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Factors Affecting the Adoption and Intensity of Use of Improved Forages in North East Highlands of Ethiopia

Hassen Beshir[1*]

[1] *Wollo University, Department of Agricultural Economics, P.O. Box 1145, Ethiopia.*

Author's contribution

The author HB designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. He managed collection, analyses and the literature searches of the study. He read and approved the final manuscript.

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ABSTRACT

Analysis of crop-livestock integration aims at understanding the existing interactions between crops and livestock and assessing their potential for improvement in smallholders' farming systems. The objective of this study was to identify factors affecting the probability of adoption and intensity of use of improved forage technologies in mixed farming systems in two districts of south Wollo zone, in Ethiopia. A double hurdle model was employed using data collected from randomly selected 252 farmers between July 2009 and November 2009. The study revealed low utilization of improved forage seed which covered only 1.3% of total cultivated land in Ethiopia. The results of the study provided empirical evidence of a positive impact of extension and credit service in enhancing the probability of adoption of improved forage technologies. The intensity of use of improved forage in the study area was influenced by labour available, size of livestock ownership and farm size. Physical characteristics like distance from farmers' home to all weather roads, markets and input supply played a critical role in the adoption of improved forage technologies. Therefore, the results of the study suggest that the adoption of improved forage should be enhanced by raising farm household asset formation, and providing extension and credit services.

Key words: Adoption; double hurdle model; improved forage technology; South Wollo.

**Corresponding author: Email: hassenhussien@gmail.com;*

1. INTRODUCTION

The economic development of Ethiopia is highly dependent on the performance of its agricultural sector. Agriculture contributes 53% of the country's Gross Domestic Product (GDP), 85% of all exports (coffee, livestock and livestock product and oil seeds) and provides employment for 85% of the population [1]. Agriculture provides also raw material for 70% of industries in the country [2]. The bulk of agricultural GDP for the period 1960-2009 had come from cultivation of crops (90%) and the remaining (10%) from livestock production [1; 3]. The industrial sector is small in size contributing, on average, only about 13% of the GDP.

The growth rate of agriculture and GDP is low for several decades mainly due to severe weather fluctuations, inappropriate economic policies and low adoption of improved agricultural technologies and prolonged civil unrest [4]. The yield of crops and livestock is very low because of low utilization of improved technologies. For instance, the amount of inorganic fertilizer applied in the 2008/09 cropping season was 423,000 tons. During the same period, the total area fertilized with inorganic fertilizer for all crops was about 29.6% of total cultivated area in Ethiopia [5]. The proportion of hybrid and exotic cattle breed was 0.81% of the cattle population while the proportion of improved forage utilized by private households was 1.3% in the country [6]. Hence Ethiopian smallholders typically produce with their indigenous seed and breed and are characterized by low adoption of improved agricultural technologies. Because of the low productivity of the agricultural sector, Ethiopia has become highly dependent on food import in that domestic food production and supply have consistently been below the national demand [1]. For instance, the country received 674,000 metric tons of cereals in the form of food aid in 2006 alone [1]. The increasing human population and higher demand for food in Ethiopia is progressively forcing farmers of the highland and mid-altitude areas to cultivate more land at the expense of natural grazing areas. Consequently, the major livestock feed resources in the country are becoming crop residues, which are nutritionally characterized as containing a high proportion of cell wall and being deficient in energy, protein and micronutrients [7]. Introduction, popularization and utilization of improved and exotic multipurpose forage crops and trees such as *Sesbania spp., Leucaena leucocephala, Calliandra spp. and Chamaecytisus palmensis* through integration with food crops cultivation in the mixed crop-livestock system in Ethiopia started in the 1970s to supplement the roughage feed resources [8,9].

