Knowledge, Adoption and Use Intensity of Improved Maize Technologies in Ethiopia

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Abstract

Since the beginning of 1970's, more than 40 improved maize varieties have been released and disseminated to maize potential areas in Ethiopia. Using cross-sectional survey data collected in 2011 from 39 districts in five Regional States, this paper examines smallholder farmers' knowledge, adoption and intensity of use of improved maize varieties in the country. Poisson, binary and multinomial Probit, Tobit and Heckman's selection models are used in explaining determinants of maize variety knowledge, adoption, intensity of maize area under improved varieties at a household level, and type of maize seed used at plot level. Results show that household characteristics, availability of family labor, wealth status, social networks, and access to credit to buy seed and fertilizer, better soil fertility and depth, market opportunities (number of traders known in villages) affect the number of improved maize varieties known to farmers, their adoption and intensity of farm area allocated to improved varieties, and the use of freshly purchased hybrid and/or OPV maize varieties. Generally, institutional arrangements that strengthen farmers' access to input and output markets and accumulation of wealth could enhance the knowledge and use of improved maize technologies for better productivity and household income.

Keywords: maize, improved variety, knowledge, adoption, seed use, Ethiopia.

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1. Introduction

Addressing food security and poverty problems in agriculture-based economies demand for substantial efforts in improving agricultural production and productivity (WDR, 2008). Since the 1950s and 1960s, agricultural research centers (both national and international institutes) have been generating a number of agricultural technologies that best fit to smallholder farmers and help increasing production and productivity. Among these technologies are many improved crop varieties, widely disseminated (Maredia *et al.,* 2000; Alene *et al.,* 2009). Recent studies witnessed the clear contributions of these technologies to the welfare of smallholder farmers and other poor households who benefited from the enhanced adoption of technologies and improved agricultural productivity and production over time (Alene *et al.,* 2009, Kassie, *et al.,* 2011; Asfaw, *et al.,* 2011). Maize is one of the major food crops where research brought tangible improvement in production and productivity.

Like in many other Sub-Sahara African countries, maize plays a major role in the livelihood and food security of most smallholder farmers in Ethiopia. Maize is grown in most parts of the country with different productivity potentials (Figure 1). For many years, maize in Ethiopia has been the first in production and second (next to *teff*) in area of cropped land *(*Legese *et al., 2011)*. Data from CSA (2010) shows that, during the 2009/10 production year, Ethiopia produced 3.89 million tons of maize on 1.77 million ha of land. This gives an average productivity of 2.2 tons/ha, which is the highest of all cereal crops produced in the same year.

The importance of maize in the country's agricultural economy and household level food security calls for increasing its production and productivity through use of modern technologies. However, smallholder farmers' knowledge and use of agricultural technologies in general and improved maize varieties in particular, are limited due to various factors that are either internal or external to the farmers' circumstances. Most commonly studied internal factors that affect adoption and use of agricultural technologies are farmers' attitude towards risk (Feder *et al.*, 1985), household characteristics that affects the level of production and consumption, resource endowments, etc. External factors could be access to technologies, in particular through a well-developed seed system (Byerlee and Heisey, 1996; Croppenstedt *et al.*, 2003; Alemu *et al.*, 2008; Shiferaw *et al.,* 2008; Asfaw *et al.,* 2011), infrastructure, institutions (Beke, 2011), markets, and enabling policy environments (Maredia *et al.,* 2000; Smale *et al.,* 2011, (Tripp and Rohrbach, 2001)).

Several studies analyzed the determinants of improved maize variety adoption in Ethiopia (Feleke and Zegeye, 2006; Tura *et al.,* 2010; Legese *et al.,* 2011; among others). However, most of these studies are limited to a specific district or agroecology and use samples that are not representative of the diverse agroecologies and maize potentials in the country. Such studies lack variations within the sample and unable to explain important policy variables (Doss, 2006).

Adoption rates computed in these studies also do not explicitly state the number of seasons or years farmers have recycled a given improved maize. This is particularly important to hybrid maize variety that quickly loses its yield potential even for a first-generation recycled seed use (Pixley and Binzanger, 2001).

Thus, this study analyzes factors enhancing the knowledge and adoption of improved maize technologies in Ethiopia using a recently collected rich dataset that has wider area coverage in terms of diversity in maize production potentials and administrative regions.

The rest of this paper is organized as follows. Section 2 discusses data and specifies models used for the analyses. Section 3 presents and discusses analyses results. Section 4 concludes the paper.

2. Data and Methodology

2.1. Defining Adopter of Improved Maize Varieties

Adoption of agricultural technologies by smallholder farmers is a continuous learning process where farmers acquire information about technologies, test and adapt the technologies on their farm, and make use of them (Doss, 2006). Some adopters completely replace the existing technologies with new ones while others combine both the newly introduced with existing technologies. There are also cases where some households try new technologies once or more times and dis-adopt due to internal and external factors influencing their decision. These factors might be technical, economic, social, or combination of them.

