Adoption and Intensity of Row-Seeding (Case of Wolaita Zone)

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Abstract

In the context of Ethiopia, agriculture and specifically crop production take lion's contribution, supporting the sector through introducing new agricultural technologies, like row planting in the recent times, boosts production. However, despite of such services, utilization of improved technologies remained low in Ethiopia. This study looks into the determinants of adoption and intensity of adoption of row planting using a survey data of 300 farming households in Wolaita zone. The survey indicates that about 87 percent of farmers adopt row planting in 2014/15 production year with mean intensity of use 2.33 Timad (about 56% of their total farm land). A dependent double hurdle analysis reveals that household being headed by Illiterate head, family size, Farm size, Annual off-farm income, Distance to nearest market and Training on row planting significantly influenced adoption and level of adoption of row planting. Moreover, adoption of row planting is significantly affected by Farming experience, No of information sources and Distance to Development Agent whereas level of adoption of row planting by livestock and Number of oxen. The study then concludes that the farmers' adoption and level of adoption of row planting could be improved by raising farm household's education, their off farm income, their endowment and by making them optimally mobilize their labor for agricultural activities and receive extension service. As a result, the study recommends local governments to work towards intensifying informal education to farming households in the study area, raising effort of investment to improve market access and enhancing agricultural extension services to farmers.

Keywords

Dependent Double Hurdle, Wolaita Zone, Row Seeding

Subject Areas: **Behavioral Economics, Socioeconomics**

1. Introduction

In the wide range of literature, it is well documented that economies of Sub Saharan Africa (SSA) are dominated

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by persistent agriculture employing about half of the population. However, agricultural production and productivity in SSA is found to be very low [1]. Growth in production and productivity of agriculture, therefore, is crucial given its low production and productivity and the rapid population growth in this region.

Like in any SSA, agricultural sector holds a prominent position in Ethiopia accounting about 41.6% of the total economy in 2010. Gross agricultural production of the country has reached ETB 64.7 billion bulk of which (90%) has come from cultivation of crops [2]. This implies that the development of the Ethiopian economy heavily depends upon the speed with which crop production growth is achieved.

In an effort to increase production and productivity of smallholder farmers engaged in growing crops, the Government of Ethiopia (GoE) has adopted different institutional support services to boost their production. One of the main support services, assigned to take major role in intensifying agricultural growth and specifically aiming at increasing productivity and production of smallholders, is the Participatory Agricultural Demonstration Extension of Technology (PADETS). Adoption of technology is found to be one of the main tools of PADETS. World Bank report [1] emphasized that adoption of new technologies, such as fertilizers and improved seeds, was central to agricultural growth and povertity reduction.

In line with this, the Government of Ethiopia (GoE) has been working in introducing new agricultural technologies. High-input maize technologies, water harvesting and inorganic fertilizer and row plantation, among others, are introduced in the past decades aiming at increasing agricultural production and productivity [3] [4].

Despite of such institutional support services, the yield of crops in general and cereals in particular is very low in Ethiopia because of low utilization of improved technologies [5]. As a result of the low productivity of agricultural sector, the country has been faced food crisis and forced to be highly dependent on food import in the previous years. For instance, the country received 674,000 metric tons of cereals in the form of food aid in 2006 alone.

This trend of low adoption of technologies is also true for the Wolaita Zone, one of the zones of Ethiopia. For instance, the amount of improved seed applied in the Meher 2012 cropping season was only about 49 tons. During the same period and cropping season, the total area covered with improved seed for all crops was only about 7% of total cultivated area in the zone [4]. Hence, smallholder farmers in Wolaita typically produce with their indigenous seed and are characterized by low adoption of improved technologies. This makes the zone to have low production of 14 quintals per hectare, below national average of 19 quintals per hectare, in the Meher season. In addition to the low production and productivity, about 12.08% of the total Meher production in 2012 is utilized for seed. This shows that a considerable amount of harvest is also lost due to inappropriate seeding [4].

In such difficulties, the GoE, to meet GTP goals, is doing its best to increase production and productivity of smallholder farmers by complementing the existing technologies with new technologies. One of the technologies in crop production introduced in the recent years is row seeding. Compared to the traditional broadcasting, row seeding gives better yield as it allows better weeding and for better branching out and nutrient uptake of the plants and diminish competition between seedlings [3]. According to the Ministry of Agriculture and Rural Development [6] row plantation on average increases production by 30% and reduces the amount of seed to one-fifth of existing seed use.

However, despite its vital role in production improvement, there are no studies focused on its adoption and intensity which could help to broaden the use of technology. Hence, this study is to look in to the factors that affect adoption and intensity of row seeding specifically. i) To identify factors that affect adoption of row seeding technology; and ii) To assess factors that affect intensity of row seeding technology so as help the zonal government in intensifying the practice with this technology.

