Vol.12(3), pp. 62-75 July-September 2020
DOI: 10.5897/JAERD2020.1132
Articles Number: 14B692564619
ISSN: 2141-2170

http://www.academicjournals.org/JAERD

Journal of Agricultural Extension and Rural Development

Full Length Research Paper

Determinants of adoption of agricultural extension package technologies by smallholder households on sorghum production: Case of Gemechis and Mieso districts of West Hararghe Zone, Oromia Regional State, Ethiopia

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Received 14 January, 2020; Accepted 15 July, 2020

This study identified the socio-economic factors that significantly influence adoption of agricultural extension package technologies on sorghum crop production. Primary and secondary data were collected for the study. In the sampling procedure, multi stage sampling procedure was used. Data was analyzed using both descriptive statistics and econometric models. In econometric models Multivariate Probit (MVP) and Double Hurdle models were used. Multivariate Probit output indicates that, the probability of the household to use inorganic fertilizer (NPS and Urea), organic fertilizer, crop protection chemicals and row planting were 43.43, 63.07, 12.51, and 25.04%, respectively. Multivariate Probit output also shows that, the joint probability of success and failure of using all agricultural extension package technologies were 3.18 and 24.81%, respectively. Multivariate Probit and Double Hurdle models result confirm that district, extension visit, livestock holding, perception of the expectation of the coming rainfall, total farm land and participation on agricultural training significantly affect adoption decision and intensity use of different agricultural extension package technologies.

Key words: Household, agricultural extension package technology, Multivariate Probit model, Double Hurdle model.

INTRODUCTION

The most fundamental challenge facing the world today and Ethiopia as a country, is food insecurity. For instance, between 1998 and 2012 the average number of Ethiopians in need of food assistance fluctuated between 3 and 14 million (Integrated Regional Information Networks (IRIN), 2012). To divert the problem, the country, Ethiopia has undertaking different programs to enhance the productivity of agricultural crops at the farm level. Ethiopia has been implementing a participatory extension system (PES) since 2010 (Ministry of

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Agriculture (MoA), 2010) following the commencement of the first Growth and Transformation Plan. The major changes made in PES as compared to Participatory Demonstration Training and Extension System (PADETS) were organization of farmers in development groups and social networks (one in five farmers groups, development units), farmers training center (FTC) categorization into watershed management and full-package extension service provision to adopt better technologies (MoA and Agricultural Transformation Agency (ATA), 2014).

Despite such efforts to make the extension system effective and efficient, the system is not producing the desired results (MoA and ATA, 2014). Varies yield and quality improving technologies have been generated in the agricultural sector, but they are not reaching smallholder farmers. Equally, the agricultural sector is not reaching its full potential in terms of attaining food self-sufficiency and reducing poverty. The adoption of new technologies such as agricultural extension packages technologies (AEPTs) improves productivity of agricultural crops if they are implemented properly. Thus, effective and efficient use of AEPTs is encouraged by concerned stakeholders to boost agricultural crop productivity at farm level.

To fulfill the sharp rising demand for food either productivity must be improved, or more land must be cultivated. As it is well known facts which indicate that, cultivation of extra land is very much narrow in west Hararghe due to scarcity of agricultural land. One of the feasible remedy that contributes achieving food self-sufficiency is to enhance the productivity of land at farm level by implementing improved AEPTs. Ethiopian government is undertaking different efforts to improve the utilization of the AEPTs so that productivity of agricultural crops in the rural areas can be improved. Among the known efforts, thousands of development agents were trained and distributed in rural areas of the country. Numbers of FTCs were built and demonstration sites were established to adopt new technologies and implement the extension service in multidisciplinary system. Different projects have also been designed on implementing to enhance realization positive impact of these technologies. For instance Agricultural Transformation Agency (ATA) of Ethiopia is doing different encouraging activities such as developing evidence based application of inorganic fertilizer by developing a digital soil map for Ethiopian agricultural land (ATA, 2014) to improve implementation of new and improved technologies. Even though different efforts were undertaken by different sectors, the productivity of agricultural crops was not improved as it is expected with rapid growth of the food demand in Ethiopia.

Farmers have been adopting AEPTs in the selected districts of the study areas. However, some smallholder farmers did not adopt these AEPTs. Intensity use of AEPTs also deviates from household to another household which results in gaps in crop productivity on crops production in general and on sorghum crop production in particular. According to planning and program section report of West Hararghe Zone of Agricultural Office (WHZAO, 2017) and Muhammed (2020) only 9% of the total cultivated land is sown with full extension package technologies in 2016/2017 crop year. Based on the same report, when zonal cropland area of sorghum is considered, out of total cropland cultivated for different crops, 101,960 ha areas of land cultivated and sorghum crop was planted. Out of the total area planted with sorghum crop, only 841 ha (0.82%) was sown by improved seed with inorganic fertilizer; 12,605 ha (12.36%) was covered by improved seed without any fertilizer; 25,144 ha (24.66%) was covered by local seed without any fertilizer; and 63,370 ha (62.15%) was covered by local seed and organic fertilizer in 2016/2017 crop year (Muhammed, 2020; WHZAO, 2017). These figures show that, there are still problems of using important inputs such as inorganic fertilizer, improved seed and organic fertilizers on sorghum crop production. One of the possible reasons might be because of diverse socio-economic and institutional factors which are not, due attention is given by concerned stakeholders on sorghum crop production.

Plenty of research evidences were available on adoption of AEPTs on other major crops like wheat and maize. However, there are limited research findings that indicate factors that influence adoption decision and level use of AEPTs on sorghum crop production in holistic manner. There is still research gap that shows how the competing and supporting inputs are interrelated. The use of one input may positively or negatively affect the use of other inputs. This can be seen by taking all the package technologies used by the households by exploring important models. By taking only one input, the reality behind implementing and not implementing these technologies may not be identified. Therefore, it is very vital to identify socio-economic and institution factors that affect adoption of the AEPTs in inclusive way and intervene on these factors and enhance use of the AEPTs so that is contributes to the realization of food security plan. Thus, this study identified socio-economic and institution factors that affect adoption choice and use of intensity of AEPTs on sorghum crop production.