The nature of improved maize variety adoption is quite different from the adoption of other agricultural technologies like chemical fertilizer, pesticides or herbicides. In the use of chemicals (fertilizer, pesticide, herbicides, etc.), farmers buy these technologies from external sources each season they decided to use. In the case of improved maize varieties, however, there is a possibility of saving maize seeds from the previous harvest to use in the next production season. This is common in open-pollinated maize varieties and also experienced in hybrid maize varieties when farmers lack access to seed supply or unable to afford buying new hybrid seeds each production season. However, studies in Southern Africa by Pixley and Banzinger (2001) show that, on average, hybrid maize varieties lose their productivity by 32% if a first-generation recycled seed is used. The loss in yield potential could be much higher when recycled second- or more generation seeds are used. For this reason, in this paper, maize seed used by smallholder farmers is considered as improved variety if the farmer uses freshly purchased hybrid seeds, freshly purchased Open Pollinated Varieties (OPVs), and recycled OPVs for not more than three production seasons. Accordingly, a farmer is categorized as an adopter if she/he used either or all of these three maize seed types during the 2009/10 production year.

2.2. Survey design and data

The cross sectional data used in this analysis come from a stratified random sample of 2455 farm households from 39 districts in five regional states of Ethiopia (Tigray, Amhara, Oromia, Benishangul-Gumuz, and SNNPR[1]). First, a list of 118 maize growing districts was obtained from the CSA/IFPRI 2002 dataset that has both the production and area under maize at a district level. The CSA/IFPRI 2002 data shows an average maize productivity of 2.051 tons/ha with a standard deviation of 0.648. Based on these values, we assigned a mean ± standard deviation cut-off points to categorize the districts in to a '*high*', '*medium*', and '*low*' maize potential. Accordingly, districts with average maize productivity of less than 1.403 tons/ha were assigned as *'low potential'*, above 2.698 tons/ha as *'high potential'*, and between 1.403 and 2.698 tons/ha (both inclusive) as '*medium potential*' maize districts. Then, we selected 39 districts (slightly above 30% of the districts in the list) using a proportionate probability sampling method. Geographical locations of the sample districts and the maize production potential of each district are given in Figure 1.

< FIGURE 1 HERE >

In each selected district, 4 peasant associations (PAs) were randomly selected from maize growing PAs and in each PA, an average of 10-16 farmers were randomly selected for a one-to-one interview. This resulted in a sample of 603 households from the high potential districts, 1528 from the medium and 324 from the low potential districts (Table 1).

< TABLE 1 HERE >

The household level survey was conducted on one-to-one basis using experienced and well trained enumerators. The overall fieldwork was closely monitored and supervised by staff from the Ethiopian Institute of Agricultural Research (EIAR) and the International Maize and Wheat Improvement Center (CIMMYT). To support the household level data, a community level survey was conducted with Focus Group Discussions (FGD), with a group of experienced farmers familiar with maize production, village administrators, women representatives, and extension agents within each village.

A questionnaire was developed and tested to collect the adoption data. The questionnaire captured individual, household, farm and plot level characteristics, as well as the institutional environment. The individual characteristics included age, gender, and education of the head of the household, and his or her knowledge of different varieties. Household characteristics included, resource endowments, farm and non-farm assets, and the use of maize varieties. Institutional factors included access to markets, institutions and infrastructure.

[1] Southern Nations, Nationalities and Peoples Regional State.

The characteristics of the different farm plots were also taken, in particular fertility, slope, soil type, distance from homestead, manager of each plot from the household members, etc.), crops grown on each plots including the detailed inputs used per plot, maize varieties grown per plot, source of maize seed and number of years/seasons the maize seed used was recycled, production and marketing constraints, and so forth. The data were collected during January to June 2011 and covered production and input use for the 2009/10 production seasons.

2.3. Empirical models

2.3.1. Knowledge of improved maize variety

From 1970s to 2009, 20 OPVs and 22 hybrid maize varieties have been released in Ethiopia. These varieties have different yield potentials and adaptability to different agroecologies. The popularity of these varieties among farmers depends on how best these varieties fit to the farmers conditions and need. Households also vary in their level of gathering information on new maize varieties. The survey data shows that 10% of the sample households could not name a single improved maize variety (Table 2). On the other side, there are farmers who mentioned names of ten improved maize varieties they knew. Farmers know, on average, two improved maize varieties. Overall, farmers knew the names of more hybrids than of OPVs. Since the number of improved maize varieties known to farmers is a count data, we used Poisson model in examining its determinants.