2. Literature Review

2.1. Basic Concepts and Theoretical Foundations of Analysis of Technology Adoption

Technology is assumed to mean a new, scientifically derived, input supplied or introduced to farmers by organizations with deep technical expertise. Majority of the agricultural technology include irrigation, fertilizer use, high yield verity seeds and row plantation that focused on green revolution technologies.

Adoption of Technology, which plays an important role in economic development, describes the decision to use or not to use of a particular technology. Adoption is not a one step process as adopters may continue or cease to use the new technology. The duration of adoption of a technology vary among economic units, regions and characteristics of technology itself. Thus, adequate understanding of the process of technology adoption is necessary for designing effective agricultural extension programs.

The two common approaches of technology adoption of agricultural technology include whole package adoption advocated by technical scientist and stepwise or sequential adoption recommended by farming system and participatory research groups. In the developing world there is a tendency of agricultural extension programmers to promote technology as a package.

Adoption decision involves the choice of how much resources (like land) to be allocated to the new technology and the old technology if the technology is not divisible (like mechanization, irrigation). However, if the technology is divisible (like improved seed, fertilizer, row planting and herbicide), the decision process involves area allocation as well as intensity of use or rate of application [7]. Thus the process of adoption includes the simultaneous choice of whether to adopt or not to adopt and the intensity of its use.

Measurement of intensity of adoption, therefore, needs to identify whether the technology is divisible or not divisible. The intensity of divisible technologies can be measured at the individual level in a given period of time by the share of farm area under the new technology or quantity of input used per hectare in relation to the agricultural research recommendations [7]. On the other hand, the extent of adoption of non-divisible agricultural technologies such as tractors and combine harvesters at the farm level at a given period of time is dichotomous (use or not use) and the aggregate measure of becomes continuous. Aggregate adoption of a lumpy (non-divisible) technology can be measured by calculating the percentage of farmers using the new technology within a given period of time.

After identifying the divisibility or indivisibility of a technology, one can static or dynamic models of technology adoption to answer the question of what determines whether a particular technology is adopted or not and intensity of adoption using maximization of expected utility or expected profit subjected to resource constraints. Static model refers to farmers' decision to adopt an improved technology at a specific place and specific period of time. Such models attempt to answer the question of what determines whether a particular technology is adopted or not and what determines the pattern of adoption at particular pint in time. On the other hand dynamic models allow for changes in farmers' adoption decisions as farmers gain skill in growing or marketing the improved seed from year to year.

2.2. Empirical Review of Technology Adoption

A wide range of literature measuring technology adoption involve factors that are spelled by Feder, Just and Zilberman [7]. These explanatory indicators vary from study to study based on their contextual applicability, but traditionally include farm size, risk exposure and capacity to bear risk, human capital, labor availability, credit constraints, tenure, and access to commodity markets [8].

The effect of farm size vary depending on the institutional setting of the community and type of technology being introduced. For example there may be positive relationship between farm size and adoption if farm size acts as a proxy for other socio-economic indicators such as access to credit as the larger farm has more collateral value [8]. Moreover, human capital which comprised of individual or community characteristics such as education, human health indicators, age and gender have mixed effect. Considering human capital as allocative ability, farmers with higher education possess will possess higher allocative abilities and in turn able to adjust faster to farm and market conditions [7].

Another important factor which affects adoption is labor. The effect of labor on technology adoption differs depending on whether the area targeted with the technology has a net labor shortage or net labor surplus or whether the proposed technology is labor-saving or labor-intensive. Higher labor supply is associated with higher rates of adoption of labor-intensive technologies. On the other hand the dual nature of off farm labor possibilities but can also reduce the availability of labor and thereby decrease the likelihood of adopting high-labor technologies [9].

The observed patterns of technology adoption are also typically influenced by the farmers' individual risk preferences and their ability to bear the risk of a new and uncertain endeavor. There is strong evidence to suggest a strong and significant relationship between low return on assets, low asset levels, the ability to diversify and manage risk, and income poverty. This relationship between poverty and extreme risk aversion (or extreme inability to bear risk) may show that poor farmers to accept any technology that is expected to produce increased future yields [7].

Another important factor that need to be considered while dealing with technology adoption is access to market. Access to markets is not only needed as an outlet for production but also as a means of securing inputs. Farmers need something to do with their increased output. If there are no markets that can bear the extra supply without creating a reactionary price decline, their investment in new agricultural technologies will be for nothing [8]. Some studies often use a farmer's distance to a major road as a simple proxy for commodity market access, and they show that the likelihood of a farmer to adopt an agricultural technology decreases with distance from road [9]. Roads also imply the level of access farmers have to information. Studies suggest the likelihood that a farmer will continue using an agricultural technology is related to the frequency of contact with trained extension workers, especially for technically complex technologies, contact with neighboring farmers who possess knowledge of the proposed technology also increases the likelihood of adoption [8].