RESEARCH METHODS

Description of the study area

The study was conducted in Gemechis and Mieso districts of West Hararghe Zone, Oromia Region State, Ethiopia. According to basic data of West Hararghe Zone of Agriculture and Natural Resource Office (2017), Mieso district is located at about 300 km from Addis Ababa to east in West Hararghe Administrative Zone of Oromia Regional State and 25 km to West of Chiro town, capital of the zone; whereas Gemechis district is one of the districts in West Hararghe Zone which is located at 343 km east of Addis Ababa and

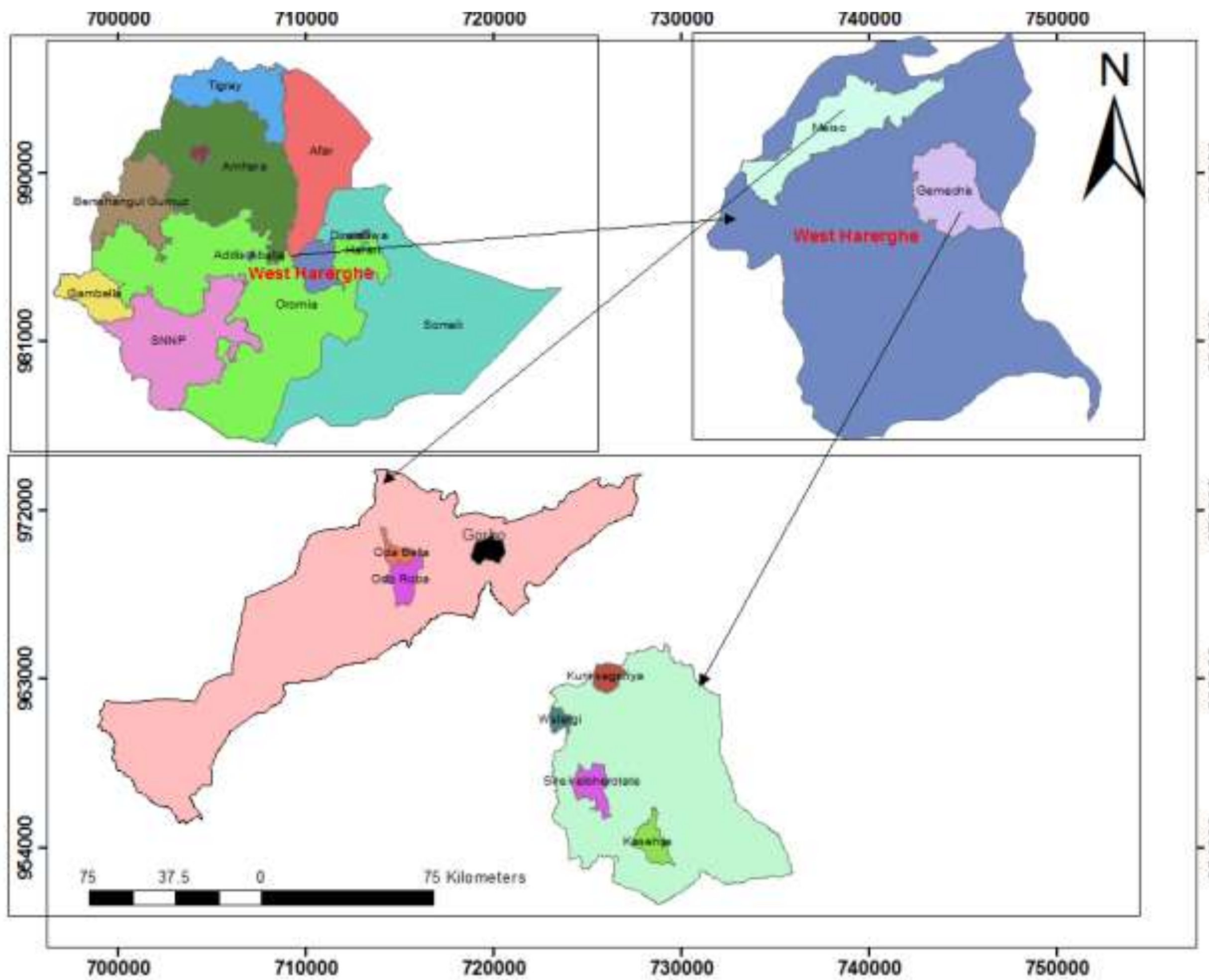

Figure 1. Location of the study areas.
Source: West Hararghe Zone Agriculture and Natural Resource Office.

about 17 km south of Chiro (Figure 1). Mieso district covers an area of 186,716 ha and it has 31 rural and one urban kebeles with total of 31,456 household members; whereas Gemechis district covers an area of 77,785 ha and it has 35 rural and one urban kebeles with total of 38,700 household members. According to the CSA (2017) population projection, Mieso district have 144,750 total populations of which 82,796 and 61,954 are male and female, respectively; whereas Gemechis district have 235,638 total populations of which 119,485 are males and 116,153 are females in 2019. The altitude of the Mieso district is within an altitude of 900 to 2500 m above sea level with an average annual rainfall of 790 mm; whereas Gemechis district is found within altitude of 1300 to 2400 m above sea level with an average annual rainfall of 850 mm. The two districts receive a bimodal rainfall where the short rain season is between March and April while the main rain is between July and September. The economic bases of the population of the two districts are mixed agriculture, which is crop and livestock production. The major crops grown in the district are sorghum, maize, and haricot bean. *Khat*, fruits and vegetables are important cash crops in Gemechis district. Kebele is the smallest administrative unit of the local government. Khat (*Catha edulis*) refers to plant containing a psychoactive substance, cathinone, which produces central nervous system stimulation analogous to amphetamine (Tekalign et al., 2011).

Data types and sources of data

The study was based on both primary and secondary data. Primary data were collected from the sample farm households to know information on different social, economic and institutional variables of sample households. Moreover, focus group discussion and key informant interviews were undertaken with concerned stakeholders so as to support the primary data. Secondary data were also collected from both published and unpublished documents.

Sampling technique, sample size and methods of data collection

Gemechis and Mieso districts were purposively selected for the study because of these two districts have potential of production of sorghum crop and can characterize the highland, midland and lowland parts of West Hararghe Zone.

To choose the sample kebeles and households, multi-stage sampling procedures were used. In the first stage, kebeles of the districts were stratified into three agro-ecologies. In the second stage, numbers of kebeles per the district and agro-ecology were decided and randomly selected based on probability proportional to size.

Table 1. Sample kebeles, agro-ecologies, total HHs and distribution of sample HHs.

District	Name of kebele	Agro-ecology	Total HH heads	Sample HH heads
Gemechis	Harotate	Midland	1494	34
	Kuni Sagariya	Highland	1319	30
	Kase Ija	Lowland	1320	30
	Walargi	Midland	1187	27
	Sub total		5320	121
Mieso	Gorbo	Lowland	1175	27
	Oda Bal'a	Lowland	1207	27
	Oda Roba	Lowland	1165	26
	Sub total		3547	80
Total			8867	201

"HH" refers to Household .
Source: Own survey (2019).

In the last stage, a total of 201 sample households from the selected kebeles of the two districts was taken and numbers of sample households per kebele was decided based on kebeles household population size (probability proportional to the size); finally, households were selected randomly and interviews were undertaken.

The sample size was determined based on formula provided by Cochran (1977). To decide the required sample size, 95% confidence level, 0.5 degree of variability and 7% level of precision were used. Therefore, by using Cochran (1977) formula, the sample size was:

$$n = \frac{pqZ^2}{E^2}$$

where n is the sample size, Z is confidence level (α=0.05), p is proportion of the households participating in adopting agricultural extension package technologies in sorghum production in the study areas and it is assumed that 50% (0.5), q=1-p = 0.5 and E the level of precision given as 0.07. The value of Z at α=0.05 confidence level is 1.96.

