International Journal of Foodand Agricultural Economics
ISSN 2147-8988
Vol. 2 No. 4, (2014), pp. 91-106

ADOPTION AND IMPACT OF AGRICULTURAL TECHNOLOGIES ON FARM INCOME: EVIDENCE FROM SOUTHERN TIGRAY, NORTHERN ETHIOPIA

Berihun Kassa Hailu
College of Social Science and Humanities, Samara University, P.O. Box 132, Samara, Ethiopia, E-mail: berihun2@gmail.com, Phone: +251 913 28 55 45

Bihon Kassa Abrha
College of Business and Economics, Mekelle University Ethiopia

Kibrom Aregawi Weldegiorgis
College of Business and Economics, Mekelle University, Ethiopia

Abstract

The importance of agricultural technology in enhancing production and productivity can be realized when yield increasing technologies are widely been used and diffused. Standing from this logical ground, this paper aimed at identifying the determinants of agricultural technology adoption decision and examining the impact of adoption on farm income. Cross sectional data was collected through semi-structured questionnaire administered on 270 randomly selected smallholder farmers. Probit and Ordinary Least Square (OLS) regression models were employed. Consistent with the findings of previous studies, regression results showed that agricultural technology adoption decision of farm households has been determined by irrigation use, land ownership right security, credit access, distance to the nearest market, plot distance from the home stead, off-farm participation and tropical livestock unit. The regression result also revealed that agricultural technology adoption has a positive and significant effect on farm income by which adopters are better-offs than non-adopters.

Key words: *Technology, adoption*, *Agriculture, Ordinary Least Square, Probit*

1. Introduction

The importance of agricultural technology adoption in ending poverty and food insecurity has been well discussed by Besley and Case (1993); Doss and Morris (2001); Mendola (2007); and Becerril and Abdulai (2009).According to Ajayi *et al*.(2003), Gemeda *et al*. (2001) and Morris *et al*. (1999) in developing countries, improving the livelihoods of rural farm households via agricultural productivity would remain a mere wish if agricultural technology adoption rate is low. Hence, there is a need to adopt the proven agricultural technologies so as to heighten production as well as productivity and thereby the living condition of the rural poor. Furthermore, for developing countries, the best way to catch developed countries is through agricultural technology diffusion and adoption (Foster and Rosenzweig, 2010). Additionally, in Nigeria, Uaiene *et al*. (2009) have had acclaimed as if production and productivity would likely to slow down and rural poverty would prevail more if attention is not given to the use and adoption of agricultural technologies. Datt and Ravallion (1996) and Hossain (1992) have purported that, since the need of the rapidly growing population could not be meet by expanding the area under cultivation, developing, employing and disseminating yield increasing agricultural technologies is imperative. In their finding, Ibrahim *et al.* (2012) purport about the direct effect of technology adoption on the farmer's income resulting from higher yields and prices. In line with this thought, according to Besley and Case (1993) purport that, adoption of HYV has long been taken as a solution to heighten agricultural income and diversification.

Commensurately, agricultural productivity can be ensured either by producing higher per unit of land using agricultural inputs or by expanding the area under cultivation. Adoption and proper utilization of yield increasing technologies, in Asia, have resulted with what we call it Green Revolution (World Bank, 2008) where its replication in African countries is paramount importance for increasing productivity.

As part of developing countries in general and Sub-Saharan Africa in particular, Ethiopia is an agrarian country that predominantly relied on subsistence agriculture. According to Ministry of Finance and Economic Development (MoFED, 2003), since 1990s as a national strategy, Ethiopia has espoused Agricultural Development-Led Industrialization (ADLI) which predominantly advocates smallholder agriculture and their transformation in to commercial agriculture by employing agricultural technologies. Supporting this, Ministry of Agriculture and Rural Development (MoARD, 2010) inferred that majority of the country's total production is been produced by smallholder farmers; and the sector contributes 90% of the foreign earnings and 70% of the raw materials for industry. Although the sector contributes this much, due to insufficient rate of production and productivity, persistent poverty and drought are actually the main manifestations. To trim down and make poverty history, the country has designed and been implementing different poverty reduction papers including Sustainable Development and Poverty Reduction Program (SDPRP), the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) and Growth and Transformation Plan (GTP).

Basing from the logical ground of limited arable land size and understanding the priceless importance of agricultural technologies, in Ethiopia, procurement and distribution of agricultural inputs more particularly HYVs and chemical fertilizer have been the central patterns of the above mentioned poverty reduction papers. Despite the relentless government and policy efforts, in Southern part of Tigray region particularly in Raya-Azebo and Raya-Alamata districts, employing these agricultural technologies is at its grass-root level and been employed reluctantly as has been reported by Bureau of Finance and Economic Development (BoFED,2011) of Tigray regional state in the final report of PASDEP. Far beyond this well-recognized reluctant usage, in the districts, agricultural technology adoption rate is too slow where its impact on farm income is not well understood and exemplified. Therefore, the general objective of this paper is to identify the determinants of farm households' agricultural technology adoption decision and to examine the impact of adoption on farm income of Tigray region particularly in Raya-Azebo and Raya-Alamata districts.

2. Review of Related Literature

Traditionally, according to Foster and Rosenzweig (1996) and Kohli and Singh (1997) agricultural technology adoption decision was seriously been determined by imperfect information, risk, uncertainty, institutional constraints, human capital, input availability and infrastructural problems. As a remedy for such traditional conception, Sasakawa Global 2000 (SG-2000) program is been in place and intended to work with smallholder farmers and their respective agriculture ministry's so as to increase agricultural production and productivity by employing agricultural technologies that could best keep soil fertility. The program has put farmers as the forerunners and drivers in adopting agricultural technologies and promotion of agricultural intensification. According to Crawford *et al*. (2005); Galiba *et al*. (1999); Nubukpo and Galiba (1999); Gakou *et al*. (1995); Brown and Addad (1994) and Smaling (1993) when soil degradation is rampant the program, SG- 2000, has obliged to use organic and mineral fertilizer as well as the natural phosphate; all to be backed by technological package options. Following the advent of SG- 2000, the determinants of agricultural technology adoption decision of farm households turned to be mainly social networks and learning (Bandiera & Rasul, 2002); and adoption would be in place through farmers' own and neighbors' experience (Foster & Rosenzweig, 1995).