Considering these above stated factors in the empirics, different studies focused on adoption of new agricultural technology has been undertaken in Ethiopia. Most of the studies since the mid 1980 used the conventional static adoption models (logit and probit). In few studies the Tobit model was used to study farmers' extent and intensity of adoption of improved technology. Studies like by Berhanu and Swinton [10], Abay and Assefa [11], Teklewold *et al.* [12], Hailu [13], and Hassen Beshir [5] focused on the adoption of agricultural technologies like fertilizer, high yield verity seeds, soil conservation, using static adoption models. However, none of adoption studies in Ethiopia used dynamic models.

3. Methodology of the Study

3.1. Empirical Framework

Our main concern in this study is modeling technology adoption behavior of farmers. In modeling such decision making behavior of farmers, the two possible questions need to be addressed are first why one decides to adopt a technology and second quantity one decides to apply. Now let us assume we drive an equation which relates the intensity of use of new technology to the explanatory variables from optimization problem of expected utility/profit through the following quantity equation and an observation rule.

$$d_i^* = \alpha z_i + v_i \tag{1}$$

$$y_i^* = \beta x_i + \varepsilon_i \tag{2}$$

where y_i^* is the value which corresponds to the latent variable, d_i^* is a non-observable variable which determines whether the individual i is adopter or non-adopter of new technology, x_i and z_i are vector of conditioning variables and v_i and ε_i are non-observable random variables.

Discrete choice models allow us to analyze situations in which only the decision to adopt is considered and the second aspect that we need to consider, quantity of adoption, can be modeled using the Tobit model. The censoring mechanism for an equation such us Equation (1) is then $y_i = \text{Max}\left(y_i^*, 0\right)$ *i.e.* whenever y_i is not observed it is replaced by zero, otherwise it is observed and replaced by its value. So zero intensity of adoption arise when a farmer does not adopt the technology but we do not know the specific reason for this non adoption [14].

The main sources of non-adoption in technology adoption analysis are infrequency of application of the new technology and non-consideration of the new technology by farmers. Infrequency of application of new agricultural technology mainly arise in situations where markets are imperfect and even missing [15]. In these cases access to input (modern technology) is the key threshold that farmers with positive desired demand for new technology have to overcome.

In situations where some portion of farmers are constrained to access new technology and other portion of farmers are not considering the new technology, Tobit specification is not appropriate as the key underlying assumption of this specification is farmers demanding modern inputs have unconstrained access to the technology [15]. Hence, it is important to treat farmers' decision under Equations (1) and (2) by introducing a new scheme of censoring as:

$$d_i = \begin{cases} 1, & \text{if } d_i^* > 0 \\ 0, & \text{if } d_i^* \le 0 \end{cases} \qquad y_i = \begin{cases} y_i^*, & \text{if } y_i > 0 \text{ and } d_i^* > 0 \\ 0, & \text{if other wise} \end{cases} \tag{3}$$

where d_i^* and y_i^* are defined as in Equations (1) and (2) respectively. The main reasons for the separation of these decision processes are first a farmer may not consider the new technology at all and the values of exogenous variables determining adoption and intensity of use will therefore do not exist and second a farmer may be potential adopter but for certain level of relevant exogenous variables s/he may decide not to adopt. Thus, it is clear that two hurdles must overcome before observing a positive intensity of use [14].

This structure, which was first proposed by Cragg [16], is called double hurdle model. The first stage of this model is a probit model to analyze determinants of adoption, and the second stage is a truncated model for determinants of the level of adoption [16]. Use of Cragg's model for analyzing adoption and intensity of adoption is common in agricultural economic literature [17]-[20]. Another alternative here might be the Heckman selection model. According to Jones [21], one of the important differences between these two models concerns the sources of zeros. In the Heckman model, the non-adopters will never adopt under any circumstances. This may contradict with the possibility that improvements in extensive extension programs and changes in input prices may encourage non-adopters to adopt. On the other hand, in a double hurdle model, non-adopters are considered as a corner solution in a utility-maximizing model. In this case, the assumption of Heckman's seems to be too restrictive.