Therefore, the sample size was:

$$n = (0.5 \times 0.5)\,(1.96)^2 / (0.07)^2 = 196$$

The formula suggests that 196 sample households should be taken. However, 201 sample households were taken for the study (Table 1).

Based on interview scheduled, primary data was collected by employing a semi-structured questionnaire modified after conducting an informal survey. Pretesting was undertaken on 10 households to correct the questionnaires before formal survey was started. Trained enumerators were used to gather data on different social, economic and institutional variables from sample households. Focus group discussions and key informants' interviews were also made with farmers incorporated from important social groups such as influential persons, members from different social cooperatives, women, youths, development agents, concerned agricultural professionals and administration offices by the researchers.

Methods of data analysis

To address the objectives of the study, descriptive and inferential statistics and econometric models of data analysis methods were employed with statistical software package tool, Stata12. In the descriptive and inferential statistics part, simple measures of central tendencies and variations, frequency, mean, Chi-square test, t-test and percentages were used to assess characteristics of sample respondent households and agricultural extension package technologies used. In the econometric analyses, a Multivariate Probit model was used to identify factors influence adoption decision of agricultural extension packages technologies on production of sorghum and correlation among extension package technologies; finally, Double Hurdle model was employed to analyze the intensity use of AEPTs on production of sorghum crop in the study areas.

Specification of the econometric models

In past researches, despite the recognition that adoption of technology components is multivariate, econometric methods were limited to use feasible approaches such as Multinomial Logit, in which adoption outcomes were redefined to create an order (Kamau et al., 2013).

Recognizing that, parameter estimates based on individual Probit models may be biased by cross-practice correlations. Based on the aforementioned justification, number of scholars such as Mabiratu and Perm (2020), Wondimagegn and Lemma (2016) and Kamua et al. (2013), used Multivariate Probit model for more than one outcome or dependent variables. Based on these justifications, Multivariate Probit (MVP) model regression was selected and used to estimate the probabilities that households use one, two, or three mutually exclusive agricultural extension package technologies. Dependence among decisions was tested and average partial effects were reported. Finally, Double Hurdle model was employed to estimate factors influence intensity use of agricultural extension package technologies.

Multivariate Probit model

Following Tabet (2007) the Multivariate Probit model assumes that each subject has T separate binary responses, and a matrix of covariates that can be any combination of discrete and continuous variables. Specifically, let Y_i= (Y_{i1}, Y_{iT}) denote the T dimensional vector of observed binary 0 and 1 responses on the i^{th} subject, i=1,…,n. Let X_i be a Txp design matrix and let Z_i= (Z_{i1},…Z_{iT})' denote a T-variate normal vector of latent variable such that:

$$Z_i = X_i\beta + \epsilon_i, i = 1, \dots, n \quad (1)$$

The relationship between Z_{ij} and Y_{ij} in the Multivariate Probit model is given by:

$$Y_{ij} = \begin{cases} 1\ if Z_{ij} > 0\ ; \\ 0\ otherwise \end{cases} j = 1, \dots, T \quad (2)$$

Double Hurdle model (Craggit model)

The Double Hurdle model allows for separate stochastic processes for participation and level of consumption decisions (Akinbode and Dipeolu, 2013; Eakins, 2013). The model was first proposed by Cragg in 1971 to allow for two independent processes within the analytical framework. Therefore, a positive observable use of agricultural extension package technologies inputs are dependent on both the choice of the household to adopt and the observed use of intensity. The first process is the decision to participate, and which has a dichotomous variable as the dependent variable. The second process measures the level of use. While the first process is similar to a Probit analysis is used to model the decision to participate, a truncated regression model determines the extent of use of the input. Since the first part of Double Hurdle model is similar with that the Multivariate Probit model result and it is discussed under Multivariate Probit model, only the second part of Double Hurdle model was discussed and analyzed to identify factors influence intensity use of agricultural extension package technologies. The Double Hurdle model is seen as an improvement to both the Tobit and the generalized Tobit (Heckit models) (Cragg, 1971; Eakins, 2013). The Cragg model explicitly allows the factors that determine the adoption and level of use to differ- an independent Double Hurdle model. Following Crag (1971) independent Double Hurdle model is specified as follows:

(A) The adoption decision Equation:

$$d_i^* = z_i{}'\alpha + \mu \quad (1)$$

where

$$d_i = \begin{cases} 1, if d^* > 0 \\ 0, \quad Otherwise \end{cases} \quad (2)$$

(B) The extent of use

$$y_i^* = x\beta + v_i \quad (3)$$

(C) The observed/positive use of agricultural extension package technology inputs

$$y - d_i \quad (4)$$

where d_i is the decision to adopt and y_i^* is the extent of use of the input adopted; y is the observed of agricultural extension package technology inputs use which is a function of both the decision to adopt and the extent of use. Also, μ, is the error term associated with the adoption decision and v_i is the error term associated with the extent of use equation. Thus, positive use of agricultural extension package technology inputs is observed if the household decides to adopt and also use the inputs chosen. Independence is achieved when the following is obtained with regards to the error terms of Equations 1 and 3, when:

$$\mu_i \sim N(0\,, 1)$$
$$v_i \sim N(0\,, \sigma)$$

That is, there is no correlation between the two error terms. The independent Double Hurdle model is estimated by maximum likelihood as follows:

$$LogL = \left[1 - \varphi(z_i\alpha)\varphi\left(\frac{x_i{}'\beta}{\sigma}\right)\right] + \sum_{+} ln\left[\varphi(z_i{}'\alpha)\frac{1}{\alpha}\varphi(y_i - x_i\beta)\right] \quad (5)$$

If $z_i\alpha$ =1 then there is no zero adoption and in fact we have a Tobit model, which just estimates the extent of use of the adoption. Where, z_i is the vector of socio economic characteristics and other factors that determine the choice of adoption of any agricultural extension package technology input method among the respondents; x_i is the vector of socioeconomic characteristics and other factors that determine the extent use of the agricultural extension package technology input adopted; α and β are parameters to be estimated. This study carried out its empirical analysis on the assumption that the decision to participate and the extent use of agricultural extension package technologies are independent of each other.

Variables definition and working hypothesis

Dependent variables

The AEPTs on the production of sorghum crop in the study areas were included in the model as dependent variables are use of four classes AEPTs of inputs: Y^* was measured using dummy variables with a value of one when the input is used and zero otherwise (inorganic fertilizer = Y_1; organic fertilizer = Y_2; crop protection chemicals =Y_3 and row planting=Y_4). Use of improved sorghum seed was dropped from dependent variables as users of this technology were very few in number. The intensity use of inorganic fertilizer, use of organic fertilizer, use of crop protection chemicals, and row planting were analyzed using the second part of Double Hurdle model for those households used the AEPTs on the production of sorghum crop in the study areas.