In a certain country, chemical fertilizer adoption can be determined by economic, social, physical and technical aspects of farming (Abay & Assefa, 2004); and these aspects influence the type of crops to be grown and the production method to be used (Sassenrath Schneider *et al*. 2012). According to Yanggen *et al*. (1998), in Africa in general and SSA in particular, fertilizer use capacity is being determined by human capital (basic education, extension and health/nutrition); financial capital (income, credit and assets); basic services (infrastructure, quality controls and contract enforcement, information and government policies); yield response (biophysical environment, technology and extension) and input and output prices (structure conduct and performance of subsector, competition efficiency and equity). In Madagascar, according to Minten *et al*. (2006) chemical fertilizer adoption was determined by the financial capital (income and credit) and farmers' willingness to invest.

Similar with the findings of Solomon *et al*. (2011) in Malawi and Minten *et al*. (2006) in Madagascar, in Ethiopia, Samuel (2006) found that farmers are too reluctant to use chemical fertilizer as they believe it will damage the crop due to the erratic rain fall nature; poor marketing capabilities, high transportation costs, weak extension services, lack of credit and unpredictable rain fall (Wallace & Knausenberger, 1997).

Despite the priceless importance of HYV, in developing countries, according to Dixon *et al*. (2006), during 1988-2002, of the total 1700 released improved wheat varieties, small varieties have been adopted. Furthering the problem of adoption, in Mali, although there are varieties of yielding enhancing seeds, Christensen and Cook (2003) found as if farmers do prefer their indigenous seed mainly in transacting and exchanging with their neighbors. In Ethiopia, due to awareness problem about the vitality of HYV and in fear of keeping seeds without losing its originality, farmers prefer to adopt seeds that are already deformed, diseased, mixed origin and unmarketable (Eshetu *et al*., 2005); due to the in hospitability of the physical environment and poor market infrastructure network, HYV is considered as complimentary for indigenous seeds (Benin *et al*., 2003).

3. Methodology

3.1 Sampling Method and Data Collection

A cross sectional primary data was collected through semi-structured questionnaire administered on 270 randomly selected smallholder farmers in 2013 cropping year; 172 and 98 households from Raya- Azebo and Raya-Alamata districts of Tigray region respectively. For validity of the data collection instrument and reliability of the collected data, purposefully, the questionnaire was pre-tested and pilot study was conducted. Primary data was supplemented by interview, focus group discussion and secondary data from the bureau of agriculture and finance and economic development. The research used a multi stage stratified random sampling method. Firstly, districts that are conducive for agriculture were selected purposively by the overall researchers' affiliation to the study area. Secondly, of the total 29 sub-districts, four sub-districts were selected randomly. Thirdly, eleven villages were selected proportionally where sub-districts with larger number of villages were given more weight. Fourthly, villages' sample size was determined proportionally from the already defined sample size from which adopters and non-adopters were identified; and finally, final respondents were selected randomly from the list of the farm households from each targeted villages; where its detail is described in table 1 below.

Table 1.Targeted Sub-Districts, Their Total Population and the Sample Size Taken

No	Sub-district	Population size	Sample Size				Total
			Adopters		Non-Adopters		
			Fertilizer	HYV	Fertilizer	HYV	
1	Bala-Ulaga	2164	25	15	38	48	63
2	Kukufito	3784	17	34	92	75	109
3	Lemeat	1697	10	23	39	26	49
4	Tao	1697	20	21	29	28	49
	Total	9342	72	93	198	177	270

Source: Own Computation, 2014

3.2 Theoretical Model and Empirical Specification

In this paper, regardless of the intensity and quantity of technologies being used, a farmer was taken as an adopter if he or she sows any improved seed and uses chemical fertilizer; either independently or together with their indigenous seeds and manure. The dependent variable, technology adoption, has a binary nature taking the value of 1 for adopters (chemical fertilizer and HYV independently) and 0 for non-adopters. In this regard an econometric model employed while examining probability of farm households' agricultural technology adoption decision was the probit model. Often, probit model is imperative when an individual is to choose one from two alternative choices, in this case, either to adopt or not to adopt chemical fertilizer and HYV. Hence, an individual *i* makes a decision to adopt chemical fertilizer and HYV if the utility associated with that adoption choice (V_{1i}) is higher than the utility associated with decision not to adopt (V_{0i}). Hence, in this model there is a latent or unobservable variable that takes all the values in (-∞, +∞). According to Koop (2003) these two different alternatives and respective utilities can be quantified as: $Y_i^* = V_{1i} - V_{0i}$ and the econometric specification of the model is given in its latent as:

$$Y_i = \begin{cases} 1, Y^*_i \geq 0 \\ 0, Y^*_i \leq 0 \end{cases} \tag{1}$$

Where Y_i takes the value of One (1) for adopters and Zero (0) for non-adopters.

$$Y^*_i = x'\beta_i + u_i \tag{2}$$

Where $u|\,x$ is a normally distributed error term.

From this unobserved or latent model specification, therefore, the utility function depends on household specific attributes *X* and a disturbance term (*u*) having a zero mean:

$$U_{i1}(X) = \beta_1 X_i + u_{i0} \text{ for adopters} \tag{3}$$

As utility is random, the *i*th household will adopt if and only if $U_{i1} > U_{i0}$. Thus, for the household *i*, the probability of adoption is given by:

$P(1) = P(U_{i1}>U_{i0})$ (4)
$P(1) = P (\beta_1 X_1+ u_{i1}> \beta_0 X_i+ u_{i0}$ (5)
$P(1) = P (u_{i0}- u_{i1}<\beta_1 X_i-\beta_0 X_i)$ (6)
$P(1) =P (u_i< \beta X_i)$ (7)
$P(Y_i=1)= \varphi (-X'_i\beta/\sigma)$ (8)

Where: *P(1)* is the probability of adopting chemical fertilizer and *HYV*

φ is the cumulative distribution function of the standard normal distribution.