Variety of family of Cragg's models can be derived depending on the type of assumptions on the joint distribution of error terms interring Equations (1) and (2). Under the hypothesis of independence between v_i and ε_i, that is $v_i \sim N(0, 1)$ and $\varepsilon_i \sim N\left(0, \sigma_\varepsilon^2\right)$, we have an independent double hurdle model applied by Carroll, McCarthy, and Carol. But given the relation which exist between the two processes of decision making undertaken by farmers, it seems adequate to think the unobserved factors in both Equations (1) and (2) could generate dependent errors. We can suppose that $\left(v_i, \varepsilon_i\right)$ is distributed as a bivariate normal random variable with zero means, unit variance and ρ coefficient of correlation *i.e.* $\left(v_i, \varepsilon_i\right) \sim BVN\left(0, \Sigma\right)$, $\Sigma = \begin{bmatrix} 1 & \sigma\rho \\ \sigma\rho & \sigma^2 \end{bmatrix}$. We can write the likelihood function for the dependent double hurdle model as:

$$L_{DDH} = \prod_{y_i=0}\left[1-\Phi\left(Z\alpha, X\beta/\sigma, \rho\right)\right] \cdot \prod_{y_i>0}\left[\left(\frac{\Phi\left(Z\alpha + \frac{\rho}{\sigma}\left(Y - X\beta\right)\right)}{\sqrt{1-\rho^2}}\right)\frac{1}{\sigma}\phi\left(\left(Y - X\beta\right)/\sigma\right)\right] \tag{4}$$

where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The log-likelihood function is estimated using the maximum likelihood estimation (MLE) technique. Assuming no relation which exist between the two processes of decision making ($\rho = 0$), we can reduce the likelihood function for the independent double hurdle model as:

$$L_{IDH} = \prod_{y_i=0}\left[1-\Phi\left(Z\alpha\right)\Phi\left(X\beta/\sigma\right)\right] \cdot \prod_{y_i>0}\left[\Phi\left(Z\alpha\right)\frac{1}{\sigma}\phi\left(\left(Y - X\beta\right)/\sigma\right)\right] \tag{5}$$

Furthermore, when $\alpha = \beta/\sigma$, we have Tobit model with likelihood function as:

$$L_T = \prod_{y_i>0}\left[\frac{1}{\sigma}\phi\left(\left(\frac{Y - X\beta}{\sigma}\right)\right)\Phi\left(-\frac{X\beta}{\sigma}\right)\right] \tag{6}$$

Among the above models we can establish relationships. Tobit and independent hurdle models are nested in the dependent double hurdle model. Hence, it is possible to compare these models through standard tests. When the same set of independent variables are used in the first and second hurdles Green [22], show the Tobit model is a restricted version of the double hurdle model, in which $\alpha = \beta/\sigma$. The appropriateness of the Tobit versus the double hurdle can be tested with likelihood ratio test. The likelihood ration statistic (Γ) can be calculated as:

$$\Gamma = -2\left[\ln L_{\text{Tobit}} - \ln LF_{\text{Probit}} - \ln LF_{\text{Truncated regression}}\right] \tag{7}$$

where ln$L$ represents the maximized log likelihood of function values for the model type indicated in the subscript, each of which estimated independently. The null hypothesis is that the Tobit model is the appropriate specification. *i.e.* $\beta_1 = \beta_2/\sigma$. If the calculated likelihood ratio statistic exceeds the critical chi square value with number of degree of freedom equal to the number of variables in X, the Tobit is rejected in favor of the double hurdle model.

On the other hand, to see if the depend double hurdle model dominate the independent double hurdle model, we use the test procedure developed by Heckman [23]. We treated correlation as an omitted variable in the independent double hurdle specification and introduced using invers mills ratio (the ratio of density function to cumulative density function) as a proxy. Specifically the coefficient of this additional regressor is the covariance between the two error terms. If the error terms are indeed correlated then, the invers mills ratio from the first hurdle (probit model) must have an explanatory power for the second hurdle (truncated model).

3.2. Definitions and Measurement of Variables Foradoption

The dependent variable in the first stage (probit model) have dichotomous value depending on the farmers; decision to adopt row planting technology. However, in the second stage (truncated model) we have a continuous value which should be the intensity, the use and application of the technology. In this case, it is the row planting land ratio (the ratio of quantity of land under row planting to total farm land). As the variables explaining adoption can also explain level of adoption, the same set of independent variables are used in both stages (Probit and Truncated models).

Farmers' decision to use improved agricultural technologies and the intensity of the use in a given period of time are hypothesized to be influenced by a combined effect of various factors. The explanatory variables included in the empirical models were selected following the literature spelled by Feder, Just and Zilberman [7]. These explanatory variables used in this study include farm size, risk exposure and capacity to bear risk, human capital, labor availability, credit constraints and access to commodity markets. The potential explanatory variables which are hypothesized to influence the probability of adoption and intensity of adoption of row planting in the study area are summarized in annexed **Table 1**.

Table 1. Summary of definitions and measurement of variables used in the study.