Inorganic fertilizer (Y_1): The use of inorganic fertilizer refers to application of available and supplied commercial fertilizer by the local government. The commonly used inorganic fertilizers in the study areas were NPS Boron, NPS Zink, NPS Boron Zink, NPS blend, Potassium, and urea. It takes the value "1" if one or more of these fertilizers are used on sorghum plot; and "0" otherwise. Question is followed by how much amount kilogram of inorganic fertilizer used by the household in the study year on sorghum crop planted plot if the response is positive to know intensity use of AEPTs in the study year.

Organic fertilizer (Y_2): Organic inputs included were application of compost, farmyard manure and bio-fertilizer. It takes the value "1" if one or more of these organic fertilizers are used; and "0" otherwise. Question is followed by how much amount in quintal used by the household in the study year on sorghum plot if the response is positive to know intensity use of AEPTs in the study year.

Crop protection chemicals (Y_3): It is the application of chemicals for controlling diseases, pests, and weeds. It takes the value "1" if one of crop protection chemicals is used and "0" otherwise.

Question is followed by how much amount in kilogram or liter of chemicals used by the household in the study year on sorghum plot if the household response is positive.

Row planting (Y_4): It is refers to the use of row planting for sorghum crop production using recommended row and plant spacing. It takes the value "1" if the row planting is undertaken by the household and "0" otherwise. Question is followed by how much areas of land in hectare was planted by the household using row planting in the study year on sorghum plot if his response is positive.

Table 2. Summary of independent variables and their hypothesis.

No.	Variable	Measurement	Hypothesis of relationship
1	Age of the household head	Continuous	+
2	Administrative or social position of the HH head	Dummy	+
3	Sex of the HH head	Dummy	-
4	Household family size	Continuous	+
5	Education level of the HH head	Continuous	+
6	Frequency of extension visit	Continuous	+
7	The agro-ecological location	Dummy	-
8	District	Dummy	-
9	Slope of the plot	Dummy	-
10	Distance of the plot from the residence	Continuous	-
11	Livestock holding (TLU)	Continuous	+
12	Off/non-farm income	Continuous	+
13	HH Perception on rainfall distribution in the coming crop year	Dummy	+
14	Credit received and utilized	Continuous	+/-
15	Market access	Continuous	+
16	Number of plots	Continuous	-
17	Plot area	Continuous	+
18	Farmers' training	Dummy	+

The independent variables expected to have relationship with the adoption decision and use of intensity AEPTs in the production of agricultural crops are selected based on existing literature. Based on this, 18 variables were selected of which 11 and 7 are continuous and dummy variables, respectively (Table 2).

RESULTS AND DISCUSSION

Before presenting and discussing the results obtained from the econometric models, it is important to briefly describe the socio-economic, demographic, institutional variables and AEPTs adopted using descriptive statistics. This would help to draw a general picture about the study area, AEPTs used and characteristics of sampled household farmers.

Socio-economic and demographic characteristics inputs used by sample households

The average family size for the sample households was about 7.09 persons and ranging between 2 and 15 persons (Table 3).

The mean age of the sample household heads was 41.81 years with a maximum of 75 and a minimum of 22 years. The average education level of the household was 2.05 years. The average area of cultivated, homestead, grazing land and forest land by the sample households of the two districts was 0.74, 0.072, 0.048 and 0.034 ha, respectively. The average land size of the household is 0.924 ha (Table 3). The average number of plots of the sampled households during the survey time was greater than one in number, that is, 1.48 in average. The farm plots of the households take 18.44 walking minutes from the house of the households. The average farming experience of sample households ranges from 9 to 52, with a mean value of 23.27 years. As indicated in Table 3, the average livestock holding was 3.47 TLU. On average 0.232, 0.515 and 0.042 ha of land was allocated for maize, sorghum and *khat* production, respectively during main season of crop year of the 2017/2018 by sample households.

The amount fertilizer (organic and inorganic) used varied from farmer to farmer; as a result of socio-economic, environmental and other factors. Survey result revealed that, average amount of use of fertilizer NPS, Urea and farm yard manure used by the sample households was 19.88 kg, 17.39 kg and 8.38 Quintals respectively (Table 3). As we can see from t-statistic there is significance difference between using these technologies between these two districts. Gemechis district is better using the technologies than Mieso districts because of different factors such as agro-ecology and rainfall distribution.

Agricultural extension package technologies used by households

As shown on Table 4, the result of the survey indicated that, 43.28 and 23.38% of the sample HHs use inorganic fertilizers NPS kinds with urea and urea with other fertilizers, respectively. Regarding organic fertilizer, farmyard manure and compost are the major inputs used

Table 3. Age, family structure, crops grown and inputs used by HHs during the 2017/18 production year.

Variable description	Mean			Std.	t-statistic
	Gemechis	Mieso	Both		
Age	42.59	40.62	41.81	9.57	1.43
Family size	6.89	7.41	7.09	2.32	-1.55
Adult equivalent	5.20	5.59	5.36	1.60	-1.60
Man equivalent	2.87	2.59	2.77	1.07	1.88*
Education level	1.80	2.43	2.05	2.86	-1.54
Cultivated land (ha)	0.47	1.16	0.74	0.49	-13.38***
Homestead area (ha)	0.029	0.136	0.072	0.096	-9.24***
Grazing land (ha)	0.044	0.054	0.048	0.187	-0.36
Forest land (ha)	0.052	0.006	0.034	0.127	2.55**
Total farm land (ha)	0.58	1.46	0.93	0.72	-10.60***
Home to plot average distance (min.)	12.81	26.97	18.44	15.98	-6.81***
Number of plots	1.42	1.58	1.48	0.59	-1.95*
Farming experience	25.25	20.27	23.27	10.48	3.38***
Livestock holding	2.87	4.39	3.47	2.44	-4.53***
Total cultivated Land	0.519	1.397	0.865	0.76	-10.78***
Maize	0.125	0.395	0.232	0.27	-7.79***
Sorghum	0.25	0.917	0.515	0.45	-14.93***
Other crops	0.016	0.003	0.012	0.043	2.15**
Vegetables	0.033	0	0.020	0.06	3.98***
Khat	0.066	0.006	0.0422	0.097	4.48***
NPS	27.24	8.75	19.88	27.63	4.90***
Urea	10.51	4.53	8.13	17.39	2.41***
Farm yard manure	10.89	4.57	8.38	12.87	3.5***

***, ** and * represents significance at 1, 5 and 10% probability level, respectively.
Source: Own computation (2019).

by the farmer in the study areas. Majority (62.19%) of the sample households used farm yard manure and 13.43% of the sample households used compost. Out of the total respondent, only 5.47% of the respondent use improved sorghum varieties in the study areas. Thus, this shows more work is needed to improve utilization of improved sorghum varieties so that productivity of sorghum production can be improved.