β is the parameters that are estimated by maximum likelihood

x′ is a vector of exogenous variables that explains adoption of chemical fertilizer and *HYV*(e.g. age of household head, sex of the household head, education, membership to an agricultural association, access to credit, etc). Therefore, on the basis of the two dependent variables indicated: chemical fertilizer and *HYV*, probit model was applied independently for each binary dependent variable; given below.

$$CHEMFERTADOPT=\delta_0+ \delta_1 GEN + \delta_2 AGE +\delta_3 EDUC +\delta_4 LANDSZ +\delta_5 PLTDIST+\delta_6 DISMRKT+\delta_7 OFFFARM +\delta_8 IRRIG +\delta_9 LANDOWN +\delta_{10} CREDIT+\delta_{11} EXTENS +\delta_{12} ASSOCI +\delta_{13} TLU +\varepsilon_i \quad (9)$$

$$HYVADOPT=\delta_0+ \delta_1 GEN + \delta_2 AGE +\delta_3 EDUC +\delta_4 LANDSZ +\delta_5 PLTDIST +\delta_6 DISMRKT + \delta_7 OFFFARM +\delta_8 IRRIG +\delta_9 LANDOWN +\delta_{10} CREDIT +\delta_{11} EXTENS +\delta_{12} ASSOCI +\delta_{13} TLU +\varepsilon_i \quad (10)$$

Where: *CHEMFERTADOPT* is a dependent variable indicating for probability of chemical fertilizer adoption; and

HYVADOPT is a dependent variable representing the probability of High Yielding Variety adoption.

Given the above two dependent variables (chemical fertilizer and HYV adoption), to estimate the magnitude of parameters or variables basically to put clearly the percentage probability of adoption, marginal effect of variables was calculated (see table 3 for marginal effect results). Marginal effect of a variable is the effect of unit change of that variable on the probability of

P(Y = 1|X = x), given that all other variables are constant. The marginal effect is expressed as:

$$\frac{\partial P(Yi=1/Xi)}{\partial Xi} = \frac{\partial E(Yi/Xi)}{\partial Xi} = \varphi(X_i'\beta)\beta \quad (11)$$

On the other hand, to examine the impact of agricultural technology adoption on farm income, Ordinary Least Square (OLS) regression model was employed. The rationale was due to the continuous nature of the dependent variable, farm income. Furthermore, according to Gujarati (2006), with the assumption of classical linear model, OLS estimators are with unbiased linear estimators with minimum variance and hence they are Best Linear Unbiased Estimators. Hence, its specification is given below using similar independent variables used and described in the probit model above.

$$Y = \beta_0 + \beta iXi +U_i \quad (12)$$

Where: *Y* is the dependent variable (farm income), *X*i is a vector of explanatory variables, β*i* is a vector of estimated coefficient of the explanatory variables (parameters) and u_i indicates disturbance term which is assumed to satisfy all OLS assumptions (Gujarati, 2006).

$$Farminc=\beta_0 + \beta_1\ GEN + \beta_2\ AGE + \beta_3\ EDUC + \beta_4\ LANDSZ + \beta_5\ PLTDIST + \beta_6 DISMRKT + \beta_7\ OFFFARM + \beta_8\ IRRIG + \beta_9\ LANDOWN + \beta_{10}\ CREDIT + \beta_{11}\ EXTENS + \beta_{12}\ ASSOCI + \beta_{13}\ TLU + ui \qquad (13)$$

Where: Farminc=Continuous dependent variable indicating farm income

3.2.1. Description of Variables used in the Analysis (both in Probit and OLS models)

The variables used in the analysis and their theoretical expectations about the sign and magnitude of these variables on the adoption decision of agricultural technologies more particularly chemical fertilizer and HYV as well as its impact on farm income are discussed below. These variables were chosen based on the available literature reviewed.

Gender of household head (GEN): It is a dummy variable 1 if gender of the household head is male and 0 otherwise. Male-headed households would have better opportunity to adopt both chemical fertilizer and HYV since they are exposed to new information and tend to be risk takers (Adebiyi & Okunlola, 2013). In such instances, negative sign was hypothesized while adopting chemical fertilizer due to their reluctant behavior and higher probability of adopting manure as a proxy for chemical fertilizer; whereas positive coefficient was expected for HYV adoption.

Age of household head (AGE): It is a continuous variable measured in numbers; as age increases households' probability of adopting chemical fertilizer and HYV were expected to decrease; where younger farmers were expected to adopt unlike elder farmers. The coefficient hypothesized in the final result both for chemical fertilizer and HYV was negative.

Education (EDUC): It is a continuous variable measured in number of years of schooling; where the educated farmers are believed to acquire, analyze and evaluate information on different agricultural inputs and market opportunities. Positive was the coefficient expected from the final result both for chemical fertilizer and HYV adoption.

Land Size (LANDSZ): This is a continuous variable measured in hectare. Those with large land size could use chemical fertilizer and HYV mainly to increase productivity. On the other hand, those with large land size could not be in a position to adopt chemical fertilizer since they could use fallowing system. Besides, large land size holders may not use HYV so long they could use their own indigenous seed. On the other side of the coin, small land size holders may use chemical fertilizer and HYV so as to heighten production and productivity and thereby satisfy their annual household consumption needs. Hence, the coefficient was not determined or hypothesized in prior.

Plot Distance (PLTDIST): It is a continuous variable measured in minutes walking; as plot is far away from the homestead, the less will be on time plot preparation, weed, harvest and input utilization and then less will be farm income (Minale *et al*., 2012). Hence, farmers will be less probable to adopt chemical fertilizer and HYV. As a result, negative coefficient was hypothesized from the final probit estimation result.

Distance to the nearest market (DISMRKT): This is a continuous variable measured in kilo meters; and the longer the distance of farmers' residence to the nearest market, the improbable will be their adoption decision for chemical fertilizer and HYV. Hence, negative sign was expected from the final probit estimation result.

Off-Farm Participation (OFFFARM): It is a dummy variable representing 1if a household head participates in off-farm activities and 0 otherwise. Participating in off-farm activities can solve liquidity problem while intending to purchase chemical fertilizer and HYV. Due to this positive coefficient was hypothesized in the final estimation result both for chemical fertilizer and HYV adoption decision.

Irrigation Use (IRRIG): It is a dummy variable 1 if farm households did use irrigation practices and irrigation water 0 otherwise. If there is irrigation water, farm households would be probable to adopt chemical fertilizer and HYV since the presence of water can best be taken as guarantee for crop failure and the resultant shock. Hence, both for chemical fertilizer and HYV adoption, positive sign was expected from the final probit estimation result.

