability to perceive, interpret, and respond to new events in the context of production. Educational so increases farmers' ability to obtain, and analyse information that helps them to make appropriate judgment and application. Similar result also found in the work of (**Kabunga et al. 2012**).

The negative relationship between age of the household head and adoption of improved seed is justifiable as older farmers are more interested in following traditional methods that are familiar to them rather than adopting new practices. Similar result also found in the work of (**Assefa and Gezahegn 2004**).

An increase in the groundnut production experience of a household head has a positive relationship with adoption of improved seed. Experienced farmers have more experience, knowledge, skill and attitudes with farming that enables them to easily understand and be familiar with the benefits of the technology better than less experienced counterpart.

Livestock ownership is another essential factor that determines adoption of inorganic and organic fertilizer. The justification for the relationship between TLU and organic fertilizer is that since there is no developed market for organic fertilizer in the country adoption of organic fertilizer is supply driven and farmers with more animals will also have more manure and will in turn be more likely to use organic fertilizer. The possible explanation for the positive relationship between TLU and application of inorganic fertilizer could be that if the farmer possesses more number of livestock, they will have better capacity to purchase agricultural inputs, as income obtained from livestock serves for investment on crop production.

Extension access is a necessary catalyst to technology adoption as they are the major source of agricultural information in Ethiopia. The study also indicated positive relationship between extension contact and adoption of improved seed. Farmers who have a frequent contact with extension agents have more information that would influence farm household's demand for new technologies.

Training regarding groundnut production is also found to have positive relationship with adoption of improved seed. The result is credible as training increases the awareness of farmers and exposes them to new ideas and information about productivity of inputs, opportunities, input and output management and prudent handling of cash.

As expected, cooperative membership is found to have positive relationship with both organic and inorganic fertilizer adoption decision. With scarce or inadequate information sources and imperfect markets, social networks such farmers' associations or groups facilitate the exchange of information, and enable farmers to access inputs on schedule and overcome credit constraints (**Tekelwold et al. 2013**).

Plot size is related with adoption of improved seed positively. Same result was also found in the work of **Solomon et al. (2011).** The other plot characteristics found to be significant is the distance between the plot and the house where the farmers is living. This variable is found to have inverse relation with the application of organic fertilizer. Owing the fact that organic fertilizer is bulky and less transportable farmers become less interested to apply organic fertilizer if the plots are far from their home.

Plain slop is found to have a positive relationship with application of inorganic fertilizer. As the slop of the plot, with other factors determines the rate of soil erosion, which could reduce the fertility of the plot, farmers are less interested to invest on plots that are susceptible to erosion.

Social responsibility is found to have a positive relationship with adoption of inorganic fertilizer. This is justifiable because individual who have role in the society will get timely access to useful information and their status in the community will help them to get inputs easily.

Number of Technology Adopted: Ordered Probit

The dependent variable of this model is the number of technologies adopted by the farmers out of the combination of improved groundnut seed, inorganic and organic fertilizer. About 85 percent of the respondents have adopted at least one of them and nearly 40% of the respondents indicated that they have adopted two technologies. The descriptive statistics of number of technologies adopted along the probability predicted from the ordered probit model is presented in Table 5.

Table 6 shows the results from ordered probit models. The chi-squared statistic for the ordered probit models statistically significant (Wald chi^2 (17) = 93.44, P = 0.0000), indicating that the joint test of all slope coefficients equal to zero is rejected. Results show that the number of technologies adopted is positively related with groundnut farming experience, educational status of the head, livestock ownership, cooperatives membership, size of groundnut plot, training about groundnut farming and it is inversely related with distance between groundnut plot and the home of the farmer.