Farmers use crop protection chemicals for controlling weeds, worms, pests, insects and diseases. Even though, some of the farmers used crop protection chemicals to control weeds most of the farmers prefer manual weeding. Out of the total respondent, only 12.44% used crop protection chemicals. Of the total household interviewed, only 25% of sample respondent household used row planting on production of sorghum crop.

Sample households used different types of inorganic fertilizers provided by the local government to the study areas. Among the supplied inorganic fertilizer, NPS and Urea are the common ones. From the total sample household respondents, 55.72% did not use any type of inorganic fertilizer. When we compare the two districts, 82.5% of sample households of Mieso district household did not use any kind of fertilizer as this district unsuitable agro-ecology for crop production and low annual rainfall amount and distribution.

Out of the total household respondents, 11.94, 8.96 and 1% used NPS only, NPS Boron, and Urea, respectively. Of the total respondents, 6.47% used NPS Boron and Urea in combination (Table 4). Of the total respondents, 15.9% used NPS and Urea in combination.

Summary of dependent and independent variables

The dependent variables include the inorganic fertilizer, organic fertilizer, row planting and crop protection chemical used as shown in Table 5). The independent or continuous variables are as shown in Table 6. Also, the independent or dummy variables are mentioned in Table 7.

Econometric result analysis

Multivariate Probit model was selected to know factors that affect adoption decision of agricultural extension package technologies by farmers to maintain or improve

Table 4. Farmers adopted ınorganic and organic fertilizer and other inputs in 2017/18 production year.

Inputs used	Gemechis		Mieso		Both	
	Freq.	%	Freq.	%	Freq.	%
No use of any fertilizer	46	38.02	66	82.50	112	55.72
NPS (all kinds)	73	60.33	14	17.50	87	43.28
NPS only	24	19.83	0	0.00	24	11.94
NPS Boron	18	14.88	0	0.00	18	8.96
NPS Boron and Urea	13	10.74	0	0.00	13	6.47
NPS and Urea	19	15.70	13	16.25	32	15.9
Urea (with other fertilizers)	34	27.27	14	17.50	47	23.38
Urea only	1	0.83	1	1.25	2	1.00
Farm Yard Manure (FYM)	95	78.51	30	37.50	125	62.19
Compost	24	19.83	3	3.75	27	13.43
Improved sorghum seed	8	6.60	3	3.75	11	5.47
Crop protection chemicals	16	13.22	9	11.25	25	12.44
Row planting	49	40.50	1	1.25	50	25

"Freq." refers to frequency.
Source: Own survey (2019).

Table 5. Dependent variables.

No.	Types of variable	Unit	Mean	Sd.	Total number of users	%	Total number of non-users	%
1	Inorganic fertilizer use	kg	28. 002	40.36	89	44.82	112	55.72
2	Organic fertilizer use	Qn	8.30	12.99	75	37.31	126	62.69
3	Row planting Use	-	-	-	50	24.88	151	75.12
4	Crop protection chemical use	-	-	-	25	12.44	176	87.56

Source: Own computation (2019).

their plots productivity. The model was selected based on the justification discussed earlier in the methodology part. The adoption of improved sorghum variety by household farmer in the study areas was very small and it was dropped out from the Multivariate Probit model analysis. This study identified the most important determinants affect decision to use AEPTs using a Multivariate Probit model.

The result of the Multivariate Probit model shows that, the likelihood ratio test P (χ^2) (6)>20.324 = 0.0024 of the independence of the disturbance terms (independence of choice of multiple decision in using AEPTs) is rejected, implying that selection of several options of AEPTs in the study areas is interdependent and supporting use of Multivariate Probit model. The binary correlations between the error terms of the four agricultural extension package technologies are shown in Table 8. Results of the correlation between the error terms on Multivariate Probit model indicate that, some AEPTs are substitutes or compete (negative sign) and some are complements (positive sign). The correlation coefficients are statistically significant in two of the six pairs, confirming the suitability of Multivariate Probit specification choice and the choice of agricultural extension package technologies are interdependent.

The correlation coefficients of the error terms are significant for two relations indicating that they are correlated and insignificant for four pair equations indicating that they are not correlated. The simulated maximum likelihood estimation results suggested that, there was negative and significant interdependence between household decision to use organic fertilizer and row planting. This is due to these two technologies are labor intensive technologies and competes for the same labor forces. There was positive and significant interdependence between household decision to use inorganic fertilizer (NPS and urea) and row planting. This may be due to the fact that, once the famer decided to use inorganic fertilizer, row planting was used so that he can maximize the return he will get from the product. Multivariate Probit model regression output revealed that, the likelihood of household to use inorganic fertilizer NPS and urea, organic fertilizer, row planting and crop protection chemicals were 43.44, 63.07, 25.05 and

Table 6. Independent (Continuous) variables.

No.	Types of variable	Unit	Minimum	Maximum	Mean	Sd.
1	Age of the household	Year	22	82	42.08	9.94
2	Level of education of the household	Years of schooling	0	11	2.05	2.86
3	Family size of the household	Man equivalent	0.9	7.8	2.77	1.06
4	Frequency of extension contact	Frequency of visit	0	52	19.06	14.33
5	Distance of the farm plot	Minutes	2	90	18.44	15.98
6	Livestock holding of the household	TLU.	0	17.96	3.47	2.44
7	Off-farm income of the household	Birr	0	20000	775.12	2393.75
8	Credit received and utilized	Birr	0	10000	170.64	1045.55
9	Average market distance	Minutes	0	225	80.39	41.49
10	Number of farm plots	No.	1	3	1.48	0.59
11	Total farmland	Hectare	0.125	5.25	0.936	0.72

Source: Own computation (2019).

Table 7. Independent (Dummy) variables.

No.	Type of variables	Frequency	%	Frequency	%
1	Sex of the household head	Male 175	87.06	Female 26	12.94
2	District of the household	Gemechis 121	60.20	Mieso 80	39.80
3	Responsibility of the household heads	No responsibility 122	60.70	Have responsibility 79	39.30
4	Agro-ecology of the household lives	Highland/Midland 91	45.27	Lowland 110	54.73
5	Perception about the coming rainfall distribution	Better 93	46.27	Bad 108	53.73
6	Slope of the sorghum plot	Flat 132	65.67	Steep 69	34.33
7	Participation on training by the household	Participated 76	37.81	Did not participated 125	62.19

Source: Own computation (2019).

12.51%, respectively as shown in Table 9. As indicated in Table 9. Multivariate Probit model output also indicates that, the joint probability of using all agricultural extension package technologies options was only 3.19% and the joint probability of failure to use all of the agricultural extension package technologies was 24.82%. This implies the probability to use full extension package technologies is 3.19% which is very low at this time. Thus, more efforts and interventions are needed by concerned sectors and stakeholders to improve the probability of using all agricultural extension package technologies in holistic approach in sorghum crop production. In contrast to this, the probability of failure or not to use all agricultural extension package technologies is higher which should be minimized by encouraging adoption full extension package.