Land Ownership (LANDOWN): It is a dummy variable 1 if farm households have land ownership right and certified for that0 otherwise. If farm households do have ownership right and certificate, they tend to purchase and adopt both chemical fertilizer and HYV; on the other hand, if they do not have ownership right, they become reluctant to adopt and incur a cost for chemical fertilizer and HYV. Hence, for these two different independent variables, positive coefficient was expected from the final probit estimation result.

Access to Credit (CREDIT): It is a categorical variable; representing 1 if household has had credit access and 0 otherwise. Credit access reduces liquidity problems that household could face while intending to purchase agricultural inputs; and hence paves the way for timely application of inputs thereby increase the overall productivity and farm income (Mpawenimana, 2005). Hence, from the final estimation result, access credit was expected to have a positive sign both for chemical fertilizer and HYV adoption decision.

Extension Agents' Contact (EXTENS): It is a categorical variable representing 1 if households were visited by extension agents and 0 otherwise. Farmers' visited by extension agents are believed to be exposed for different, new, updated information used to adopt chemical fertilizer and HYV thereby increase and double agricultural production that finally could increase farm income (Wondimagegn *et al.*, 2011). Hence, both for chemical fertilizer and HYV adoption decision, extension agents' contact was expected to have a positive sign or coefficient from the final probit estimation result.

Membership to an Association (ASSOCI): It is a categorical variable; 1 represents if a household was a member of a certain farmers' association or cooperatives and 0 otherwise. Membership to an association let farmers to access inputs easily with an affordable price that is pertinent to increase agricultural production and thereby farm income (Uwagboe *et al.*, 2012 and Tewodaj *et al.*, 2009). Hence, farmers can easily adopt chemical fertilizer and HYV on time through an affordable price as well as through credit that will be returned back soon after harvesting. Due to this, while determining chemical fertilizer and HYV, membership to an association was expected to have a positive coefficient.

Tropical Livestock Unit (TLU): It is a continuous variable measured in number; where those who possess a flock of TLU were expected to adopt chemical fertilizer and HYV better than the have-nots. The presence of tropical livestock unit can solve the liquidity problem that farm households could face while intending to purchase and adopt chemical fertilizer and HYV. Hence, both for chemical fertilizer and HYV adoption decision, positive were the coefficients expected from the final probit estimation result.

4. Results and Discussion

It is believed that demographic characteristics of sampled households, tabulated in table below, are pertinent in providing insights and a hunch about the general features of an area under investigation.

Table 2. Descriptive Statistics of Variables Used in Regression Analysis and Some Major Ones.

Variables	Non-adopters		Adopters	
	Fertilizer (N=198)	HYV (N=177)	Fertilizer (N=72)	HYV (N=93)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
GEN(1=Male)	0.753(0.433)	0.797(0.404)	0.889(0.316)	0.774(0.420)
ADE	43.313(9.975)	45.627(11.072)	48.375(10.946)	42.828(8.972)
EDUC	1.106(2.073)	0.779(1.676)	0.681(1.287)	1.398(2.227)
LANDSZ	1.492(0.684)	1.493(0.678)	1.5(0.643)	1.497(0.661)
PLTDIST	36.414(22.001)	33.927(20.386)	32.153(17.579)	37.849(21.911)
LANDOWN(1=Yes)	0.944(0.231)	0.949(0.220)	1.000(0)	0.978(0.146)
IRRIG(1=Yes)	0.258(0.438)	0.158(0.366)	0.222(0.419)	0.419(0.496)
CREDIT(1=Yes)	0.364(0.482)	0.277(0.449)	0.388(0.491)	0.548(0.500)
EXTENS(1=Yes)	0.798(0.403)	0.825(0.381)	0.903(0.298)	0.828(0.379)
ASSOCI(1=Yes)	0.646(0.558)	0.582(0.589)	0.5(0.581)	0.656(0.521)
DISMRKT	23.520(12.522)	26.367(13.049)	26.889(14.208)	20.709(12.294)
TLU	5.288(3.815)	5.346(3.823)	6.166(4.449)	5.858(4.332)
OFFFARM(1=Yes)	0.717(0.452)	0.729(0.446)	0.861(0.348)	0.806(0.397)
Crop yield in quintal	11.308(6.675)	10.616(6.846)	22.451(9.491)	21.253(8.459)

Source: Own Survey Result, 2014   SD; Standard deviations (Values in bracket are standard deviations)

As it can be seen in table 2 above, 73.33% and 65.56% of the sample respondents were, respectively, chemical fertilizer and HYV non-adopters. Besides, Tropical Livestock Unit (TLU) that households do possess and off-farm activities participation status vividly shows as if both chemical fertilizer and HYV adopter are much better than their counter parts in wealth and the resultant off-farm participation and income diversification. While comparing the two groups in their respective crop yield measured in quintal, adopters have a much better yield that can best be taken as an important contribution of chemical fertilizer and HYV.

4.1 Determinants of Agricultural Technology adoption Decision of Farm Households

As already have indicated in model specification part, there are two dependent variables (adoption of Chemical Fertilizer and adoption of HYV) where similar independent variables have been indentified and used. Before rushing to econometric estimation[1] and result display, different econometric assumptions were tested. In cross sectional data set, expecting and facing multicollinearity and hetroscedasticity problems is very much common. To check and address multicollinearity problem, pair-wise correlation matrix was made that could let to drop some of the variables that really show a serious multicollinearity problem. Besides, as a proxy and solution for Brush Pagan test (hettest) of detecting heteroscedasticity problem,

[1]The econometric software Stata version 11 was used to estimate empirical models

robust standard error calculation of probit model was made. Besides, as for Ordinary Least Square regression model, Variance Inflation Factor (VIF) was employed to test the presence of multicollinearity problem among independent variables. Secondly, the inclusion and exclusion of irrelevant and relevant variables respectively were tested by link and OV (Omitted Variable) tests. Thirdly, hetroscedasticity problem was tested by using Breusch-Pagen test (hettest), unfortunately unequal variance was detected; as a remedy, therefore, robust standard error calculation was used. Estimate of the probit model for the two dependent variables and Marginal effects after probit estimation is depicted in table 3 below.