Table 4. Multivariate Probit simulation results for households' technology adoption decisions

	Improved seed		Inorganic fertilizer		Organic fertilizer	
Variables	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex of the head	0.046	0.241	0.080	0.234	0.448*	0.230
Age of the head	-0.028*	0.012	-0.005	0.011	-0.005	0.010
Education	0.790***	0.188	0.680***	0.197	-0.035	0.182
GN farming experience	0.034**	0.013	0.015	0.012	0.004	0.011
Family size	0.013	0.046	0.033	0.049	0.007	0.047
Cooperative membership	0.003	0.206	0.370*	0.203	0.532**	0.189
Social responsibility	-0.138	0.203	0.486*	0.207	0.256	0.193
Off/nonfarm income	0.064	0.221	-0.084	0.238	0.009	0.226
Livestock (TLU)	0.011	0.018	0.071*	0.038	0.087*	0.038
Size of Land owned	0.019	0.024	0.020	0.028	0.016	0.024
Extension contact	0.002*	0.001	0.000	0.001	-0.002	0.001
Training	0.372*	0.183	0.268	0.178	0.131	0.173
Distance to market	-0.003	0.013	0.010	0.016	0.027*	0.012
Plot size	0.190**	0.061	0.002	0.066	0.019	0.054
Soil fertility good	0.890	0.571	0.148	0.460	0.153	0.475
Soil fertility medium	0.725	0.582	0.204	0.477	-0.204	0.484
Slope plain	0.077	0.225	0.455*	0.222	0.134	0.210
Plot to home distance	-0.580	0.665	-0.044	0.630	-1.886***	0.586
_cons	-2.341***	0.721	-1.375*	0.618	-1.172	0.599

Source: Own estimation result (2016)

***, ** and * significant at 1%, 5% and 10% probability level, respectively

Table 5: Percentages and predicted probabilities of technologies adopted by sample farmers

Number of technologies	Percent	Predicted probability
0	15.61	15.77
1	27.57	27.65
2	38.87	38.40
3	17.94	18.17

Source: Own estimation result (2016)

Groundnut farming experience has a significant and positive effect on the level of technology use. Experienced farmers would acquire knowledge and skills that are required of adjusting the production system and adopt new technologies. The marginal effect indicates a one-year increase in the groundnut farming experience will increase the probability of adoption of three technologies by a percentage of 0.4.

The educational level of the household head has a positive effect on the level of technologies adopted. Education increases human capital and contributes positively to change farmer's attitudes towards modern technology. It determines the readiness to accept new ideas and innovations. The marginal effect indicates educated farmers are 11.6 percentage points more likely to adopt three technologies. The other significant variable related with human capital is training. Farmers who got training regarding groundnut farming are 6.7 percentage points more likely to adopt three technologies. Farmers who are members of agricultural cooperatives are also 8.1 percentage points more likely to adopt three technologies.

The size of livestock also related with number of technologies adopted positively. A one-unit increase in the size of livestock owned measured in TLU will increase the probability of adoption of three technologies by a percentage of 0.14.

The size of groundnut plot has also a significant and positive effect on the level of technology use. A one-unit increase in the size of the plot could increase the probability of adoption of two and three technologies by 1.1 and 2.1 percentage respectively. The distance between the residence of the respondent and groundnut plot are related inversely. Farmer requires longer time to visit and manage the farm properly if the plot become far from the homestead. Therefore, the plot will receive less attention. A kilometer increase in the distance between the plot and the home of the farmers could decrease the probability of adoption of two and three technologies by 11.6 and 22.1 percentage respectively.

Intensity of Improved Groundnut Seed Adoption

The chi-squared statistic for the Tobit model is statistically significant (Wald chi^2 (18) = 60.35, P = 0.0000), indicating that the joint test of all slope coefficients equal to zero is rejected. The result of the model indicated that age of the household head has a negative coefficient indicating an inverse relation between age of the head and intensity of improved seed adoption (Table 7). The marginal effect results of the model also indicate that the probability of adoption of improved seed decreases by 1.1% if the age of the head increases by one year. Moreover, it decreases the intensity of adoption of improved seed by 21.9% among the whole population and 23.7% among the adopters only.