In the northeast Ethiopia where this study is conducted, crop and livestock productions are highly integrated as a means to generate income, cope up with market and environmental risks and meet household consumption requirements. The major crops grown by sample households were improved and local wheat, barley, teff (Eragrostis tef), local and improved horse bean, field pea, maize, local and improved potato, oat, fenugreek, garlic, lentil, chickpea, grass pea, sorghum, haricot bean and linseed. The major livestock reared by sample households were improved and local dairy cow, improved and local poultry, local and improved beehives, sheep and goat products. The outputs of crops and livestock were used mainly for home consumption but were rarely used for markets to obtain cash income. The straws of crops were used for animal feed. Animals like oxen were also used for draft power in plowing and planting. Moreover, the wastes of animal in the form of manure were used for improvement of soil fertility. However, the production and productivity of crop and livestock is very low resulting in food insecurity. The average cultivated area with inorganic fertilizer is 19% of the total cultivated area in south Wollo. Due to low use of improved practices the productivity of all crops and livestock is below the national average. For example, the yield of cow in south Wollo is 1.488 liters per cow per day for traditional practices but more than

8.0 liters per cow per day using improved dairy cow and improved forage. It is supported by empirical evidence that improved forage and health service improves the productivity of livestock. This study tried to assess the factors responsible for the probability of adoption and intensity of use of improved forage technologies (oat, vetch and trilucern). Oats are planted for good grain yield and quality with high protein and low screenings. Some oats and vetch are used for dual purpose usage with very good hay quality. Oats are particularly useful in rotations with vegetable crops because they grow quickly and are easily killed. They are also useful as a nurse crop with legumes, such as hairy vetch and peas, for forage, erosion control and weed suppression.

Though there have been various empirical studies conducted to identify determinants of adoption of agricultural technologies in Ethiopia, [for example [10,11,12,13], to the best of the author knowledge, there were no similar studies undertaken in the study area. Moreover, since adoption is dynamic, it is imperative to update the information based on the current technologies being adopted by farmers. The general objective of the study was to identify the determinants of the adoption of improved forage technology in mixed crop and livestock farming systems in two districts of South Wollo, North East highland of Ethiopia.

2. METHODOLOGY OF THE STUDY

2.1 Description of the Study Area

This study was carried out in South Wollo. South Wollo is located in the North East part of Ethiopia. South Wollo is one of the eleven administrative zones of the Amhara National Regional State. It is situated between the Eastern highland plateaus of the region and the North Eastern highland plateaus of Ethiopia. It is divided into 20 administrative districts (weredas) and has two major towns (Kombolcha and Dessie) and 18 rural districts. Among the eighteen rural districts, Dessie Zuria and Kutaber are selected for this study. South Wollo is located between latitudes 10°10'N and 11°41'N and longitudes 38°28' and 40°5'E. According to the Central Statistical Agency's population census data, in 2007 the total population of South Wollo was 2,519,450 of which 50.5% were females and 88% were rural residents [14]. The total land area in South Wollo, Dessie Zuria and Kutaber is 1,773,681 hectares, 180,100 hectares and 72,344 hectares, respectively. The cultivated land area accounts for 39%, 20% and 35.3% of the total area of Dessie Zuria, Kutaber and South Wollo, respectively.

2.2 Sample Size and Sampling Procedure

Dessie Zuria and Kutaber districts were selected purposively based on their accessibility and relevance of the study. A multistage random sampling method was used for the selection of the sample respondents. In the first stage of sampling, 6 Farmers' Associations (FAs) were selected randomly from a total of 54 FAs (3 from Dessie Zuria and 3 from Kutaber). In other words, as the number of Farmers' Association in Dessie Zuria (28) was equal to that of Kutaber (26), three Farmers' Associations were selected from each district using simple random sampling procedure. In the second stage, a total of 252 farmers were selected using probability proportional to sample size sampling technique (Table 1).

Table 1. Distribution of sample farm household heads by farmers' association and district

Name of District	Name of FA	Total household* head		Sample farm household heads		
				Female	Male	Total
		Male	Female	Number	Number	Number
Dessie Zuria	Tita	686	182	7	27	34
	Bilen	1,179	161	8	45	53
	Endod Ber	688	102	4	27	31
Kutaber	Boru	490	123	5	20	25
	Beshlo	797	201	8	32	40
	Alasha	1,297	458	18	51	69
Total		5,137	1,227	50	202	252

*Source: *Kebele Administration Office (Personal Communication)*

2.3 Data Collection and Sources

A structured questionnaire was designed, pre-tested and refined to collect primary data. Experienced numerators were recruited and trained to facilitate the task of data collection. Farm visit, direct observation and informal interview were undertaken both by the researcher and the enumerators. The secondary data were extracted from studies conducted and information documented at various levels of Central Statistical Agency, Ministry of Agriculture and Rural Development and Finance and Economic Development Offices in the study area.