The regression result show that gender, land ownership, irrigation use, access to credit, contact with extension agents and participation in off-farm activities have positive and significant relationship with chemical fertilizer adoption decision while plot distance from the home stead, distance to the nearest market and TLU carried a negative sign indicating their negative relation with chemical fertilizer adoption decision. Likewise, for HYV adoption, positive and significant relationship was found with land ownership, access to credit facilities, irrigation use and TLU where as age and distance to the nearest market carries a negative sign.

Implication of gender on fertilizer adoption is positive and statistically significant at 1% level. Male headed households, citrus paribus, have 15.5% higher probability of participation than female headed households. In fact, in the study districts, letting females to be a household head is not yet well developed and recognized. Consequently, female headed households mostly are those who are widowed and divorced. In such instances, beside the cultural factors, their probability of adopting fertilizer becomes negligible. Despite this, as the result reveals, gender could not be a factor for HYV adoption decision of farm households. The overall finding is consistent with the findings of Adebiyi and Okunlola (2013); Menale *et al.* (2012); Chiputwa *et al*. (2011) Datar and Del Carpio (2009) and Abay and Assefa (2004). Although age was not found to be a determinant factor of chemical fertilizer adoption, statistically, it was found to be significant at 5% level and negatively related with HYV adoption decision. Hence, as age increases by one year, citrus paribus, the probability of HYV adoption decision of farm households would decrease by 0.07%. The possible interpretation here is, as age increases, farm households would become too reluctant and conservative in adopting new seed varieties and do prefer their indigenous seeds.

Plot distance from the home stead, though not determining HYV adoption decision, was found to be negatively related with the probability of chemical fertilizer adoption decision and it was statistically significant at 5% significance level. Accordingly, as plot distance increases by one minute, the probability of adopting chemical fertilizer would decrease by 0.02%. The far remote the plot from the homestead, the lesser would be the probability of agricultural input utilization. The prior hypothesized coefficient was negative and the hypothesis is not rejected at 5% significance level. The finding is in line with the findings of Menale *et al.* (2012) in rural parts of Tanzania where input adoption and farm income decreases as plot distance increases.

Land ownership status of farm households was found to be statistically significant in determining adoption decision of both chemical fertilizer and HYV at 10% significance level. The magnitude of positive sign show that, those who are certified and whose land ownership status is secured, keeping other things constant, have 20.9% and 25.3% higher probability of adopting, respectively, chemical fertilizer and HYV unlike their counterparts. Possibly, owning an arable land could best be taken as a prerequisite to adopt and employ agricultural technologies since farmers could incur a cost. Being a rational decision makers, while incurring a cost for technologies, farmers want totally to employ technologies within their own land where the final crop yield could not be shared and sub-divided which is too common in sharecropping system.

Table 3.Determinants of Agricultural Technology Adoption Results from Probit Model.

Variables	Chemical Fertilizer				HYV			
	Coef.	SE	P>|z|	Marginal Effect	Coef.	SE	P>|z|	Marginal Effect
Gender	0.068	0.256	0.008***	0.155	0.231	0.225	0.305	0.079
Age	0.019	0.012	0.109	0.003	-0.019	0.009	0.039**	-0.007
Education	-0.057	0.056	0.304	-0.010	0.018	0.049	0.705	0.006
Farm size	-0.038	0.209	0.856	-0.007	-0.128	0.154	0.406	-0.046
Plot distance	-0.012	0.006	0.038**	-0.002	0.002	0.004	0.583	0.001
Landownership	0.078	0.466	0.094*	0.209	0.969	0.525	0.065*	0.253
Irrigation Use	0.660	0.306	0.031**	0.098	0.629	0.196	0.001***	0.236
Access to Credit	0.471	0.253	0.062*	0.099	0.671	0.189	0.000***	0.245
Contact to Extension Workers	0.497	0.277	0.073*	0.111	-0.143	0.023	0.545	-0.052
Membership to an association	-0.140	0.215	0.513	-0.026	0.09	0.174	0.588	0.034
Distance to the nearest market	-0.023	0.011	0.039**	-0.004	-0.026	0.008	0.001***	-0.009
Tropical Livestock Unit	-0.007	0.047	0.091*	-0.016	0.060	0.027	0.027**	0.022
Off-farm participation	1.553	0.241	0.000***	0.418	0.006	0.218	0.781	0.021
_Cons	-2.052	0.744	0.006		-0.702	0.681	0.302	
Log likelihood = -85.115526 Number of obs = 270 LR chi2(13) = 102.74 Prob > chi2 = 0.0000 Pseudo R2 = 0.374					Log likelihood = -144.52546 Number of obs = 270 LR chi2(13) = 58..68 Prob > chi2 = 0.0000 Pseudo R2 = 0.1687			

Source: Own Estimation Result, 2014 asterisks*, **and*** significant at 10, 5 and 1 % respectively. SE; Standard Error

Presence of irrigation practices and irrigation use was found to be statistically significant in determining adoption of chemical fertilizer and HYV, respectively, at 5 and 1% significance level. Farmers who have an irrigable land and who use irrigation water, keeping other things constant, have 9.8% and 23.6% higher probability of adopting chemical fertilizer and HYV unlike their counter parts respectively. Farmers' reluctance in adopting agricultural technologies mainly steams from erratic nature of rain fall and lack of irrigation water where the technology is in question for increasing yield rather believed to damage the productive potential of crops sown. Due largely to this reason, if farmers get irrigable water, their probability of adopting the intended technology was found to be high.

It is worth to note that, access to credit is one best option whereby smallholders could be instigated in diversifying their economic base; and it is statistically significant at 10% and 1% significance level, respectively, in determining the adoption decision of chemical fertilizer and HYV. In line with this, farm households who have credit access, keeping other things constant, have 9.9% and 24.5% higher probability of adopting chemical fertilizer and HYV unlike the credit rationed farmers respectively. As a liquidity factor, the more farmers have access to source of finance, the more likely to adopt agricultural technologies that could possibly increase crop yield.

Distance to the nearest market was negatively related with adoption of both chemical fertilizer and HYV and statistically significant at 5% and 1% level of significance respectively. Actually, there might be chemical fertilizer and HYV suppliers within a certain sub-district or village, but if once finished, to avail it again, time will fly and the probability of adopting these technologies would undoubtedly be compromised. Hence, due to on time procurement and distribution problem, as distance from the nearest market increases by one kilo meter, keeping other things constant, the probability of adopting chemical fertilizer and HYV, respectively, would decrease by 0.4% and 0.9%.