Assuming the number of improved maize varieties known to household (K_i) follows a Poisson distribution with expectation $\lambda_i \equiv exp\{X_i'\beta\}$, the probability function of K_i conditional upon X_i is given as:

$$P\{K_i = K|X_i\} = \frac{exp\{-\lambda_i\}\lambda_i^K}{K!}, \; K = 0, 1, 2, ..., \tag{1}$$

Where X is a vector of explanatory variables augmenting farmers' access to information and knowledge of improved maize varieties.

2.3.2. Probability of technology adoption

Farm households adopt improved agricultural technologies when the expected utility from adoption is higher than their traditional practices. In a simple dichotomous agricultural technology adoption, household decision to adopt or not is based on the objective of utility maximization. The underlying utility function (U) depends on household specific attributes (X) and the disturbance term (ϵ) with zero mean and given as:

$$U_{i1} = X_i'\beta_1 + \epsilon_{i1} \qquad \textit{for adopters} \tag{2}$$

$$U_{i0} = X_i'\beta_0 + \epsilon_{i0} \qquad \textit{for non-adopters} \tag{3}$$

A household adopts agricultural technology if $U_{i1} > U_{i0}$. Thus, the probability of adoption for household *i* is given as:

$$P(1) = P(U_{i1} > U_{i0}) \tag{4}$$

$$P(1) = P(X_i'\beta_1 + \epsilon_{i1} > X_i'\beta_0 + \epsilon_{i0}) \tag{5}$$

$$P(1) = P\left(\epsilon_{i0} - \epsilon_{i1} < X_i'\beta_1 - X_i'\beta_o\ \right) \tag{6}$$

$$P(1) = P(\epsilon_i < X_i'\ \beta) = \Phi(X_i'\beta) \tag{7}$$

where Φ is the cumulative distribution function of the standard normal distribution. The parameters β are estimated by maximum likelihood, X is a vector of exogenous variables which explains adoption. In the case of normal distribution function, the model to estimate the probability of observing a farmer adopting agricultural technology can be stated as:

$$P(Y_i = 1|X) = \Phi(X_i'\beta) = \int_{-\infty}^{X'\beta} \frac{1}{\sqrt{2\pi}} exp(-z^2\ /2)dz \tag{8}$$

Where *P* is the probability that a household adopts the technology and Probit model is estimated using a simple latent model:

$$Y_i^* = X_i'\beta + e_i \tag{9}$$

where e_i is a normally and independently distributed error term.

2.3.3. Intensity of technology adoption

In analyzing the adoption of improved maize varieties, the dichotomous adopter or non-adopter classification may not give a complete picture. Even within adopters there is a wider range of variation in the intensity of maize area allocated to improved varieties. Some households allocate only limited share of their maize plots to the improved varieties while others are completely replacing the existing practices. To assess the intensity of adoption, here we used the area of maize under improved varieties. Tobit and Heckman's selection models are used in assessing the intensity of maize adoption. Both methodologies are briefly discussed below.

Tobit Model

Tobit model is used when the decision to adopt and intensity of adoption are assumed to be made jointly and factors affecting the probability to adopt and intensity of adoption are assumed to be the same (Asfaw *et al.,* 2011). Moreover, Tobit model is used when we have truncated distribution of observations where considerable proportion of the sample households is not using the specific technology under analysis (in our case, improved maize varieties).

Tobit model is given as:

$$Y_i^* = X_i'\gamma + u_i \tag{10}$$

and

$$Y_i = \begin{cases} Y_i^* & if\ Y_i^* > 0 \\ 0 & Otherwise \end{cases} \tag{11}$$

Where Y_i^* is the latent variable (desired level of maize area under improved varieties) and observed only when a household adopts the technology. Y_i is the observable intensity of technology adoption given the household is using the specific technology.

The probability that intensity of technology adoption is not observable is given as:

$$P(Y_i = 0) = P(Y_i^* \leq 0) = 1 - \Phi(\frac{X_i'\gamma}{\sigma}) \tag{12}$$

And for a positive value $[P(Y_i > 0)]$, it follows the expression in equation (8) above. Thus, the full likelihood function is the product of probabilities that the limit observation occurs times the probability density functions for all the positive, non-limit, observations. The full likelihood function is given mathematically as:

$$L(\gamma, \sigma) = \prod_{Y_i \leq 0} \left\{1 - \Phi(\frac{X_i'\gamma}{\sigma})\right\} X \prod_{Y_i > 0} \left\{(2\pi\sigma^2)^{1/2} \exp(-\frac{1}{2\sigma^2})(Y_i - X_i'\gamma)^2\right\} \tag{13}$$

Heckman's selection model

In the Heckman's selection model, it is assumed that technology adopters are not randomly selected but there is a self-selection bias that needs to be corrected in obtaining unbiased estimates of the intensity of adoption. Moreover, the model assumes that the probability to adopt and the intensity of use are not explained with exactly the same set of explanatory variables, where some (at least one) variables are only explaining the probability to adopt. In this particular case, the number of improved maize varieties known to a household is assumed as an identifier variable where it only affects the probability to adopt but not the intensity of adoption.