2.4 Econometric Specification of Agricultural Technology Adoption Model

Adoption refers to the decision to use a new technology, method, practice, etc. by a firm, a farmer or a consumer. A farm level (individual adoption) adoption reflects a farmer's decisions to incorporate a new technology into the production process. On the other hand, aggregate adoption is the process of spreading or diffusion of a new technology within a region or population. Therefore, a distinction exists between adoption at the individual farm level and aggregate adoption, within a targeted region or within a given geographical area [15]. This study focuses on individual or farm household improved technology adoption. The rate of adoption is defined as the proportion of farmers who have adopted a new technology. The extent of adoption is the percentage of farmers using a technology at a specific point in time (e.g. the percentage of farmers using improved forage technologies). The intensity of adoption is defined as the aggregate level of use of a given technology within a household [15].

The adoption of agricultural innovations can provide the basis for increased production and income. More precisely, farmers will adopt only those technologies that suit their needs and circumstances [16]. As part of the effort to increase agricultural productivity, researchers and extension staff in Ethiopia have typically promoted a technological package consisting of a number of components. However, because of capital scarcity and risk considerations, farmers are rarely adopting complete packages [17].

There is now an agreement in the literature that agricultural development implies the shift from traditional methods of production to new, science-based methods of production that include new technological components and/or even new farming systems. For farmers to adopt these new production technologies successfully, they must first learn about them and how to use them correctly in their farming system [18]. Moreover, farmers are assumed to maximize expected utility according to [19] utility function defined over wealth (W). When confronted with a choice between two alternative practices, the i^{th} farmer compares the expected utility with the modern technology, $E_{mi}(W)$ to the expected utility with the traditional technology, $E_{ti}(W)$. While direct measurement of farmers' perceptions and risk attitudes on farming technology are not available, inferences can be made for variables that influence the distribution and expected utility evaluation of the technology. These variables are used as a vector 'X' of attributes of the choices made by farmer 'i' and ε_i is a random disturbance that arises from unobserved variation in preferences, attributes of the alternatives, and errors in optimization.

Given the usual discrete choice analysis and limiting the amount of non-linearity in the likelihood function, $E_{mi}(W)$ and $E_{ti}(W)$ may be written as:

$$\begin{aligned} E_{mi}(W) &= \alpha_{mi} X_{mi} + \varepsilon_{mi} \\ E_{ti}(W) &= \alpha_{ti} X_{ti} + \varepsilon_{ti} \end{aligned} \tag{1}$$

The difference in expected utility may then be written as:

$$E_i(W) = E_{mi}(W) - E_{ti}(W) = \alpha_i X_i + \varepsilon_i \tag{2}$$

A preference for the modern technology will result if $E_i = E_{mi}(W) - E_{ti}(W) > 0$; whereas, a preference for the traditional technology will be revealed if $E_{mi}(W) - E_{ti}(W) < 0$. The observed adoption choice of an improved wheat variety is hypothesized to be the end result of socioeconomic characteristics of farmers and a complex set of inter-technology preference comparisons made by farmers [20].

Different researchers used different models for analyzing the determinant of technology adoption. In principle, the decisions on whether to adopt and how much to adopt can be made jointly or separately [21]. Adoption studies based up on dichotomous regression model have attempted to explain only the probability of adoption versus non-adoption rather than the extent and intensity of adoption. Such knowledge that a farmer is using high yielding technology may not provide much information about the farmer’s behavior because he/she may be allocating some percent or 100 percent of his/her farm for the new technology. A strictly dichotomous variable often is not sufficient for examining the extent and intensity of adoption for some problems such as fertilizer [15]. In adoption studies, the Tobit model used with the assumption that the two decisions are affected by the same set of factors [22]. In the double-hurdle model, on the other hand, both hurdles have equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of them [13]. Empirical studies have also indicated that a variable appearing in both equations may have opposite effects in the two equations. The double-hurdle model, developed by [23], has been extensively applied in several empirical studies [see for instance, 24, 25, 21, and 13]. The double-hurdle model has been applied and provided promising results for agricultural technology adoption decisions [13]. In this study, the double hurdle model was used to identify the determinant of probability of adoption and intensity of use of improved forage technology in south Wollo.