Table 6: Ordered probit results for number of technologies adopted

Variables	Coef.	Std. Err.	Marginal effects							
			Prob(Y=0|X)		Prob(Y=1|X).		Prob(Y=2|X).		Prob(Y=3|X).	
			Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex of the head	0.219	0.182	-0.045	0.037	-0.028	0.023	0.025	0.021	0.048	0.040
Age of the head	-0.012	0.008	0.003	0.002	0.002	0.001	-0.001	0.001	-0.003	0.002
Groundnut farming experience	0.018*	0.009	-0.004	0.002	-0.002	0.001	0.002	0.001	0.004	0.002
Education	0.532***	0.147	-0.109	0.031	-0.067	0.019	0.061	0.019	0.116	0.031
TLU	0.066*	0.031	-0.014	0.006	-0.008	0.004	0.008	0.004	0.014	0.007
Landowned	0.017	0.020	-0.004	0.004	-0.002	0.003	0.002	0.002	0.004	0.004
Family size	0.021	0.038	-0.004	0.008	-0.003	0.005	0.002	0.004	0.005	0.008
Cooperative	0.374*	0.162	-0.077	0.033	-0.047	0.021	0.043	0.019	0.081	0.035
Social responsibility	0.236	0.157	-0.048	0.033	-0.030	0.020	0.027	0.019	0.051	0.034
Extension contact	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Training	0.309*	0.136	-0.064	0.028	-0.039	0.018	0.035	0.016	0.067	0.030
Distancetomarket	0.012	0.009	-0.002	0.002	-0.002	0.001	0.001	0.001	0.003	0.002
Plotsize	0.098*	0.048	-0.020	0.010	-0.012	0.006	0.011	0.006	0.021	0.010
Soilfertilitygood	0.363	0.350	-0.075	0.072	-0.046	0.044	0.042	0.040	0.079	0.077
Soil fertility medium	0.164	0.361	-0.034	0.074	-0.021	0.046	0.019	0.041	0.036	0.079
Slopeplain	0.251	0.176	-0.052	0.037	-0.032	0.022	0.029	0.021	0.055	0.038
Plot to home distance	-1.016*	0.420	0.209	0.085	0.128	0.055	-0.116	0.049	-0.221	0.092
/cut1	0.780	0.454								
/cut2	1.768***	0.457								
/cut3	3.054***	0.469								

Source: Own estimation result (2016)
***, ** and * significant at 1%, 5% and 10% probability level, respectively

Table 7:Tobit model results for intensity of technology adoption decisions

Variables	Coef.	Std. Err.	Marginal effects Change in probability of adoption		Change in intensity of use		Total change	
			Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Sex of the head	0.772	1.935	0.032	0.079	0.216	0.531	0.257	0.622
Age of the head	-0.486	0.34	-0.021	0.014	-0.139	0.096	-0.167	0.116
age2	0.003	0.004	0	0	0.001	0.001	0.001	0.001
Education	.710***	0.277	0.033	0.011	0.225	0.078	0.272	0.094
GN farming exp.	.311 ***	0.102	0.013	0.004	0.089	0.028	0.107	0.034
Cooperative	-0.109	1.544	-0.004	0.066	-0.031	0.441	-0.037	0.532
Social responsibility	-0.878	1.56	-0.037	0.065	-0.248	0.436	-0.298	0.52
Land owned	0.123	0.178	0.005	0.008	0.035	0.05	0.043	0.061
Extension contact	.019 **	0.008	0	0	0.006	0.002	0.006	0.002
Training on groundnut	3.458 **	1.446	0.143	0.057	0.955	0.383	1.123	0.44
Distance to market	-0.093	0.117	-0.004	0.001	-0.027	0.033	-0.032	0.04
Plot size	.983 **	0.42	0.041	0.0176	0.28	0.118	0.338	0.143
Kola	-2.877 *	1.551	-0.125	0.0681	-0.863	0.485	-1.078	0.625
Plot distance	-7.149	5.02	-0.304	0.213	-2.037	1.427	-2.458	1.724
Soil fertility low	-7.002	5.056	-0.235	0.118	-1.604	0.915	-1.564	0.633
TLU	-0.015	0.102	0	0.004	-0.004	0.029	-0.005	0.035
Family size	0.063	0.256	0.002	0.01	0.018	0.072	0.021	0.088
Cons	-0.943	6.721						
Sigma	8.662	0.69						