The Heckman's selection model follows a two-step estimation procedure where in the first step the probability of adoption is estimated and Mill's Inverse Ratio (MIR) is obtained. In the second stage, the intensity of adoption is estimated using the IMR as one of the explanatory variables to correct selection bias. The selection equation is expressed in terms of latent variable, z_i^*, which is adoption of improved maize varieties in this case, depends on set of explanatory variables, w_i, and is given by:

$$z_i^* = w_i'\alpha + \varepsilon_i \tag{14}$$

The latent variable (z_i^*) is not observed, but we do observe the binary variable (z_i) whether a household adopted improved maize or not. Then, the binary variable is given as:

$$z_i = \begin{cases} 1 & if \ z_i^* > 0 \\ 0 & otherwise \end{cases} \tag{15}$$

The second equation is a linear intensity of adoption equation, and given as:

$$Y_i = X_i'\theta + u_i \tag{16}$$

The intensity of adoption (Y_i) is observed when a household adopts improved variety ($z_i = 1$). This causes selectivity problem and the parameter estimates using ordinary least square are inconsistent and biased. One can get consistent estimates using the following conditional regression function:

$$E(Y_i|z_i^* > 0) = X_i'\theta + \theta_\lambda \lambda_i \tag{17}$$

Where λ_i is Inverse Mill's Ratio (IMR) and given as:

$$\lambda_i = \frac{\phi(w_i'\alpha)}{\Phi(w_i'\alpha)} \tag{18}$$

Where $\phi(.)$ denotes the standard normal probability density function and $\Phi(.)$ denotes the cumulative distribution function for a standard normal random variable. The value of λ_i is not known, but the parameters (α) can be estimated using a Probit model based on the observed binary outcome (z_i). Then the estimated IMR, $\hat{\lambda}_i = \frac{\phi(w_i'\hat{\alpha})}{\Phi(w_i'\hat{\alpha})}$ is inserted into the regression equation as an extra explanatory variable, and yielding an estimating equation of:

$$Y_i = X_i'\theta + \theta_\lambda \hat{\lambda}_i + v_i \tag{19}$$

In obtaining the parameter estimates, one can use either the Full Information Maximum Likelihood (FIML) or the two stage estimation procedure. However, the full information maximum likelihood estimation is believed to be more efficient than the two stage estimation procedure in obtaining consistent and efficient parameter estimates.

2.3.4. Type of maize seed used

In the survey data, there were six maize seed types used during the 2009/10 production season. These are; freshly purchased hybrid, freshly purchased OPV, recycled hybrid, OPV recycled for not more than three seasons, OPV recycled for more than three seasons, and local maize varieties.

Assuming there are M alternative seed types that households use and the households follow a random utility framework in which the utility from each alternative seed type used (U_{ij}) is a linear function of observed characteristics (in this case, household and plot level characteristics), the linear utility function in the type of seed use is specified as:

$$U_{ij} = X'_{ij}\eta + \tau_{ij} , \quad \text{where } j = 1,2, \dots , M \tag{20}$$

Again assuming that household i chooses seed type j if it gives the highest utility, the probability that seed type j is chosen is given as:

$$P[y_i = j] = P\left[U_{ij} = \max(U_{i1}, U_{i2}, \dots , U_{iM})\right] = P\left\{U_{ij} > \max_{k=1,2,\dots,M,k\neq j}(U_{ik})\right\}$$

$$= P[\tau_{i1} - \tau_{ij} > \left(X_{ij} - X_{i1}\right)'\eta, \dots , \tau_{iM} - \tau_{ij} > \left(X_{ij} - X_{iM}\right)'\eta] \tag{21}$$

With a strong assumption that the disturbance terms τ_{ij} are mutually independent, equation (21) could be estimated using a multinomial Probit or Logit model (Greene, 2003:727; Verbeek, 2004:208). In this paper, we followed a multinomial Probit approach.

2.4. Selection of explanatory variables and hypotheses

Though there is no firm economic theory that dictates the choices of independent variables in adoption studies, most adoption literature suggest that farmers' decision to adopt an agricultural technology depends on their economic position and institutional environment (Feleke and Zegeye, 2006). Easily available complementary inputs such as improved seed, fertilizer, herbicides and pesticides facilitate the adoption of agricultural technologies (Kohli and Singh, 1997). Availability and accessibility of credit facilities to purchase these complementary inputs could also affect the adoption of agricultural technologies (Beke, 2011). More educated household heads could have the capacity to acquire, process, and interpret information and tend to adopt agricultural technologies (Asfaw and Admassie, 2004; Feleke and Zegeye, 2006).