As already noted, in this study a double hurdle model is used to identify factors affecting the probability and intensity of use of an improved forage technology. The double-hurdle model consists of two separate stochastic processes that determine the decision to adopt and the intensity of use of a technology. The double-hurdle model has an adoption (D) decision with an equation:

$$\begin{aligned} &D_i = 1....if....D_i^* > 0...and \\ &D_i = 0....if...D_i^* \leq 0 \\ &D_i^* = \alpha' Z_i + U_i \end{aligned} \tag{3}$$

where D_i* is a latent variable that takes the value 1 if a farmer adopts improved forage technology and zero otherwise, Z is a vector of household characteristics and α is a vector of parameters.

The level of adoption decision (Y) is represented by the equation:

$$\begin{aligned} &Y_i = Y_i^*....if....Y_i^* > 0....and...D_i^* > 0 \\ &Y_i = 0\ldots otherwise \\ &Y_i^* = \beta' X_i + V_i \end{aligned} \tag{4}$$

Where Y_i is the observed amount of improved forage technology, X_i is a vector of household socioeconomic characteristics and β is a vector of parameter.
The log-likelihood function for the double hurdle model is

$$\log L = \sum ln\left[1 - \Phi(\alpha Z'_i\left(\frac{\beta X_i}{\sigma}\right)\right] + \sum ln\left[\Phi(\alpha Z'_i)\frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X'_i}{\sigma}\right)\right] \tag{5}$$

Under the assumption of independency between the error terms V_i and U_i the double hurdle model is equivalent to a combination of univariate Probit model (3) and the truncated regression model (4). The double hurdle log-likelihood is the sum of the truncated regression and the Probit models. A hypothesis test for the double hurdle model against the Tobit model can be made. The test can be made by estimating three regression models (Tobit model, the truncated regression and the Probit models) separately and use a log-likelihood ratio (LR) test. The LR statistics can be computed using the following formula [22]:

$$\Gamma = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \sim \chi^2_k$$

Where L_T= likelihood for the Tobit model; L_P= likelihood for the Probit model; L_{TR}= likelihood for the truncated regression model and k is the number of independent variables in both equations.

The test hypothesis is written as:

H_0: $\lambda = \frac{\beta}{\sigma}$ and H_1: $\lambda \neq \frac{\beta}{\sigma}$

H_0 will be rejected on a pre-specified significance level if $\Gamma > \chi^2_k$

2.5 Measurement and Definitions of Variables for Adoption

2.5.1 The dependent variables of Probit and truncated regression models

The dependent variable of the Probit model takes a dichotomous value depending on the farmers' decision either to adopt or not to adopt the improved forage technology. However, the truncated regression model would have a continuous value which is the intensity, the use and application of the technology. In this case, it indicates the amount of improved forage cultivated in hectare. Adopters are farmers who use improved forage technology (oat, vetch and trilucern). Non-adopters are farmers who did not use either of this technology during the survey year (2008/2009 production year). The improved technologies in question are oat, vetch and trilucern which were developed and released by the Ethiopian Institute of Agricultural research.

2.5.2 The independent variables and their definitions in the double hurdle model

Adoption literatures provide a long list of factors that may influence the adoption of agricultural technologies. Generally, 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 such as household characteristics, socio-economic and physical environments in which farmers operate.

The explanatory variables included in the empirical models were selected following the literature on farm level investment theory [15, 26, 27,21]. Following these literature, farm investment can be modeled as a function of market access factors (as a proxy for return on investment factors); capacity to invest; physical incentive to invest; socio-institutional factors; and household demographic characteristics.