Definition of Variables	Measurement	Expected Sign
Dependent Variables		
Adoption of Row Planting (first hurdle)	Binary (Yes/No)	
Proportion of land under Row Planting (second hurdle)	Continuous (*Timad*)	
Independent Variables		
Age of house head	Continuous (Years)	+/−
Sex of household head (Male = 1)	Binary (Male/Female)	+/−
Illiterate (Yes = 1)	Binary (Yes/No)	+/−
Farming experience	Continuous (Years)	+/−
Man equivalent	Continuous (No)	+/−
Farm size (*Timad*)	Continuous (*Timad*)	+/−
Vertisol (Yes = 1)	Binary (Yes/No)	−
Very fertile plot (Yes = 1)	Binary (Yes/No)	−
Number of plots	Continuous (No)	−
Tropical Livestock Unit (TLU)	Continuous (No)	+
Number of oxen	Continuous (No)	+/−
Log of Value of Communication Equipment	Continuous (Birr)	+
Log of Annual off-farm income	Continuous (Birr)	+/−
No of DA contacts per annum	Continuous (No)	+
Distance to DA	Continuous (Hours)	−
Distance to the nearest market	Continuous (Hours)	−
Trained row planting (Yes = 1)	Binary (Yes/No)	+
Access to credit (Yes = 1)	Binary (Yes/No)	+
No of information sources	Continuous (No)	+
Labour per Land (Days)	Continuous (Days)	−

3.3. Study Area, Data and Sampling

The data were obtained from a survey conducted from the residents of rural households in Wolaita zone. Wolaita zone was found in southern nations, nationalities and peoples region. The total population of the zone is estimated to be 1,796,436 (374,258 households). Crop production is the main stay of rural Wolaita.

Primary data on farm household characteristics, crop production (outputs and inputs) and agricultural extension services was collected through a survey from a sample of farmers in Wolaita Zone After the end of crop planting season of Meher 2007 EC. A two-stage sampling technique is used to select the sample. At the first stage, a sample of kebeles are randomly selected. At the second stage, sample households are selected using systematic random sampling. A sample of 300 households are drawn from the selected kebeles in proportion to the population size in each kebele.

4. Results and Discussions

4.1. Descriptive Analysis

The rate of adoption of row planting is very high. Out of the sampled households it was only 13 percent that do not adopt row planting in the 2006/7 production year. However, the mean intensity of use of row planting for adopters is only 2.33 *Timad* (about 56% of their total farm land) and for the whole sample is 2.03 *Timad* (about 48% of their total farm land) (annexed **Table 2**).

According to annexed **Table 2** and **Table 3**, significant differences between the adopters and non-adopters exist in all the variables except farming experience, distance to development agent (DA), soil quality (Vertisol and very fertile soil) and access to credit. The description of continuous descriptors of probability and intensity of adoption of row planting (**Table 2**) indicated that adopters are slightly older, resource endowed (mainly labor, land, livestock and communication equipment like cell phone, TV and Radio) and earn higher off farm income

Table 2. Continuous descriptors of probability of adoption and intensity of adoption of row planting.

Variable	Adopters		Non Adopters		Total		Ho: diff = 0	
	Mean	SD	Mean	SD	Mean	SD	*t*-value	*P*-value
Age of house head	38.67	10.21	34.44	6.625	38.12	9.908	−3.43	0.001
Farming experience	18.37	9.81	17.87	6.109	18.31	9.414	−0.43	0.666
Man equivalent	4.17	1.294	3.26	0. 819	4.05	1.278	−5.89	0.000
Farm size (Timad)	4.82	2.762	2.85	1.631	4.560	2.723	−6.31	0.000
Farm size with row plantation (Timad)	2.33	1.532	0.00	0.000	2.03	1.631	−24.58	0.000
Proportion of farm with row plantation (Timad)	0.56	0.313	0.00	0.000	0.48	0.347	−28.68	0.000
Number of plots	1.36	0.663	1.10	0.307	1.33	0.634	−4.08	0.000
Tropical Livestock Unit	5.67	5.633	2.96	2.326	5.32	5.396	−5.31	0.000
Number of oxen	1.54	2.059	0.69	0.800	1.43	1.962	−4.69	0.000
Value of Communication Equipment (Birr)	190.81	334.049	28.21	102.466	169.67	318.384	−6.16	0.000
Annual off−farm income	2614.1	5242.9	1519.0	2927.3	2471.7	5012.7	−1.921	0.058
No of DA contacts/annum	24.83	17.611	16.46	20.577	23.74	18.206	−2.411	0.020
Distance to DA (Hours)	0.69	0.058	0.803	0.141	0.707	0.054	0.719	0.475
Distance to market (Hours)	0.93	0.596	1.13	0.644	0.95	0.606	1.862	0.0687
No of information sources	2.19	1.216	1.13	1.031	2.053	0.072	−5.863	0.000
Labor per Land (Days)	22.30	17.804	34.48	19.884	23.88	18.512	3.62	0.001

Table 3. Discrete descriptors of probability of adoption and intensity of adoption of row planting.