Markets in developing countries, and particularly in rural areas, are known for their imperfections or complete failure (de Janvry *et al.*, 1991). Under such circumstances, the level of production mainly depends on the ownership and access of basic agricultural inputs like land, labor and draft power. Thus, households endowed with larger number of oxen and available family labor for farming could adopt improved maize technologies more intensively (Feleke and Zegeye, 2006).

The number of improved maize varieties a farmer could know depends on several factors which include farmer's own interest in gathering variety information, social networks he/she has within and outside the village, maize production potential of area where he/she lives, closeness of maize breeding research centers and variety testing sites, etc.

3. Results and Discussion

3.1. Descriptive analysis

During the 2009/10 production season, 96% of the sample households grew maize and 26% grew improved maize varieties. The average maize area per household was 0.86 ha. Average maize area per household is higher for maize potential areas (0.98 ha) and lower for low potential areas (0.70 ha). On average, a household allocates 0.24 ha of farmland to improved maize varieties. The average area under hybrid maize is higher at the high potential areas and higher for OPVs at lower potential areas. From the total 2544 sample households, 92% was male headed households. The average age of household head was 42 years. On average, household heads attended formal school for three years. The average farmland holding was 1.92 ha per household. Landholding is relatively lower for households in the low potential areas for maize production. Descriptive statistics of all variables used in this paper is presented in Table 2.

< TABLE 2 HERE >

3.1.1. Knowledge of improved maize varieties

There is a clear difference in knowledge and adoption between hybrids and OPVs by Ethiopian smallholder farmers. Only 17% of the respondents knew improved OPV maize, while 85% know at least one improved hybrid maize variety (Table 3). The maximum number of improved verities a farmer could mention was 4 for OPVs and 8 for hybrids (Table 3). Relatively, improved maize varieties were more popular among households in the high maize potential areas than in the medium and low potential areas. Table 3 shows that 9.7% of the sample households could not able to list a single improved maize variety they are aware of (be it hybrid or OPV). Overall, hybrid maize varieties are more popular than OPVs.

< TABLE 3 HERE >

From the survey, 17 hybrid and 16 OPVs were identified as most popular maize varieties. From the hybrid maize, BH-660 is the most known IMV in all the three maize potential categories. Overall, 47% of the sample households reported their familiarity with BH-660. In addition, BH-

540, BH-140, Tabor (30H83) and Shone (30G19) were also known hybrid maize varieties (Table 4). In high potential areas, were hybrid varieties perform well, farmers knew more hybrid maize varieties. OPV maize varieties are better known in low potential areas. Awassa-511 is the most well-known OPV and reported by 19% of the sample households from low maize potential areas (Table 5). Next to Awassa-511, Katumani, Fetene, Gibe-1, Melkassa-1, and Melkassa-2 are also popular varieties from the OPV maize.

< TABLE 4 HERE >

< TABLE 5 HERE >

3.1.2. Experience in planting maize improved varieties known to them

A farmer might know or have information about a specific maize variety but that may guarantee that the farmer has ever planted the variety. Planting a variety depends on several factors which include productivity and profitability, access to seed and complementary inputs such as fertilizer, herbicides, pesticides, and adaptation to agroecology. Tables 4 and 5 show frequency of sample households who know, ever planted, and those who planted the specific maize variety during 2009/10 production season, for both hybrids and OPVs. The best known variety was BH660, known by 47% of respondents, and grown at least once by 37%. In the 2009/10 production season, it was planted by 22% (Table 4). The most popular and widely used maize varieties are those released in 1970's for OPV, and 1980s and 1990s for hybrid.

From hybrid maize varieties, Bako hybrid (BH) and Pioneer maize varieties are the most popular ones. Specifically, from Bako hybrid, BH-660, BH-540, and BH-140 are widely known and grown varieties. Similarly, from the Pioneer varieties, Tabor (30H83), Shone (30G19) and Agar (30D79) hybrid maize are relatively popular among the maize farmers. Overall, compared to Pioneer, Bako hybrid varieties are more popular and used among the sample farmers. Similarly, from OPV maize, Awassa-511 and Katumani varieties were released in 1973 and 1974, respectively. These two varieties are also relatively well known among the sample farmers and most farmers who had the knowledge also tried to grow them at least once. Looking at the maize variety varietal used during 2009/10 production season, next to Awassa-511 and Katumani, few farmers also used Fetene, Melkassa-1, Melkassa-2, Melkassa-4, Gibe and Morka varieties. Compared to Awassa-511 and Katumani, most of these varieties were released recently (in 2000s).

3.1.3. Level of maize variety adoption

In analyzing the level of improved maize variety adoption, we considered households using improved maize seed and area of maize under improved maize seeds during the 2009/10 production seasons. As discussed in section 2 above, a farm household is assumed as an adopter of improved maize varieties if it used freshly purchased hybrid and/or OPV maize seeds and recycled OPVs for not more than three seasons.