The market access factors affect the relative profitability of investment in improved technology. Ideally such factors would include crop prices, cost of labour and materials used for improved agricultural technologies and the yield effect of such practices. However, the survey results revealed that it was not possible to get accurate information on grain selling prices from the majority of the sample respondents. Instead, relative prices were proxied by distance from market place and input supply institutions. Labour input is a major cost component in crop and livestock production investment in the study area. Distance from an all-weather road was used to proxy for differences in the opportunity cost of labour.

Physical factors create opportunities for investing in crop and livestock production. These factors were expected to detract from investment due to increased transaction costs. The factors expected to affect the capacity to invest include livestock holding, off/non-farm income, farm size and family labour. Farm size is measured as the total acreage (in hectares) of cultivated land, and family labour is measured as number of household members in man equivalent. The effect of farm size is that more land indicates greater wealth and capacity and should encourage investment in improved technology. Own labour availability should encourage investment either due to availability of labour to do the work or due to the need to feed more people. Livestock holding is measured as the number of livestock in Tropical Livestock Unit (TLU). Livestock are important source of income, food and draft power, and represent an asset which indicates the wealth status of the household and as such are expected to facilitate the adoption of improved agricultural technologies. Off/non-farm income is captured as a dummy variable indicating whether or not the farmer had access to additional income from off/non-farm activities.

Several socio-institutional variables were hypothesized to encourage farmers to invest in crop and livestock production. These include access to credit service and contact with agricultural extension agents. Household demographic variables include age, sex, number of dependents in the household expressed in adult equivalent and literacy level of the household head.

In the course of identifying factors influencing farmers' decision to use improved agricultural technologies, the main task is to analyze which factor influences the decision, how and by how much. In this study, it was hypothesized that probability of adoption and intensity of use of improved forage technologies are influenced by the combined effect of various factors. The potential explanatory variables which are hypothesized to influence the adoption and intensity of adoption of improved forages in the study area are given in Table 2.

Table 2. Definitions and measurements of variables used in the Probit and Truncated regression model

Definition of variables	Nature and units of measurement of variables	Expected sign
Dependent variables		
Adoption of improved forage technology	Dummy (Yes/no)	
Amount of improved forage cultivated	Continuous (hectare)	
Independent variables		
Distance to nearest market	Walking minutes	-
Distance to nearest all weather road	Walking minutes	-
Age of the household head	Years	+/-
Education of the household head	Formal schooling in years	+
House hold size in adult equivalent	Number	-
Labour force in Man equivalent	Number	+
Farm size	Cultivated area in ha	+
Fragmentation	Number of plots	-
Livestock owned	TLU	+
Distance to input supply institution	Walking minutes	-
Sex of the household head	Male/female	+
Distance to DA office	Walking minutes	-
Distance to credit office	Walking minutes	-
Access to off/non farm income	Yes/no	+/-
Access to extension service	Yes/no	+
Access to credit service	Yes/no	+

3. RESULTS AND DISCUSSION

As already noted, the majority of smallholder farmers in Ethiopia are producing both crops and livestock. However, the productivity of the agricultural sector is very low due to low adoption and application of improved agricultural technologies. This study attempts to identify factors affecting the adoption and intensity of use of improved forage technologies in the study area.

3.1 Description of Variables of Empirical Adoption Models

The survey results reveal that only 11.9% of the sample respondents adopted the improved forage technologies. The average amount of improved forage seed that farmers used was 3.63 kg and 0.43 kg for adopters and the whole sample respondents, respectively. As shown in Table 3, adopters are slightly old, more educated and own more resources (mainly labour, land and livestock) than the non-adopters.

Moreover, there was a significant difference between adopters and non-adopters with regard to sex and access to extension and credit service (Table 4).