Tropical Livestock Unit that households do possess has a negative and positive relationship for adopting chemical fertilizer and HYV respectively. The presence of Tropical Livestock Unit would be an impediment for adopting chemical fertilizer where farmers do prefer utilizing manure without incurring product and transportation cost. In such scenario, farmers would prefer to use their animals' manure by transporting through their own pack animals when need arises or on time. Unlike this, the contribution of Tropical Livestock Unit for adopting HYV is positive; this might be due to the conduciveness of the land for productivity of HYV since farmers do use manure as proxy for chemical fertilizer. The magnitude of negative and positive sign indicates that, as Tropical Livestock Unit increases by one unit, keeping other things constant, the probability of adopting chemical fertilizer and HYV would decrease and increase by 1.6% and 2.2% respectively.

The regression result reveals that contact with extension workers positively affects adoption of chemical fertilizer and statistically significant at 10% level of significance. The magnitude of positive sign show that, farmers who are visited by extension agents, keeping other things constant, have 11.1% higher probability of adopting, chemical fertilizer unlike non-visited or non-contacted farmers.

Participating in different off-farm activities was found to have a positive and significant relationship with chemical fertilizer adoption decision which is statistically significant at 1% level of significance. Off-farm income could best be taken as an important ingredient of adopting chemical fertilizer in such a way that farmers could easily afford fertilizer cost; and these farmers are mostly exposed to new and updated information since they move from one town to another and contacted with different people with different background. Due to this reason, off-farm participants, citrus paribus, have 41.8% higher probability of adopting chemical fertilizer unlike off-farm non-participants.

In a nutshell, the most salient determinant factors of chemical fertilizer and HYV adoption decision are irrigation use, land ownership right security and credit access. Hence, compared with indigenous seed, HYV have higher water intake requirement; and for fruitfulness of chemical fertilizer, there has to be sufficient rainfall and irrigable water. Datar and Del Carpio (2009) argued that use of irrigation practices is an important breakthrough to adopt and produce high yielding and profitable crops. Due largely to this fact, unless there is water, farm households would become too reluctant in adopting these technologies; as if HYV could not be productive and chemical fertilizer would damage the productive potential of crops sown. Hence, farmers do not want to be risk takers and invest their resource in a barren land. The finding corroborates with the findings of Ransom *et al*. (2003); Kandji *et al*. (2006) and Paudel and Matsuoka (2008).

It is worth to note that, access to credit is one best option whereby smallholders could be instigated in diversifying their economic base and adopt all imperative yield increasing technologies. As a liquidity factor, the more farmers have access and source of finance, the more likely to adopt agricultural technologies that could possibly increase crop yield. The finding is in line with the findings of Uaiene *et al.* (2009) in Nigeria. Possibly, owning an arable land could best be taken as a prerequisite to adopt and employ agricultural technologies since farmers incur a cost. Being rational decision makers, while incurring a cost for technologies, totally, farmers want to employ technologies within their own land where the final crop yield could not be shared and sub-divided which is too common in sharecropping system. The finding is consistent with the findings of Lugandu (2013).

4.2 Impact of Agricultural Technology Adoption on Farm Income

Table 4 below shows the impact of agricultural technology adoption mainly chemical fertilizer and HYV on farm income. The OLS regression model was considered as impact measurement and analysis and its estimation result is shown here under.

Table 4.The Impact of Chemical Fertilizer and HYV Adoption on Farm Income: OLS Result

Explanatory Variables	Coeff.	Std. Err.	t	P>|t|
High Yielding Varieties	4717.575	2328.241	2.03	0.044**
Chemical Fertilizer	6672.022	2722.107	2.45	0.015**
Gender	6246.228	2623.037	2.38	0.018**
Age	-61.795	105.934	-0.58	0.560
Education	281.8286	558.1144	0.50	0.614
Farm size	4053.782	1091.148	3.72	0.000 ***
Plot distance	43.45512	52.89325	0.82	0.412
Landownership	4567.513	5293.694	0.86	0.389
Irrigation Use	75.15914	2490.294	0.03	0.976
Access to Credit	2902.156	1367.957	2.12	0.035**
Contact to Extension Workers	1880.734	1687.631	1.11	0.266
Membership to an association	2213.214	1204.256	1.84	0.067**
Distance to the nearest market	-58.938	95.914	-0.61	0.539
Tropical Livestock Unit	6766.944	314.8419	21.49	0.000***
Off-farm participation	-2150.71	1689.8	-1.27	0.204
_Cons	-4098.418	7533.117	-0.54	0.587
Number of obs = 270	R-squared = 0.7606			
F(15, 254) = 53.79	Adj R-squared = 0.7464			
Prob> F = 0.0000	Root MSE = 16228			

Source: Own Estimation Result, 2014 asterisks*, **and*** significant at 10, 5 and 1 % respectively.

The prior hypothesis stating the positive impact of agricultural technology adoption on farm income is accepted at 5% significance level. Far beyond chemical fertilizer and HYV adoption, farm income was found to be determined positively by gender (given male headed households do have a better farm income), farm size, access to credit, membership to an association and TLU. Validating the hypothesis, chemical fertilizer adopters were much better to get birr[2] 6672.022 than their non-adopter counterparts. Furthermore, still validating the null hypotheses, HYV adopters were found to be earners of birr 4717.575 much better than their counter parts. Hence, the result is as expected with our hull hypotheses in such a way that, agricultural technology adopters can really produce high valued and marketable

[2] Birr is Ethiopian currency where one dollar was exchanged with 19.65 Ethiopian birr

crops that accelerate additional income and further motivate farm households to adopt technologies again and again.

5. Conclusion and Policy Implications

This research paper examined the underlying determinants of chemical fertilizer and HYV adoption by the rural households in Raya- Azebo and Raya-Alamata districts of Tigray region, Ethiopia. The probit regression result showed that gender, land ownership right security, irrigation use, access to credit, contact with extension workers and off-farm participation were found to be positive in determining chemical fertilizer adoption decision. Besides, plot distance from the homestead, distance to the nearest market and TLU were statistically significant while influencing chemical fertilizer adoption decision negatively. While adopting HYV, farm households' decision were positively influenced by land ownership right security, irrigation use, access to credit and TLU; whereas age and distance to the nearest market carried a negative coefficient.