Source: Own estimation result (2016)

***, ** and * significant at 1%, 5% and 10% probability level, respectively

Education has a positive coefficient and is significant at one percent. This implied that educated farmers tend to be better at recognizing the importance of improved seed. This is plausible as educated people can better understand agricultural instructions very easily and be able to apply technical skills imparted to them than the uneducated. The marginal effect results of the Tobit model indicate that, when the household head is educated, the probability of adopting improved groundnut seed increases by 21.5%.

Groundnut production experience has positive coefficient and is significant at one percent. Having cumulative knowledge explains adoption and intensity of use of improved technologies as it determines farmers' skill of information accessing and utilization behaviour. The marginal effect results of the model indicate that, when groundnut production experience of the household head increases by one year, it increases the probability of adoption of improved seed by 1.2%. Furthermore, an additional increase in the groundnut farming experience increases the intensity of adoption of improved seed by 25.1%among the whole population and 27.2%among the adopters only.

Size of land owned affects the intensity of improved seed adoption positively and significantly at 10% significance level. Farmers with larger area of cultivated land have the capacity to use compatible technologies that could increase the efficiency of the farmer, enjoying economies of scale. The marginal effect results of the Tobit model indicate that, when the size of owned land increases by one unit, it increases the probability of adopting improved seed by 1.5%. Moreover, an increase in a unit of size of owned land increases the intensity of adoption of improved seed by 31.6% among the whole population and 34.3% among the adopters only.

CONCLUSION AND RECOMMENDATIONS

This study has analysed the adoption of different technologies among groundnut farmers using data collected from eastern Ethiopia. The technologies considered for this study are improved groundnut seed, inorganic fertilizer and organic fertilizer. The results of the multivariate correlation coefficient indicated that there are positive relationships between improved seed and fertilizer and between organic and inorganic fertilizer. Educational level of the household, groundnut farming experience, livestock ownership, cooperative membership, age of the head, training regarding groundnut production, size of land owned and size of groundnut plot play significant roles, partly with differing signs across technologies. The following are the major recommendations drawn based on the findings of this study:

Appropriate and adequate extension services should be provided as extension services are the main instrument used in the promotion of demand for modern technologies. This could be done by designing appropriate capacity building program to train additional development agents to reduce the existing higher ratio of farmers to development agents as well as by providing refreshment training for development agents.

Local institutions such as cooperatives need to be supported because they can effectively assist farmers in providing credit, inputs, information, and stable market outlets.

The government and other stakeholders have also to give due attention for training farmers through strengthening and establishing both formal and informal type of framers' education, farmers' training centres, technical and vocational schools.

Education, training and farming experience are also found to be crucial factors in determining farmers' decision to adopt the technology. This underscores the importance of human capital development through improving farmers' access to agricultural knowledge, skill and experience. Thus, government and other stakeholders have to give due attention to training farmers through strengthening and establishing both formal and informal type of framers' education, farmers' training centers, technical and vocational schools. Beside this, development agents, local leaders and other participants should create the room for experience sharing among farmers regarding the importance of improved technologies.

Increasing land size contributes to increasing adoption of improved groundnut seed. It is therefore, important to promote different ways of acquiring more land to farmers. This can be done by creating and promoting the culture of renting land or sharecropping.

Future research

This research used a cross-sectional data set to analyse the determinants of the decision to adopt multiple technologies, unobserved heterogeneity is not controlled. Future research, by using panel data, can provide a more adequate and precise information on the determinants.

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