Table 3. Descriptive statistics of explanatory variables by farmers' group (mean)

Variables	Non-adopters (222)	Adopters (30)	Total (252)	t
Distance to nearest market	82.29	92.50	83.50	1.15
Age of the household head	52.93	55.6	53.25	0.97
Education of the household head	2.14	2.87	2.22	1.13
House hold size in adult equivalent	4.74	5.26	4.8	1.7*
Labour force in Man equivalent	3.83	4.17	3.87	1.06
Farm size	0.68	0.64	0.68	-0.52
Fragmentation	3.78	4.13	3.82	0.87
Number of oxen	1.05	1.47	1.1	3.85***
Number of cow	0.83	1.23	0.88	3.98***
Livestock owned in TLU	3.432	5.174	3.639	3.97***
Distance to input supply institution	97.36	72.17	94.36	-2.32**

*Significant *at 10%, ** at 5% and *** at 1% probability level, Source: Own survey, 2009*

Table 4. Distribution of sample respondents by demographic and institutional factors and farmers' group

Variable	Character	Non-adopters (N=222)	Adopters (N=30)	Total (N=252)	χ2
Sex	female	48	2	50	3.716*
	male	174	28	202	
Access to off-farm income	no	62	7	69	0.281
	yes	160	23	183	
Access to extension	no	111	6	117	9.563***
	yes	111	24	135	
Access to credit	no	184	20	204	4.507**
	yes	38	10	48	

*Significant *at 10%, ** at 5% and *** at 1% probability level, Source: Own survey, 2009*

3.2 Econometric Results for Improved Forage Technology Adoption

As already noted, of the 252 sample respondents 30 adopted improved forage and the remaining (222) did not adopt the technology. It is evident that those who adopted the improved forage would use the improved technology at different levels. Therefore, the rate of adoption was estimated using the Probit model whereas the intensity and level of use of the improved forage was estimated using the truncated regression model. Hence, the double hurdle model was used to estimate the rate and intensity of adoption of improved forage

Accordingly, explanatory variables were checked for problems of multicollinearity, endogeneity and heteroscedasticity. Following [28], the problem of multicollinearity for continuous explanatory variables was checked using a technique of variance inflation factor (VIF) and tolerance level (TOL), where each continuous explanatory variable was regressed on all the other continuous explanatory variables. The larger the value of VIF, the more worrying is the multicollinearity or collinear is the variable (X_j). As a rule of thumb, if the VIF of a variable exceeds 10 and R^2 exceeds 0.90 the variable is said to be highly collinear. The values of VIF for the explanatory variables included in this study were less than ten and it was concluded that there was no serious problem of multicollinearity (Appendix 1). To check the degree of association among dummy explanatory variables, contingency coefficients were computed. A contingency coefficient is a chi-square based measure of association where a value 0.75 or above indicates a stronger relationship between explanatory variables [29]. This was also checked and all the values were found to be less than 0.7 (Appendix 2). For endogeneity test, there was no explanatory variable that was expected to be endogenous in the model and hence no need of undertaking the test. To avoid heteroscedasticity problem, robust standard error was estimated.

The test statistics of the double hurdle versus the Tobit model indicated the rejection of Tobit model. The result revealed that the calculated statistical value of likelihood ratio for improved forage was 30 which was greater than the tabulated or critical value of $\chi^2(16) = 26$ at 5% level of significance. Overall, the likelihood (rate) of adoption of improved forage was modest; a typical farmer had 11.9% predicted probability of adopting the technology. A typical farmer had used improved forage seed of 3.68kg with an average cultivated area of 0.031 hectare for adopters.

The parameter estimates of the Probit and truncated regression models employed to identify factors influencing farmers' adoption of improved forage technologies are presented in Table 5. In all analyses the likelihood ratio test statistics suggest the statistical significance of the fitted regression. Results of the analyses also indicate that rate of adoption and intensity of adoption of improved wheat varieties were influenced by different factors at different levels of significance.

Age of the farm household head was positively related to the probability of adoption of forage technology at 10 percent probability level. The justification for this is that older farmers might have gained knowledge. The result is consistent with the findings of 13 and 4. The model result indicates that as the age of the household increases by one year, the probability of adoption of improved forage technology increases by 0.18 percent.

Sex of the farm household head was positively related to the intensity of use of improved forage technology at 1 percent probability levels. This means that male farmers use more improved forage seed as compared to their female counterparts. The justification for this is that male farmers might have more access to information, extension and credit services than their female counterparts. 30 and 13 found similar signs for other technologies.