Variable	Adopters		Non Adopters		Total		Ho: diff = 0	
	Freq.	%	Freq.	%	Freq.	%	χ^2 Value	*P*-value
Sex of household head (Male = 1)	232	88.9	26	66. 7	258	86.0	13.917	0.000
Illiterate (Yes = 1)	64	24.5	22	56.4	86	28.7	16.873	0.000
Vertisol (Yes = 1)	70	26.8	9	23.1	79	26.3	0.245	0.621
Very fertile plot (Yes = 1)	34	13.0	4	10.2	38	12.7	0.235	0.628
Trained row planting (Yes = 1)	242	92.7	20	66. 7	262	87.3	52.668	0.000
Access to credit (Yes = 1)	207	79.3	31	79.5	238	79.3	0.001	0.980

compared to non-adopters. Moreover, adopters have higher number of contacts with DA, have higher no of information sources (like media, farmer association, DA, local government, social networks and family and friends) and reside nearer to market compared to their non-adopter counterparts, but use lower labour per land.

Description of the discrete descriptors of probability and intensity of adoption of row planting (**Table 3**) also showed that higher number of non-adopter households, compared to adopters, are headed by female and illiterate house heads. Moreover, non-adopters are found lesser to participate row planting training sessions provided.

4.2. Empirical Results

4.2.1. Model Specification Test

According to the survey data conducted for the purpose of this study, there are farmers who have adopted and non-adopted row planting and farmers are found to use row planting in different levels. Thus, we estimated the rate of adoption using probit model and intensity of use of row planting using truncated regression model. As a result double hurdle model is used to estimate the probability and intensity of adoption of row planting.

The dependent double-hurdle model is tested against two other common models, the Tobit and independent double hurdle models. First we estimated Tobit and independent double hurdle models with different hypothesizes and check which model is superior to the other. To determine this, we conducted a log-likelihood test as presented in Equation (7). The calculated test statistic is $\Gamma = -2[-117.98 + 42.9 + 42.8] = 64.56$ and is well above the tabulated value $\chi^2(20) = 10.85$ at a 5% level of significance. Hence, we can say that the Cragg's model better fits our data than the Tobit model. This implies that a farmer's decision about adoption and level of adoption row planting are made in two different stages. Second we estimated the dependent double hurdle model by introducing inverse mills ration as a proxy for the dependency between error terms that enter the first and second hurdles and we found invers mills ratio to significantly affect the intensity of use of row planting at 10 % level of significance. This implies there exist a relation between the two processes of decision making undertaken by farmers and we conclude that depend double hurdle model dominate independent double hurdle model. Hence, from here on discussions are based on the findings of the dependent double hurdle model (modified Cragg's model).

4.2.2. Econometric Results

Annexed **Table 4** presents the maximum likelihood parameter estimates of the dependent double hurdle model (probit and truncated regression models) identifying factors influencing farmers' adoption and level of adoption of row planting. The dependent variables are *Adoption of Row Planting* for the participation equation and *Proportion of land under Row Planting* for the quantity equation and we used the same explanatory variables for both participation and quantity decisions. In all the analyses the likelihood ratio test statistics suggested the statistical significance of the fitted regression. Results of the analyses also revealed that rate of adoption and intensity of adoption of row planting were influenced by different factors and at different levels of significance. The discussion of results of significant factors is presented as follows.

The probability of farmers to adopt and the level of adoption of row planting is positively and significantly affected (at most of 1% level of significant) by family size (in man equivalent) and off farm income but negatively and significantly affected by distance to market (**Table 4**). These findings are consistent with the findings

Table 4. Maximum likelihood estimates of dependent double hurdle models for adoption and intensity of adoption of row planting among farming household heads in Wolaita Zone.