Determinants of adoption decision of agricultural extension package technologies

Multivariate Probit model is regressed for 18 explanatory

Table 8. Multivariate Probit simulation result for households agricultural extension package technologies decision to use.

Explanatory variable	Use of inorganic fertilizer (NPS and urea)	Use of organic fertilizer (FYM)	Use of Row planting	Use of crop protection chemicals
	Coefficient (Std. error)	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**
Sex*	0.026 (0.365)	-0.015 (0.334)	-0.356 (0.387)	-0.231 (0.433)
Age	0.002 (0.144)	0.008 (0.014)	-0.003 (0.015)	0.004 (0.017)
District*	-1.308*** (0.503)	-1.406*** (0.498)	-3.147*** (0.890)	-0.179 (0.586)
Education level	-0.015 (0.054)	-0.091* (0.050)	0.028 (0.062)	0.044 (0.056)
Household size	0.441*** (0.138)	-0.078 (0.117)	0.255** (0.128)	0.201 (0.151)
Responsibility of the household	0.059 (0.252)	0.488** (0.246)	0.355 (0.263)	0.305 (0.290)
Agro-ecology* (lowland)	0.418 (0.279)	0.437 (0.291)	0.272 (0.283)	0.315 (0.345)
Extension visit	0.022** (0.010)	0.011 (0.009)	0.010 (0.012)	0.006 (0.012)
Slope of the plot* (Flat)	0.051 (0.156)	-0.014 (0.158)	-0.243 (0.164)	-0.192 (0.177)
Average distance of the plots from the residence	0.001 (0.008)	0.001 (0.008)	-0.012 (0.011)	-0.014 (0.011)
Livestock holding	0.103* (0.059)	0.101* (0.054)	0.160* (0.090)	-0.012 (0.079)
Credit utilized (ln)	-0.026 (0.071)	-0.003 (0.086)	-0.062 (0.077)	0.092 (0.065)
Perception of the HH about future rainfall distribution	-1.023*** (0.225)	-0.681*** (0.124)	-0.489** (0.206)	-0.480** (0.236)
Off/Non farm income of the HH	0.058 (0.041)	-0.006 (0.051)	0.010 (0.039)	-0.044 (0.048)
Market distance from the residence	0.006 (0.004)	-0.0001 (0.004)	0.004 (0.005)	0.003 (0.004)
Number of plots	-0.263 (0.245)	0.299 (0.217)	0.014 (0.257)	0.392 (0.258)
Total farmland owned by the HH	-0.215 (0.262)	-0.002** (0.240)	-0.092 (0.304)	-0.166 (0.317)
Participation of the HH on training	0.581* (0.314)	0.527 (0.265)	0.139 (0.358)	0.803* (0.447)
Constant	0.516 (1.091)	1.661 (1.065)	2.654** (1.312)	-2.208* (1.326)
Mean of Linear prediction of each equation	-0.270	0.506	-1.428	-1.502
Std .error of each prediction	0.504	0.477	0.656	0.599
Marginal success probability for each equation	0.4343	0.6307	0.2504	0.1251
Joint probability (success)	0.0318			
Joint probability (failure)	0.2481			
Correlation between independent variable	**Coefficient (Std. error)**			
Rho21	-0.302(0.191)			
Rho31	0.569***(0.133)			
Rho41	-0.195(0.196)			
Rho32	-0.477***(0.183)			
Rho42	-0.078(0.220)			
Rho43	-0.117(0.303)			

***, ** and * represent significance at 1, 5 and 10% probability level, respectively. Number of observations, 201; Number of simulations, 18; Log likelihood, -288.4647; Wald $\chi^2(72)$, 179.69; Log likelihood ratio test of $Rh_{ij}=0$, P> χ^2 (6) >20.3245, 0.0024.
Source: Multivariate Probit model output (2019).

Table 9. Intensity use of agricultural extension package technologies.

Explanatory variable	Second Hurdle model output (Use of Intensity)		
	Inorganic Fertilizer (NPS and urea)	Organic Fertilizer (FYM)	Row Planting
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Sex	4.928 (11.762)	-0.483 (13.761)	0.038 (0.035)
Age	-0.037 (0.544)	-0.158 (0.510)	0.001 (0.001)
District	-20.297 (19.486)	-36.447** (14.836)	0.103 (0.1070
Education level	0.704 (1.747)	0.805 (1.612)	0.004 (0.006)
Household size	14.874*** (3.548)	1.431 (4.156)	0.017 (0.012)
HH Responsibility	-10.737 (8.384)	-4.853 (8.375)	0.011 (0.026)
Agro-ecology	6.662 (16.470)	13.897 (9.760)	-0.010 (0.043)
Frequency of extension visit	0.6157* (0.358)	1.237** (0.515)	0.002** (0.001)
Average distance of the plots	-0.378 (0.3289)	-0.154 (0.288)	0.000 (0.001)
Livestock holding	4.304* (2.607)	-1.380 (2.189)	-0.028** (0.010)
Credit utilized (ln)	1.110 (2.319)	-3.710 (3.511)	-0.022*** (0.008)
Off/Non-farm income (ln)	-1.232 (1.212)	-5.233*** (2.004)	0.014*** (0.004)
Per. HH about coming RF	-21.103* (11.309)	-0.133 (6.452)	-0.044* (0.023)
Average market distance	-0.116 (0.133)	-0.325** (0.156)	0.001** (0.000)
Number of plots	10.695 (7.779)	20.198** (9.005)	-0.012 (0.054)
Total farmland owned	16.256* (8.984)	7.530 (10397)	0.127**0 (.054)
HH participation on training	-19.279* (10.226)	-18.689 (11.772)	-0.095** (0.042)
Constant	28.754 (33.392)	-14.468 (3.900)	0.045 (0.153)
Sigma	30.379*** (2.865)	21.01***4 (3.900)	0.078*** (0.008)
Number of Observations	89	126	50
Log likelihood	-493.105	-502.123	-16.510
Wald χ^2 (17)	69.19	60.98	31.65
Probability > χ^2	0.000	0.000	0.016
Akaike Information Criteria (AIC)	1060.211	1078.248	107.021

Source: Double Hurdle Model Output (2019).

variables to know factors that affect adoption decision of agricultural extension package technologies on sorghum crop production and the output of the model is presented on Table 9.