Table 5. Econometric model results for the probability of adoption and intensity of use improved forages technology

Variables	Probit			Truncated		
	Coefficient	**Robust Std. Err.**	**Marginal effect**	**Coefficient**	**Rob Std. Err.**	**Marginal effect**
Distance to market	0.02***	0.002	0.0002	-0.2***	0.01	-0.01
Distance to road	0.04***	0.004	0.0004	-0.06***	0.02	-0.04
Sex	0.386	0.403	0.0340	13.27***	4.40	9.45
Age	0.017*	0.010	0.0018	0.02	0.06	0.01
Education	0.016	0.041	0.0017	-0.14	0.26	-0.10
Household size	-0.169	0.149	-0.0179	-3.32***	0.85	-2.36
Labour availability	0.117	0.135	0.0124	2.13***	0.78	1.51
Farm size	-0.62**	0.314	-0.0659	3.70**	1.45	2.64
Fragmentation	-0.001	0.050	-0.0001	0.21	0.28	0.15
Livestock owned	0.19***	0.075	0.0203	-0.33	0.32	-0.24
Off/non-farm income	0.258	0.268	0.0248	-5.71**	2.56	-4.06
Distance to input office	-0.008**	0.003	-0.0008	-0.01	0.02	-0.003
Extension service	0.734**	0.290	0.0772	-3.22	2.52	-2.29
Distance to DA office	0.004	0.004	0.0004	-0.10***	0.04	-0.07
Credit service	0.462*	0.275	0.0617	-1.15	1.33	-0.82
Distance to credit office	-0.011**	0.005	-0.0012	-0.01	0.02	-0.008
Constant	-1.859*	1.104		4.17	6.27	
Test statistics	Wald χ^2*** (16) = 51			Wald χ^2*** (16) = 127		
	Log-L = -67			Log- L = -52		
	No of observation=252			No of observation=30		

*Significant *at 10%, ** at 5% and *** at 1% probability level*

Labour availability positively influenced the intensity of using improved forages at 1% probability level. The probable reason for this finding is that improved practices are labour intensive and hence the household with relatively high labour force uses the technologies on their farm plots more than others similar signs found for other technologies [4]. However, household size in adult equivalent negatively influenced the intensity of using improved forages at 1% probability level. This finding is in line with the hypothesis made earlier. The negative and significant effect of household size on intensity of using improved forages might be related more to the land allocated for food crops and higher food requirement of the household member than to the adoption of improved forages.

Farm size influenced negatively the probability of adoption of improved forages at 5% probability level. This might be due to the small farm size requirement of the technology. However, it positively influenced the intensity of using improved forages at 5% probability level. This implies that farm size is an indicator of wealth and a proxy for social status and influence within a community which had positively influenced the intensity of use of improved forages. The result is similar with the finding of [4]. Ownership of livestock in TLU had the expected positive and significant effect on the probability of adoption of improved forages due to availability of cash to buy the technology. Livestock is considered as an asset that could be used either in the production process or in exchange. 30 found similar signs for other technologies.

Off/non-farm income negatively influenced the decision behavior of the farm households and their intensity of using improved forages at 5% probability level. The possible justification for this result is that off/non-farm income might be used to utilize excess labour. The farmers might make a trade-off between investment in forage development and off/non-farm income participation. Agricultural extension services are the major sources of information for farmers to be familiar with improved agricultural technologies. Farmers can get access to information about new technologies through contacting development agent (DA). Access to extension services had the expected positive and significant effect on probability of adoption of forage technology due to mainly access to information. similar signs found for other technologies [13]. Agricultural credit services are the major sources of finance to those farmers who adopt improved agricultural technologies. Access to credit service had the expected positive and significant effect on the probability of forage seeds at 10 percent probability level. Similar signs found for other technologies [30,13].