In a nut shell, difficulty of accessing credit either formally and informally, feel of non-secured land ownership right and fear of the damaging effect of technologies for crops grown due to shortage of water were found to be sound and robust results and determinants of technology adoption. Furthermore, gender, given female headed households are mainly chemical fertilizer non-adopters since they could not be exposed to new and updated agricultural information, great discrepancy have been seen and founded.

To increase and instigate the likelihood of adopting modern agricultural technologies by smallholder farmers, policy makers should put emphasis on overcoming credit market failures, irrigation problems by introducing drip and pipe irrigations, securing land ownership status of farm households and empowering female headed households to be participants and agents of change by considering a comprehensive and an integrated development of the country where their involvement is pertinent in all endeavors of the country's overall development.

References

Abay, A., & Assefa, A. (2004). The Role of Education on the Adoption of Chemical Fertilizer under different Socioeconomic Environments in Ethiopia. *Agricultural Economics 30 (2004) 21 5-228; Available online at www- siencedirect.com*

Adebiyi, S., & Okunlola, J.O. (2013). Factors Affecting Adoption of Cocoa Farm Rehabilitation Techniques in Oyo State of Nigeria.*World Journal of Agricultural Sciences 9 (3): 258-265, 2013 ISSN 1817-3047 DOI: 10.5829/idosi.wjas.2013.9.3.1736*

Ajayi, O.C., Franzel, S., Kuntashula, E., & Kwesiga, F. (2003). Adoption of improved fallow technology for soil fertility management in Zambia: Empirical studies and emerging issues. Agroforestry Systems. 59: 317-326.

Bandiera, O., & Rasul, I. (2002). Social networks and technology adoption in northern Mozambique. Technical Report 3341, CEPR Discussion Paper.

Becerril, J., & Abdulai, A. (2009). The impact of Improved Maize Varieties on Poverty in Mexico: A Propensity Score-Approach. *World Development* 38:1024-1035.

Benin, S., Smale, M., Gebremedhin, B., Pender, J., & Ehui, S. (2003). The Determinants of Cereal Crop Diversity on Farms in the Ethiopian Highlands.*Proceedings of the 25th International Conference of Agricultural Economists (IAAE) 16 . 22 August 2003 Durban, South Africa; ISBN Number:* 0-958-46098-1

Besley, T., & Case, A. (1993). "Modeling Technology Adoption in Developing Countries."*The American Economic Review* 83:396-402.

Brown L., & Haddad, L. (1994).“Agricultural Growth as a Key to Poverty Alleviation.” 2020 Brief no. 7. Washington D.C.: IFPRI.

Chiputwa, B., Langyintuo, A.S., & Wall, P. (2011). Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the Shamva District of Zimbabwe*:* A Tobit application. *Paper accepted for the 2011 meeting of the Southern Agricultural Economics Association (SAEA) in Texas, USA.*

Christensen, P., & Cook, A.D. (2003). Mali Seed Sector Development Plan. Initiative to End Hunger in Africa: Agricultural Policy Development Progarm. PCE-1-00-9-00033-00 (order No.5).Prepared for United State Agency for International Development Mali Mision. Department of State Washington D.C. 20521-2050.

Crawford, E.W. ,Jayne, T.S., & Kelly, V.A. (2005). Alternative Approaches for Promoting Fertilizer Use in Africa, with Particular Reference to the Role of Fertilizer Subsidies.*Department of Agricultural Economics Michigan State University East Lansing, MI 48824-1039*

Datar, G., & Del Carpio, X.V. (2009). Are Irrigation Rehabilitation Projects Good for Poor Farmers in Peru? A Spatial Regression Discontinuity Approach *.Policy Research Working Paper 5154; Impact Evaluation Series No. 42*

Datt, G., & Ravallion, M. (1996). How Important to India’s Poor is the Sectoral composition of Growth? World Bank Economic Review 10(1), 1-26.

Dixon, J., Nalley, L., Kosina, P., La Rovere, R. Hellin, J., & Aquino, P. (2006). “Adoption and Economic Impact of Improved Wheat Varieties in the Developing World”. Journal of Agricultural Sciences, Vol. 144, pp. 289-502.

Doss, C.R., & Morris, M. L. (2001). “How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana.”*Agricultural Policy* 25:27-39.

Eshetu, M., Osman, E.I., & Etenesh, B. (2005). Improving Potato Seed Tuber Quality and Producers' Livelihoods in Hararghe, Eastern Ethiopia. *Journal of New Seeds, 7:3, 31-56*

Foster, A., & Rosenzweig, M. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. Journal of Political Economy 103 (6), 1176-1209.

Foster, A.D., & Rosenzweig, M.R., (1996). Technical Change and Human-Capital Returns and Investments: Evidence from the Green Revolution. The American Economic Review, 86 (4), 931-953.

Foster, A.D and Rosenzweig, M.R (2010). Micro economics of Technology Adoption. Economic Growth Center Yale University center discussion paper No.984 http://www.econ.yale.edu/~egcenter/publications.html

Gakou A., Kebe, D., & Traoré, B. (1995). “Gestion de la fertilité des sols au Mali ;Esquisse d’un plan d’action.” Sikasso, Mali: Ministère du Développement Rural et de l’ Environnement, Institutd’EconomieRurale (IER), Centre Régional de la RechercheAgronomique.

Galiba M., Camara B., & Diané, A. (1999). “Evaluation de quelques cultivars de mil et de sorgho au Mali : Hivernage 1998." Atelier des Partenairessur la planificationetl’exécution du projet FIDA.” Sadoré: Niger, 24-26 February.

Gemeda, A., Aboma, G. Verkuijl, H., & Mwangi,W. (2001). Farmers’ Maize Seed Systems in Western Oromia, Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p 32.

Gujarati, N. (2006). Basic Econometrics, *Third Edition, McGraw Hill Book Company, New York*.

Hossain, S., Alamgir, M., & Croach, R. (1992). Patterns and Determinants of Adoption of Farm Practices: Some evidence from Bangladesh. *Agric. Systems*, 38:1-15.