The variable district and perception of expectation of household on the coming rainfall from better to bad negatively and significantly influences probability to use inorganic fertilizer at 1% significance level of sorghum crop production. This means that, when we move from Gemechis to Mieso district the probability of using inorganic fertilizer decline. As household perceive negatively toward the coming rainfall distribution, the probability of using inorganic fertilizer become decline. Household family size and frequency of extension visit positively affects adoption decision of inorganic fertilizer at 1 and 5% significance level, respectively. Households with more family size have more probability of using inorganic fertilizer than those households with smaller family size on sorghum crop production. This may be due to those households who have more labor force may produce more output and earn more than those households who have smaller number labor force to purchase inorganic fertilizer. The positive relationship between household family size and adoption decision of inorganic fertilizer is also similar with that of Hassen et al. (2012) and Teame (2011). The positive relationship between frequency of extension visit and adoption decision of inorganic fertilizer is also similar with findings of Umeh and Ekwengene (2017) and Beshir et al. (2012). Livestock holding and participation of household farmer on agricultural training positively affect adoption decision of inorganic fertilizer plots at 10% significance level on sorghum crop production. The positive relationship between livestock holding and adoption decision of inorganic fertilizer may due to the fact that those households who own more livestock have probability of earning more income from the sale of their livestock and livestock products which help them to purchase inorganic fertilizer. However, study by Degefu and Mengistu (2017) shows that, the relationship between livestock holding adoption decision of inorganic fertilizer is negative.

The variable district and education level negatively and significantly affects adoption decision of organic fertilizer at 1 and 10% significance level on sorghum crop production, respectively. The negative relationship between education level and adoption decision of inorganic fertilizer is unexpected. This may be due to house who are educated are younger in age and they have smaller size of land which hinder them to use more inorganic fertilizer. The responsibility of the household and livestock holding positively affects adoption decision of organic fertilizer at 5 and 10% significance level on sorghum crop production, respectively. Livestock holding increases the probability of adoption decision of organic fertilizer at 10% significance level on sorghum crop production. The implication of this is because of those households who own more livestock obtain more livestock farmyard manure and eventually can use more organic fertilizer. Expectation of household on the coming rainfall from better to bad negatively affects adoption decision of organic fertilizer at 1% significance level. This means that, as household expectation is negative toward the coming rainfall distribution, the probability of using organic fertilizer declined. Participation of household farmer on agricultural training positively affects adoption decision of organic fertilizer at 5% significance level on sorghum crop production.

The variable district and household family size positively and significantly affects adoption decision of row planting at 1 and 5% significance level of probability on sorghum crop production, respectively. This means, households with more family size have more probability of using row planting than those households with smaller family size on sorghum crop production. The result might be due to household with more labor force have better probability of using row planting than household with smaller family size, since this activity is labor intensive. The result of MVP indicates that, being having more livestock holding increases the probability of adoption decision of row planting at 10% significance level on sorghum crop production. The implication for the positive relationship between livestock holding and adoption decision of row planting might be due to row planting activity utilizes more labor and requires hiring labor force. This is easy for those households who own more livestock since they solve problem of shortage of cash liquidity to hire labor force, so that they earn income from livestock and livestock products sales. Perception of expectation of household on the coming rainfall from better to bad negatively affects use of row planting and use of crop protection chemicals at 5% significance level. This means that, as household perception of expectation on the coming rainfall is negative, the probability of using crop protection chemicals declined. Rural household farmer forecast about the coming rainfall distribution based on the temporary weather condition of their areas.

Intensity use of agricultural extension package technologies

Double Hurdle model measures the decision and the extent to use with respect to a unit change of an independent variable on the expected value (mean proportion) of the dependent variable. Decision to use of agricultural extension package technologies were already analyzed and interpreted under Multivariate Probit model. In this case, only the Second Double Hurdle part is analyzed and interpreted. Three of the agricultural extension package technologies such as inorganic fertilizers (NPS and urea), organic fertilizer (farm yard manure), and row planting are selected and discussed because they were practiced by significant numbers of the farmer households. The determinants of intensity to use three agricultural extension package technologies such as inorganic fertilizers (NPS and urea), organic fertilizer (farmyard manure) and row planting which were undertaken by majority of the farmers are shown in Table 9.

The choice to use one new technology and the level of using may not be the same. In this case, selection of appropriate model is very crucial. Decision to adopt AEPTs was already discussed under Multivariate Probit model. Therefore, here, only intensity use of AEPTs in the second part of Double Hurdle model is discussed and analyzed.

Double Hurdle model result revealed that, when household family size increased by 1 man equivalent intensity use of inorganic fertilizer increases by 14.87 kg at 1% significance level keeping other factors constant. This may be due to households with more labor force engage in different economic activities; they may earn more income and get more chance to purchase more amount of inorganic fertilizer. The Double Hurdle model output reveals that, as frequency of extension visit increase by one contact, use of inorganic and organic fertilizer increase by 0.615 kg and 1.23 Quintals at 10 and 5% significance level on sorghum crop production, respectively keeping other factors constant. This indicates that, the level use of inorganic and organic fertilizer increases when contact of development agent advice increases as more advices motivate to use more inputs. Double Hurdle model result revealed that, when livestock holding and total farm land owned increases by 1TLU and 1 ha, intensity use of inorganic fertilizer increases by 4.30 and 16.256 kg, respectively at 10% significance level of probability by keeping other factors constant. The positive relationship between total farm land and intensity use of inorganic fertilizer may be due to farmers who own more land use more inorganic fertilizer because of economies of scale which make them reduce total cost per hectare. The Double Hurdle model output shows that, when off-farm income increases by 1% intensity use of organic fertilizer decreases by 5.23 Quintals at 1% significance level on sorghum crop production. The implication for this may be due to the fact that inorganic and organic fertilizers are two substitute goods and as a result those who earn more income may prefer to use inorganic fertilizer than using organic fertilizer as use of inorganic fertilizer less labor intensive input. The Double Hurdle model output indicates that, as average market distance increase by one minute, intensity use of organic fertilizer increases by 0.32 Quintal at 5% significance level on sorghum crop production. The implication of this may be due to the fact that when market distance increase frequency of household to go repeatedly to the market decline and eventually get more time to use organic fertilizer. The Double Hurdle model output shows that, as number farm plot increases by one use of organic fertilizer increases by 20.19 Quintals at 5% significance level on sorghum crop production. The implication of positive relationship between organic fertilizer use and number of farm plot might be due to the fact that farmer use organic fertilizer on some plots and inorganic fertilizer on other plots because using inorganic fertilizer on all plots may be difficult to afford the high price of inorganic fertilizer. The Double Hurdle model output shows that, as household perception change from better to bad, use of intensity of inorganic fertilizer and row planting decrease by 21.103 kg and 0.044 ha at 10% significance level, respectively by keeping other factors constant.