< TABLE 6 HERE >

3.2. Empirical analysis

3.2.1. Determinants of number of maize varieties known

Smallholder farmers have heterogeneous characteristics and differ from one another in their operation and level of improved maize variety knowledge. Poisson estimation results on the number of improved maize varieties known by households show that, on average, male, younger, and educated household heads know a larger number of improved maize varieties than their counterparts. The same works for the number of hybrid maize known by farmers. The number of known varieties increases with the number of social networks household members are involved in. Variety information and opportunities to get acquainted to different improved maize could be enhanced through interactions and discussions in both formal and informal social networks. Households with more number of oxen for plowing know more number of hybrid maize. The number of improved maize variety farmers know increases with increasing maize potential, i.e., compared to farmers in low maize potential districts, farmers in high and medium potential maize districts know more number of hybrid maize varieties. However, compared to the low potential areas, the number of OPV maize varieties that farmers know decreases in high and medium potential areas. This is due to the fact that most OPVs are drought tolerant or early maturing varieties that could escape late drought spells and best fit in low potential districts (Table 7).

< TABLE 7 HERE >

3.2.2. Probability of growing improved maize varieties

The probability of growing improved maize is estimated using both binary Probit and Tobit models. Estimation results from both models (Tables 8 and 9) show that the probability of adopting improved maize increases with the level of household head's education, available family labor for farming, number of improved maize varieties known to a household, livestock owned, better soil fertility and soil depth of maize plots, increased number of reliable non-relatives a household has within the village, better confidence in the skills of extension agents, availability of credit for seed purchased when needed. Compared to households in low maize potential districts, the probability of adopting hybrid maize varieties is higher for households in high and medium potential districts, but the probability of adopting improved OPVs is lower in the high potential districts.

< TABLE 8 HERE >

< TABLE 9 HERE >

3.2.3. Determinants of intensity of maize area allocated to improved varieties

Table 10 presents the coefficient estimates of Tobit model. Estimations have been made for improved maize varieties (considering both hybrid and OPVs in one), hybrid and OPV maize varieties, separately. Educated household heads allocate more farmland to improved maize varieties (and particularly to hybrid maize). Confidence in the skills of extension agents increases the intensity of maize area a household allocates to improved maize (and particularly to hybrid maize varieties). Similarly, households who needed and got credit to purchase hybrid maize seed are allocating more of their maize plots to improved maize seeds. Getting a credit for seed purchase/seed on credit basis increases the probability of growing hybrid maize.

< TABLE 10 HERE >

3.2.4. Determinants of the type of maize seed used

From the survey data, there were six types of maize seeds used during the 2009/10 production season. These are: freshly purchased hybrid maize, recycled hybrid, freshly purchased OPVs, recycled OPVs for not more than 3 seasons, recycled OPVs for more than 3 seasons, and local maize varieties. Considering the local maize varieties as a base, multinomial Probit estimation results are presented in table 11. Results show that the probability of using freshly purchased seed is higher for educated and younger household heads, and households with larger family labor available for farming. The probability of using freshly purchased seeds and OPVs recycled for less than 3 season decreases with increasing farmland owned. The more of livestock owned, the more likely that households purchase improved maize seeds. Households with relatively fertile maize plots are more likely to use freshly purchased seeds. Compared to households in low potential areas, the probability of using recycled OPV decreases for households in the medium potential districts.

< TABLE 11 HERE >

4. Conclusions

Based on cross-sectional survey data collected in 2011, different econometric models were specified and used in analyzing determinants of the level of improved maize variety knowledge, adoption and intensity of improved maize variety use in Ethiopia.

Though the number of OPV and hybrid maize varieties released in the country are slightly the same, hybrid maize varieties are much more popular among farmers in high and medium maize potential areas . The nature of hybrid maize, which demands for freshly purchased seed use in each season, could contribute to its popularity. However, many farmers recycle hybrid maize that potentially decreases the productivity they would have attained through using freshly purchased hybrid seeds.

Intensity of improved maize variety adoption is strongly affected by the level of household head's education, available family labor for farming, soil fertility and soil depth of maize plots, farmers' confidence in skills of the extension agents, and access to credit to buy seeds. Most of these variables affect the intensity of hybrid maize use more than the intensity of improved OPVs use.

The overall conclusion drawn from this study is that, enhancing smallholder farmers' knowledge on improved maize varieties, making credit services available for seed purchase on need basis, and building farmers' trust in the knowledge and operational skills of extension agents increases the probability of adopting improved maize varieties and the intensity of adoption. Moreover, enhancing farmers' resource endowment in terms of labor, livestock and number of oxen owned, soil quality of land operated, etc. could also enhance the probability and intensity of maize variety adoption by smallholder farmers.