Ibrahim, M., Florkowski, W.J., & Kolavalli, S. (2012).The Determinants of Farmer Adoption of Improved Peanut Varieties and Their Impact onFarm Income: Evidence from Northern Ghana.Selected Paper prepared for presentation at the Agricultural and Applied Economics Association Annual Meeting, Seattle, WA, August 12-14, 2012

Kandji, S.T., Verchot, L., & Mackensen, J. (2006). Impacts and Adaptation Strategies in the Agricultural Sector Impacts and Adaptation Strategies in the Agricultural Sector. World Agroforestry Centre (ICRAF) and United Nations Environment Programme (UNEP).

Kohli, D., & Singh, N. (1997). The green revolution in Punjab, India: The economics of technical change. Technical report, Conference on Agriculture of the Punjab at The Southern Asian Institute, Columbia University.

Koop, G. (2003). Bayesian Econometrics, John Wiley and Son. Inc., USA

Lugandu, S. (2013). Factors Influencing the Adoption of Conservation Agriculture by Smallholder Farmers in Karatu and Kongwa Districts of Tanzania.*Presented at REPOA's18thannual research workshop held at the Kunduchi Beach Hotel, Dar es Salaam, Tanzania.*

Menale, K., Moti, J., Bekele. S., Mmbando, F., & Muricho, G. (2012). Plot and Household-Level Determinants of Sustainable Agricultural Practices in Rural Tanzania. *Environment for Development Discussion Paper Series EfD DP 12-02*

Mendola, M., (2007). "Agricultural Technology Adoption and Poverty Reduction: A propensity Score Analysis for Rural Bangladesh." *Food Policy* 32:372-393.

Minten, B., Randrianarisoa, J.C., & Barrett, C.B. (2006). Productivity in Malagasy rice systems: Wealth-differentiated constraints and priorities. *Invited panel paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia,August 12-18, 2006*

MoARD. (2010). Federal Democratic Republic of Ethiopia, Ethiopia's agriculture sector policy and investment framework: *Ten year road map (2010–2020). Final Report*

MoFED. (2003). Government of the Federal Democratic Republic of Ethiopia Rural Development Policy and Strategies.*Economic Policy and Planning Department Addis Ababa, government printer*

Morris, M.L., Trip, R., & Dankyi, A.A. (1999). Adoption and impact of improved maize production technologies.A case study of the Ghana Grains Development Project.Economics Program Paper 99-01.International maize and Wheat Improvement Center (CUIMMYT), Mexico.38 pp.

Mpawenimana, J. (2005). Analysis of Socio-Economic Factors Affecting the Production of Bananas in Rwanda: A Case Study of Kanama District. *University of Nairobi*

Nubukpo, K., & Galiba, M. (1999). *Agricultural Intensification in West Africa: Insights from Sasakawa Global 2000's Experience*. Paper presented at the workshop on agricultural transformation Sponsored by Tegemeo Institute / Egerton University, Njoro, Kenya Eastern and Central Africa Program for agricultural policy analysis (ECAPAPA), Entebbe, Uganda Michigan State University, East Lansing, Michigan, USA and United States Agency for International Development Nairobi, Kenya

Paudel, P., & Matsuoka, A. (2008). Factors influencing of improved maize varieties in Nepal: A case study of Chitwan district. *Australian Journal of Basic and Applied Sciences* 2(4), 823-834

Ransom, J. K., Paudyal, K., & Adhikari, K. (2003) Adoption of improved maize varieties in the hills of Nepal. *Journal of the International Association of Agricultural Economics* 29(3), 299-305.

Samuel, G. (2006). Intensification of Smallholder Agriculture in Ethiopia: Options and Scenarios. *Paper prepared for the Future Agricultures Consortium Meeting at the Institute of Development Studies 20-22 March 2006*

Sassenrath,G.F., Schneider, J.M., Gaj, R., Grzebisz, W., & Halloran, J.M. (2012). Nitrogen balance as an indicator of environmental impact: Toward sustainable agricultural production. *Renewable Agriculture and Food Systems: doi: 10.1017/S1742170512000166*

Smaling, E.M. (1993). "Soil Nutrient Depletion in Sub-Saharan Africa."In The Role of Plant Nutrients for Sustainable Food Crop Production in Sub-saharan Africa, edited by H. van Reuler and W.H. Prins.Leidschendam, TheNetherlands: Dutch Association of Fertilizer Producers.

Solomon, A., Menale, K., Simtowe, F., & Lipper, L. (2011). Poverty Reduction Effects of Agricultural Technology: A Micro-evidence from Tanzania *available at: http://democracyinafrica.org/africa-feed-world-smallholders-will-key/*

Tewodaj, M., Cohen, MJ.,Birner, R., Mamusha, L., Randriamamonjy, J., Fanaye, T., & Zelekawork, P. (2009). Agricultural Extension in Ethiopia through a Gender and Governance Lens.*Ethiopia Strategy Support Program 2 (ESSP2) Discussion Paper No. ESSP2 007*

Uaiene, R.N., Arndt, C., & Masters, W.A. (2009). Determinants of Agricultural Technology Adoption in Mozambique. *Discussion papers No. 67E January 2009 National Directorate of Studies and Policy Analysis Ministry of Planning and Development Republic of Mozambique*

Wallace, M.B., & Knausenberger, W.I. (1997). Inorganic Fertilizer Use in Africa: Environmental and Economic Dimensions. *Environmental and Natural Resources Policy and Training (EPAT) Project Applied Research, Technical Assistance and Training Winrock International Environmental Alliance Arlington,Virginia, U.S.A. September1997*

Wondimagegn, M., Bekabil, F., & Jema, H. (2011). Pattern, Trend and Determinants of Crop Diversification: Empirical Evidence from Smallholders in Eastern Ethiopia.*Journal of Economics and Sustainable Development Vol.2, No.8, 2011*

WB.(2008). The Growth Report: Strategies for Sustained Growth and Inclusive Development. *Washington D.C., Commission on Growth and Development, World Bank or The International Bank for Reconstruction and Development / The World Bank*

Yanggen, D., Kelly, V., Reardon, T., & Naseem, A. (1998). Incentives for Fertilizer Use in Sub-Saharan Africa: A Review of Empirical Evidence on Fertilizer Response and Profitability. *MSU International Development Working Papers no. 70 ISSN 0731-343*