Variable	First Hurdle (Probit)-Participation Equation					Second Hurdle (truncated model)-Quantity Equation			
	Coeff.	SD	z-value	P-value	Marginal Effect	Coeff.	SD	*t*-value	P-value
Constant	−12.8214	4.072223	−3.1485	0.001641		0.954253	0.130468	7.314079	0
Sex of household head (Male = 1)	0.696379	0.62181	1.119924	0.262746	0.035925	0.040707	0.053636	0.758961	0.447876
Age of house head	0.023538	0.037376	0.629777	0.528841	0.001214	−0.00377	0.002299	−1.64162	0.10067
Illiterate (Yes = 1)	1.252693	0.672449	1.862881	0.062479	0.064625	−0.09405	0.040602	−2.31642	0.020536
Farming experience	−0.09416	0.034634	−2.71883	0.006551	−0.00486	0.000164	0.002318	0.07073	0.943612
Man equivalent	0.948064	0.444916	2.130884	0.033099	0.04891	0.027345	0.014632	1.868854	0.061643
Farm size (Timad)	1.011262	0.415938	2.43128	0.015046	0.05217	−0.06683	0.00827	−8.08108	0
Number of plots	0.236153	1.007502	0.234394	0.814679	0.012183	0.023495	0.029691	0.791324	0.428755
Vertisoil (Yes = 1)	1.190357	0.897762	1.325916	0.184868	0.061409	−0.03967	0.049968	−0.79389	0.427258
Very fertile plot (Yes = 1)	−1.49587	1.166723	−1.28211	0.199804	−0.07717	−0.08185	0.050862	−1.60917	0.107579
Tropical Livestock Unit	0.20416	0.181575	1.124383	0.260851	0.010532	0.029548	0.008198	3.604403	0.000313
Number of oxen	0.170393	0.468382	0.36379	0.716015	0.00879	−0.04829	0.020243	−2.3853	0.017065
Log Value of Communication Equipment (Birr)	0.189898	0.16126	1.177586	0.238962	0.009797	0.004208	0.006278	0.670222	0.502717
Log Annual off-farm income	0.136916	0.076623	1.78689	0.073955	0.007063	0.016783	0.005086	3.299765	0.000968
No of information sources	1.819245	0.49008	3.71214	0.000206	0.093853	−0.00939	0.015202	−0.61781	0.5367
No of DA contacts per annum	0.012353	0.014808	0.834234	0.404149	0.000637	0.001069	0.000959	1.11421	0.265189
Distance to DA (Hours)	−0.94389	0.570878	−1.6534	0.09825	−0.04869	0.024556	0.017674	1.389361	0.164723
Distance to nearest market (Hrs)	−1.02453	0.464588	−2.20524	0.027437	−0.05285	−0.07511	0.031358	−2.39527	0.016608
Trained row planting (Yes = 1)	5.484458	1.696345	3.233103	0.001225	0.282937	−0.21659	0.072078	−3.00491	0.002657
Access to credit (Yes = 1)	−0.12399	0.558785	−0.2219	0.824394	−0.0064	−0.0516	0.046058	−1.12026	0.262604
Labor per Land (Days)	0.007566	0.014181	0.533551	0.593652	0.00039	0.000397	0.001046	0.379187	0.704549
Inverse Mills Ratio						0.144466	0.082595	1.749093	0.080275
SD of error terms (Sigma)						0.25156	0.011284	22.29292	0
χ^2 Value (P-value)	172.3893 (0.0000)					162.23145(0.0000)			
χ^2 Value (P-value)	175.38635 (0.0000)								
Log likelihood (Truncated)	−41.329551								
Log likelihood (Probit)	−42.886928								
Log likelihood (Separate Tobit)	−117.97504								

of Teklewold *et al*. [20], Hailu [13], Berhanu and Swinton [10] and Hassen B. [5] in their study of different agricultural technology adoption.

According to **Table 4**, farmers' probability of making a decision in favor of adopting row planting increases by 4.89 percent when farming households' family size rises by one unit. Such effect of family size is realistic in cases where there is no higher dependency ratio (an average of 1.76 for this study) in which majority of family members participate in farming activities. Farming households also plant a 2.74 percent more of their land using row planting for every unit rise in their size. The probable reason for this significant positive effect of family size was that row planting is labour intensive and hence the household with relatively high size (labour force when dependency ration is low in farming households) uses the technologies on their farm plots better than others.

Every one percent rise in off-farm income of households induces 0.71 percent and 1.67 percent rise in the likelihood of adopting and intensity of use of row planning respectively (**Table 4**). The possible justification for this result is that off-farm income earned might solve the financial constraints to hire labour and purchase farm inputs like fertilizer that complement row planting.

Moreover, **Table 4** confirms when households' residence is one hour more far from the nearest market, probability and intensity of adoption of row planting declines respectively by 5.28 percent and 7.51 percent. This may be due to the fact that the furthest residence of farmers is the higher cost of transportation, the limited access to inputs and the lower the output price.

Farm size, as indicated in **Table 4**, had influenced the likelihood of adopting row planting positively and significantly (at 5% level of significant). This may be because farm size is an indicator of wealth and perhaps a proxy for social status and influence within a community. The result is consistent with the finding of Feder *et al.* [7] and Abara, O.C & Singh, S, [24]. However, in this study farm size had influenced the intensity of use of row planting negatively at less than 1 percent level of significance. This may be due to the fact that there is less potential of expanding farm size in Wolaita (among the most densely populated in Ethiopia) and thus for farmers, the most likely option for betterment of their livelihood is to increase input productivity like row planting, and small farmers are most likely to intensively use row planting.

In this study, households headed by illiterate house heads have 9.4 percent lower level of intensity of use of row planting compared to households headed by literate house heads (**Table 4**). This result is consistent with the general argument that education and adoption have positive correlation [7] [25]. This may be due the fact that an educated farmer is more competent and able to access and assimilate information regarding various technologies, their advantages, and disadvantages. However, households with illiterate house heads have 6.46 percent higher probability of adopting row planting compared to households with literate house heads (**Table 4**). This may be true in cases where literate farmers are aware of agricultural risks like crop failure.