The Double Hurdle model output indicates that, as frequency of extension visit increases by one contact use row planting increases by 0.002 ha at 5% significance level on sorghum crop production. The Double Hurdle model output also shows that, as livestock holding increase by one TLU, use of row planting decreases by 0.028 hae at 5% significance level on sorghum crop production. This may be due to the fact that row planting and managing livestock are labor intensive activities compete for the same labor force. The Double Hurdle model output reveals that, as credit received and utilized increase by 1% use of row planting decreases by 0.022 ha at 5% significance level on sorghum crop production. The Double Hurdle model output also reveals that, when off-farm income and average market distance increases by 1% and 1 min use of row planting increases by 0.014 and 0.001 ha at 1 and 5% significance level, respectively by keeping other factors constant on sorghum crop production. The Double Hurdle model output depicts that, household who participate on agricultural training 0.095 ha and 19.279 kg uses less row planting and inorganic fertilizer at 5 and 10% significance level, respectively than who does not participate on training by keeping other factors constant. The relationship between participation on agricultural training and use of row planting and inorganic fertilizer is unexpected. The implication for the may be household who are screened for agricultural training based on the criteria than selecting model farmers for agricultural training or system of agricultural training have its own problems. Thus, concerned sector should revisit the procedure of screening farmers for agricultural training. Moreover, effectiveness and efficiency of agricultural training provided for farmers should be identified by undertaking further researches.

CONCLUSION AND RECOMMENDATIONS

The study identified the determinants of household's decision to use agricultural extension package technologies using Multivariate Probit model. The correlation between the error terms of different equations were significant indicating that, some AEPTs options such as inorganic fertilizer and row planting complement each other and others such as organic fertilizer and row planting substitutes each other. Multivariate Probit model regression output reveals that, the probability of the household to use organic fertilizer (NPS and Urea), organic fertilizer (farmyard manure), crop protection chemicals and row planting were 43.43, 63.07, 12.51, and 25.04%, respectively. The result also shows that the joint probability of using all agricultural extension package technologies is only 3.18% and the joint probability of failure to use all the agricultural extension package technologies options is 24.81%. Multivariate Probit model result also confirm that, district of the household, education level of the household, household family size, responsibility of the household, extension visit, livestock holding, perception of the expectation of the coming rainfall, total farm land owned and participation on agricultural training significantly influence adoption decision of different agricultural extension package technologies.

The result of the Double Hurdle model shows that, district of the household, frequency of extension visit, livestock holding, credit, off/non-farm income, perception of the expectation of the coming rainfall, average market distance, number of farm plot, total farm land and participation on agricultural training significantly affect intensity use of different agricultural extension package technologies. Various interventions are needed on significant factors such frequency extension visit, livestock holding, credit, off/non-farm income, perception of the expectation of the coming rainfall, average market distance, number of farm plot, total farm land and participation on agricultural training by concerned stakeholders. Multivariate Probit model shows that, there is interdependence of agricultural extension package technologies. Therefore, further research is needed to know how and why these technologies compete or substitute each other and identify optimum combinations of these technologies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agricultural Transformation Agency (ATA) (2014). Innovations in

Improving Access to Inputs to Smallholder Farmers in Ethiopia.
Akinbode SO, Dipeolu AO (2013). 'Double Hurdle Model of Fresh Fish Consumption among Rural Households in South West Nigeria. Current Research Journal of Social Sciences 4(6):431-439.
Central Statistical Agency (CSA) (2008). Agricultural Sample Survey 2006/7.Volume IV: Report on Report on Area and Production of Major crops.
Central Statistical Agency (CSA) (2017). Agricultural Sample Survey Report on Area and Production of Major crops.
Cochran WG (1977). Sampling Techniques, 3rd Ed., New York: John Wiley and Sons, Inc. Aldrich, J.H. and F.D., Nelson. 1984. Linear Probability, Logit and Probit Model: Quantitative Application in the Social Science. Sage publication Inc, University of Minnesota and Iola, London.
Cragg JG (1971). 'Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. Econometrica 39(5):829-844.
Degefu K, Mengistu K (2017). Why do Smallholder Farmers Apply Inorganic Fertilizers below the Recommended rates? Empirical Evidence from Potato Production in Eastern Ethiopia. Advances in Crop Science and Technology 5(265):2.
Eakins J (2013). An Analysis of the Determinants of Household Energy Expenditures: Empirical Evidence from the Irish Household Budget Survey'. Unpublished PhD Thesis in Economics, University of Surrey, May 2013.
Fufa B, Hassan RM (2006). Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption. Agrekon 45(1):38-49.
Hassen B, Bezabih E, Belay K, Jema H (2012). Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: The double hurdle approach. Journal of Research in Economics and International Finance 1(2):39-49.
IRIN (Integrated Regional Information Networks) (2012). Humanitarian News and Analysis Ethiopia. IRIN, Nairobi, Kenya.
Kalix P (1984). The Pharmacology of Khat. The pharmacology of khat. General Pharmacology: The Vascular System 15(3):179-187.
Kamau M, Smale M, Mutua M (2013). Farmer Demand for Soil Fertility Management Practices in Kenya's Grain Basket. Selected Paper Prepared for Presentation at the Agricultural and Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting. Washington, DC.
Mabiratu D, Prem KD (2020). Analysis of Climate Variability and Adaptive Strategies of Rural Household: The Case of Abobo District and Itang Special Districts, Gambella Region State, Ethiopia. Asian Journal of Agricultural Extension, Economics and Sociology 38(4):82-93.
Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA) (2014). National Strategy for Ethiopia's Agricultural Extension System Vision, Systemic Bottlenecks and Priority Interventions.
Ministry of Agriculture (MoA) (2010). Participatory Extension System. Addis Ababa, Ethiopia.
Muhammed SH (2020). Adoption of NPS Fertilizer on Sorghum Crop Production by Smallholder Farmers in Gemechis and Mieso Districts of West Hararghe Zone, Oromia Regional State, Ethiopia. Journal of Materials Science Research 9(2).
Tabet A (2007). Bayesian Inference in the Multivariate Probit Model. Estimation of the Correlation Matrix. MSc. Thesis. The University of British Columbia.
Teame H (2011). Factors Determining Fertilizer Adoption of the Peas Northern Ethiopia, Tigray Region. MSc. Thesis. Department of Economics and Resource Management. Norwegian University of Life Sciences. Ås, Norway.
Tekalign D, Andualem M, Markos T (2011). Khat Chewing and Mental Distress: A Community Based Study, In Jimma City, Southwestern Ethiopia. Ethiopian Journal of Health Science 21(1).
Umeh OJ, Ekwengene HN (2017). Determinants of Utilization of Agricultural Extension Packages of Selected Arable Crops Among Farmers in Enugu State, Nigeria. Agricultural Research and Technology: Open Access Journal 3(3):73-80
West Hararghe Zone of Agricultural Office (WHZAO) (2017). West Hararghe Zone Agricultural Office Report of Cultivated and Planted Land in 2016/2017 crop year. Chiro, Ethiopia.
Wondimagegn T, Lemma S (2016). Climate change perception and choice of adaptation strategies: Empirical evidence from smallholder farmers in East Ethiopia, International Journal of Climate Change Strategies and Management 8 (2):253-270.