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Tables

Table 1. Distribution of sample Districts and households by potential for maize production

	No. of sample districts		No. of sample households	
Maize potential	Frequency	%	Frequency	%
High	8	20.5	603	24.6
Medium	25	64.1	1528	62.2
Low	6	15.4	324	13.2
Total	***39***	***100.0***	***2455***	***100.0***

Table 2. Descriptive statistics of selected variables used in the empirical analysis (N=2455)

Variables	High potential *(N=603)* Mean (SD)	Medium potential *(N=1528)* Mean (SD)	Low potential *(N=324)* Mean (SD)	Total *(N=2455)* Mean (SD)
Grow maize *(1=yes)*	0.98(0.15)	0.96(0.19)	0.95(0.22)	0.96(0.18)
Grow improved maize *(1=yes)*	0.29(0.45)	0.28(0.45)	0.13(0.34)	0.26(0.44)
Grow improved hybrid maize *(1=yes)*	0.25(0.44)	0.25(0.43)	0.02(0.16)	0.22(0.41)
Grow improved OPV maize *(1=yes)*	0.06(0.24)	0.03(0.18)	0.11(0.31)	0.05(0.22)
Maize area per household *(ha)*	0.98(1.01)	0.84(0.84)	0.70(0.87)	0.86(0.89)
Area of improved maize per household *(ha)*	0.28(0.65)	0.24(0.57)	0.13(0.43)	0.24(0.58)
Area of hybrid maize per household *(ha)*	0.26(0.64)	0.22(0.55)	0.02(0.16)	0.20(0.55)
Area of improved OPV per household *(ha)*	0.02(0.10)	0.02(0.15)	0.11(0.40)	0.03(0.20)
Number of improved maize varieties known	3.20(2.17)	2.13(1.47)	1.22(0.90)	2.27(1.73)
Number of improved hybrid maize varieties known	3.02(1.92)	1.94(1.46)	0.76(0.80)	2.05(1.67)
Number of improved OPV maize varieties known	0.18(0.53)	0.19(0.52)	0.46(0.65)	0.22(0.55)
Sex of household head *(1=male; 0=female)*	0.93(0.26)	0.92(0.28)	0.90(0.31)	0.92(0.28)
Age of household head *(years)*	41.4(12.57)	42.7(12.97)	43.0(12.11)	42.4(12.77)
Education of household head *(years of schooling)*	3.12(3.36)	3.02(3.38)	2.03(2.60)	2.92(3.30)
No. of social networks a household head and spouse involved in	2.76(1.62)	2.58(1.48)	2.65(1.54)	2.63(1.52)
Farmland owned *(ha)*	1.97(1.99)	1.95(1.77)	1.66(1.90)	1.92(1.84)
Non-oxen livestock owned *(TLU)*	2.80(2.71)	3.86(4.65)	3.50(4.07)	3.55(4.20)
Number of oxen owned	1.77(2.40)	1.83(1.86)	1.52(1.27)	1.77(1.95)
Weighted soil fertility of maize plots *(1=low, 2=medium, 3=high)*	1.73(0.58)	1.61(0.55)	1.49(0.60)	1.62(0.57)
Weighted slope of maize plots *(1=flat, 2=gentle, 3=steep)*	1.50(0.54)	1.35(0.51)	1.38(0.54)	1.39(0.52)
Weighted soil depth of maize plots *(1=shallow, 2=medium, 3=deep)*	2.20(0.71)	2.18(0.75)	2.07(0.80)	2.17(0.75)
Number of reliable relatives within a village	4.78(7.97)	7.55(14.60)	6.96(11.32)	6.80(12.91)
Number of reliable relatives out of a village	3.96(5.38)	6.83(10.95)	6.48(12.36)	6.09(10.17)
Number of reliable non-relative within a village	3.20(5.90)	5.53(11.67)	4.12(10.68)	4.77(10.46)
Friend or relative in local leadership *(1=yes)*	0.47(0.50)	0.56(0.50)	0.49(0.50)	0.53(0.50)
Number of trades known in the village	2.25(2.83)	1.69(4.69)	1.36(2.80)	1.78(4.10)
Dummy_ confidence in the skill of extension agents *(1=yes)*	0.37(0.48)	0.46(0.50)	0.48(0.50)	0.44(0.50)
Dummy_ needed and got credit for seed purchase *(1=yes)*	0.27(0.45)	0.14(0.35)	0.02(0.15)	0.16(0.36)
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	0.27(0.44)	0.14(0.35)	0.02(0.15)	0.16(0.36)
Distance to nearest Cooperative *(minutes)*	83.0(64.52)	100.6(70.46)	86.2(60.82)	94.3(68.27)
No. of months the read to main market is passable	9.25(4.31)	8.41(4.72)	8.31(4.96)	8.61(4.66)
Distance to nearest Cooperative *(minutes)*	33.8(32.45)	58.2(72.21)	42.9(53.71)	50.8(63.98)
Distance to nearest agro-dealers *(minutes)*	28.8(28.24)	32.6(34.26)	27.8(27.91)	31.1(32.14)
Number of years lived in the village	31.3(14.05)	37.2(14.28)	38.9(12.78)	35.9(14.30)
Number or reliable relatives within the village	3.47(3.96)	6.77(21.97)	6.70(9.64)	5.9(17.86)