Training of row planting had also significant effect on adoption and intensity of row planting. Farmers who got training on row planting have about 28.3 percent higher probability of adopting row planting compared to those who did not get training. However, training is found to influence the level of adoption negatively and significantly (at 5% level of significant). This unexpected effect of training on intensity of use of row planting may question the type, quality and timing of training provided.

Farmers' probability of adopting row planting increases significantly when they have more information sources as information reduces doubts about the performance of a technology, which may change judgment from subjective to objective. But unit rise in distance to DA and farming experience of house head significantly reduces the likelihood of adoption of row planting by 4.87 percent and 0.4858 percent respectively. The negative influence of house head farming experience could be attributed to conservativeness due to the cultural practice.

As livestock is considered as a sign of wealth in farming households and increases availability of cash for adopting technologies, it had influenced intensity of adoption of row planting positively and significantly (at 1 percent of significant). This result is consistent with finding of Abay and Assefa [11] and Hassen, *et al.*, [5]. However, a unit increase in the number of oxen that farming households possess reduces the intensity of adoption of row planting by 4.8 percent. This result may be sensible if we consider the wide spread cattle fattening culture of Wolaita people that makes them to shift from crop production livestock production.

5. Conclusions

In developing economies like Ethiopia which totally depend on agriculture, supporting agrictulture sector through different institutional support services boosts agricultural production. Considering the lion's contribution of crop production in Ethiopia, the government has introduced different agricultural technologies as a component of institutional support services. Row planting is one of the new agricultural technologies being introduced during recent times. Despite of such institutional support services, utilization of improved technologies remained low in Ethiopia. Hence, this study is to identify factors influencing row planting adoption and optimum intensity use among small holder crop farmers of Wolaita zone. To achieve such goal, we analyzed farming households' decision to adopt or not and level of adoption of row planting using dependent double hurdle model. Two stage sampling procedure of sample selection was used to select 300 farmers using systematic random sampling of farm households in eight kebeles previously selected using simple random sampling in the first stage.

Descriptive analysis of decision variables reveal that about 87 percent of farmers adopt row planting in 2006/7 production year with mean intensity of use 2.33 Timad (about 56% of their total farm land). Adopters are slightly older, resource endowed, better use institutional services (DA contact, training) and earn higher off farm income compared to non-adopters. Moreover, large number of adopters compared to their non-adopter counterparts, are headed by female and illiterate house heads.

Econometric analysis also revealed that household being headed by Illiterate head, family size (in man equivalent), Farm size, Annual off-farm income, Distance to nearest market and Training on row planting significantly influenced adoption and level of adoption of row planting. Moreover, adoption of row planting is significantly affected by Farming experience, No. of information sources and Distance to DA whereas level of adoption of row planting by livestock (in TLU) and Number of oxen.

This study found that education of farmers (being literate) is important in raising the level of adoption of row planting. Hence, the study recommends local governments to intensify existing informal education for those who adopt the technology. Moreover, considering the finding that illiterate farmers are more ready to adopt row planting compared to literate, decision makers need to orient literate farm households about advantage and disadvantages of row planting and how to mitigate the associated agricultural risks like crop failure which may hider them from adopting the technology.

The fact that farm size had a negative impact on intensity of use of row planting implies that policy makers should give attention to small farmers in designing technological intervention for increased production. This can be supported by the fact that that there is less potential of expanding farm size in Wolaita (among the most densely populated in Ethiopia) and thus for farmers, the most likely option for betterment of their livelihood is to increase input productivity like row planting productivity rather than expanding farm size.

In the experience of subsistence farming row planting is found to be labour intensive compared to the traditional broadcasting. Hence, considering the positive influence of both family size and off farm income on adoption and level of row planting, farming households should optimally mobilized their family members to participate in their farming activities and in other off farm income activities to rise adoption and intensity of use of row planting.

The fact that training on row planting and number of information sources about row planting had significant positive effect and distance to DA had negative significant effect on adoption of row plating also signifies agricultural extension service should be given priority and emphasis to fasten the production and dissemination of row planting. However, the unexpected negative significant effect of training on row planting on the level of adoption of the technology urges training implementers to look in to the quality, content and timing of the training they provide.

The Negative significant effect of distance to market on the adoption and level of adoption of row planting shows us enhanced local government effort of investment to improve market access is vital. Moreover, significant negative impact of farming experience on adoption of row planting and significant positive influence of livestock (in TLU) on intensity of adoption of row planting respectively invites extension agents to select younger farmers as models to expand experiences as older once may be found to be conservative to their cultural practice and excel their efforts of introducing row planting to those farmers with higher number of livestock.

Therefore, the results of the study suggest that row planting adoption and intensity of use of farmers should be improved by raising their education, optimally mobilizing their family members, raising their off farm income, raising farm household endowment and providing extension service.

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