Market access is one other important variable for the adoption of improved technologies. This is due to the fact that a relatively closer distance of farmers' home to the market enables and facilitates marketing of inputs and outputs. The coefficient of distance to all weather roads and markets had the expected negative sign and was significant both for the probability of adoption and intensity of use of improved forage seeds. Proximity of farmers to all weather roads and markets are essential for timely input delivery and output disposal and results in less transport cost of inputs and outputs. Thus investment in improved road infrastructure is crucial for promoting adoption and hence welfare gains. Similar signs found for other technologies [21].

Distance to input supply institutions influenced adoption of improved forage technologies. The coefficient of distance to input supply institutions had the expected negative sign and was significant for the probability of adoption of improved forage seed. Proximity of farmers to such places is essential for timely input delivery and reduction of transport cost of inputs. The coefficient of distance from farmers' home to credit office had the expected negative sign and significant effect on the rate of adoption of improved forages. Proximity of farmers to such places is vital to get credit facility on time and to reduce transport costs. The coefficient of distance between Development Agent (DA) office and home of the household had the expected negative sign and significant effect on the intensity of adoption of improved forages. Proximity of farmers to such places is crucial to access extension service on time.

4. SUMMARY AND CONCLUSION

The general objective of the study was to identify the major determinant of the probability of adoption and intensity of use of improved forage technologies in two districts of south Wollo zones of north east highland of Ethiopia. In the study area, the use of improved agricultural technologies and the yield of major crops and livestock are low. Therefore, this study was initiated to identify factors that affect the probability of adoption and intensity of use of improved forage in the study area. The study employed cross-section data to analyse the effect of farmers' socioeconomic and institutional setting and physical attributes on the probability of adoption and intensity of use of improved forages.

A double hurdle model was employed to study farmers' decision to adopt and the level of use of improved forage technologies. Dessie Zuria and Kutaber districts were selected to represent medium and high agro-ecological environment in north east highland of Ethiopia. For this study, six Farmers' Associations were selected using simple random sampling technique. Finally, 252 farmers were selected using probability proportional to sample size sampling technique. Selected farmers were interviewed to generate data for the 2008/09 cropping season using a structured questionnaire. Comparison of adopters and non-adopters of improved forage technologies revealed that adopters were slightly old, educated and slightly better off interms of resource endowment (labour, land and livestock) than the non-adopters.

The study found that access to extension services was one of the powerful factors explaining probability of adoption improved forage technologies. The age of the sample household head had a positive and significant effect on probability of adoption of improved forages. Knowledge gained through experience enables older farmers to adopt improved agricultural technologies. The resource endowment of households like farm size, livestock ownership and labour available had a positive and significant effect on the adoption of forage technologies, implying that improving the resource endowment of farmers would boost agricultural production.

Physical characteristics like distance from farmers' home to all weather roads, markets and input supply institutions played a critical role in the adoption of improved forage technologies as proximity to information, sources of input supply and credit and markets save time and reduce transportation costs. Given the critical role of proximity to such centers and better roads for promoting adoption and productivity gains, the existing efforts of investment in improved roads infrastructure should be continued to achieve increased production. Based on the results of this study, it is suggested that the adoption of improved forage technologies could be enhanced by raising farm household asset formation, and providing extension and credit services. Such actions may, in turn, alleviate the current problem of food insecurity and lead in the long run to economic development.

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COMPETING INTERESTS

The author has declared that no competing interests exist.

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APPENDICES

Appendix 1. Variance inflation factors (VIF) of the continuous explanatory variables

Variables	Collinearity Statistics	
	VIF	Tolerance
Distance from home to nearest all weather road	1.09	0.92
Age of the household head	1.54	0.65
Highest Level of education of the head	1.46	0.68
Labour force in man equivalent	7.11	0.14
Household size in adult equivalent	7.01	0.14
Farm size in hectare	1.38	0.73
Land fragmentation	1.28	0.78
Livestock owned in Tropical Livestock Unit	1.35	0.74
Distance from input supply institutions	1.42	0.70

Appendix 2. Contingency coefficients for dummy explanatory variables

Variables	Sex	Extension access	Credit access	Off/non-farm access
Sex	1	0.173	0.039	0.074
Extension access		1	0.106	0.141
Credit access			1	0.026
Off/non-farm access				1

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