Table 3. Distribution of sample households by the number of maize varieties they know

No. of varieties known	Maize Potential								By Variety			
	High		Medium		Low		Total		OPV		Hybrid	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0	21	*3.5*	144	*9.4*	73	*22.5*	238	*9.7*	2,037	*83.0*	376	*15.3*
1	161	*26.7*	443	*29.0*	132	*40.7*	736	*30.0*	324	*13.2*	757	*30.9*
2	83	*13.8*	448	*29.3*	102	*31.5*	633	*25.8*	66	*2.7*	555	*22.6*
3	85	*14.1*	242	*15.9*	10	*3.1*	337	*13.7*	23	*0.9*	299	*12.2*
4	95	*15.8*	132	*8.6*	7	*2.2*	234	*9.5*	4	*0.2*	224	*9.1*
5	73	*12.1*	74	*4.9*	0		147	*6.0*	0		138	*5.6*
6	47	*7.8*	28	*1.8*	0		75	*3.1*	0		69	*2.8*
7	10	*1.7*	13	*0.9*	0		23	*0.9*	0		26	*1.1*
8	12	*2.0*	3	*0.2*	0		15	*0.6*	0		10	*0.4*
9	8	*1.3*	0		0		8	*0.3*	0		0	
10	8	*1.3*	0		0		8	*0.3*	0		0	
Total	603		1528		324		2455		2544		2544	

Table 4. Number of households who know, ever planted, and planted hybrid maize varieties during 2009/10 production season

No.	Variety	Maize potential: High *(N=603)*			Medium *(N=1528)*			Low *(N=324)*			Total *(N=2455)*		
		Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10
1	BH-660	363	327	203	691	527	294	100	67	48	1154	921	545
2	BH-540	356	261	153	577	481	331	37	21	7	970	763	491
3	Tabor	241	155	62	232	152	66				473	307	128
4	BH-140	225	137	32	359	231	58	84	44	19	668	412	109
5	Shone	198	114	71	312	162	69	1	0		511	276	140
6	BH-543	153	71	29	96	59	25	6	6	2	255	136	56
7	Jabi	125	53	26	99	67	36	2	2	2	226	122	64
8	Agar	76	27	15	103	29	10				179	56	25
9	Pioneer	28	21	6	379	316	186	1	1	1	408	338	193
10	BHQP-542	26	11	2	16	11	5	1			43	22	7
11	BH-670	16	4	3	4	2	1				20	6	4
12	Welel	13	5	1	3	0					16	5	1
13	BHQPY-545	5	1	0	17	12	4		1	0	22	14	4
14	Shinidi	1	1	0							1	1	0
15	ZAMA				25	10	6	13	9	8	38	19	14
16	AMH-800				8	4	2				8	4	2

Table 5. OPV maize knowledge, adoption and consistency till 2009/10 production season

		Maize Potential											
		High (N=603)			Medium (N=1528)			Low (N=324)			Total (N=2455)		
No.	Variety	Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10	Know	Ever planted	Planted during 2009/10
1	Awasa 511	1			73	47	20	63	53	26	137	100	46
2	Katumani				41	25	8	35	22	15	76	47	23
3	Fetene				22	10	3	41	23	11	63	33	14
4	Morka	51	24	13	15	5	3				66	29	16
5	Gibe-1	39	16	6	11	5	3				50	21	9
6	Melekasa-1	1			42	23	17	1	1	0	44	24	17
7	Melekasa-2	3	2	1	31	17	10	8	7	6	42	26	17
8	Kuleni	27	3	0	4	3					31	6	
9	Gutto	27	2	0	1	1	1				28	3	1
10	Melekasa-4				15	9	6	1			16	9	6
11	Melekasa-3	2			8	3					10	3	
12	Abo-bako				10	6	1				10	6	1
13	Alemaya comp.				7	4					7	4	
14	Hora				3	2					3	2	
15	Melekasa-7				1	1	1				1	1	1
16	Tesfa	1	1	0							1	1	
17	Gambela comp.				1	1					1	1	

Table 6. Number of plots allocated to different maize seed types (by maize potential)

	Maize Potential							
	High *(n=766)*		Medium *(n=2013)*		Low *(n=440)*		Total *(n=3219)*	
Type of maize seed used	Freq.	*%*	Freq.	*%*	Freq.	*%*	Freq.	*%*
Freshly purchased Hybrid	270	*35.2*	644	*32.0*	11	*2.5*	925	*28.7*
Recycled Hybrid	93	*12.1*	144	*7.2*	40	*9.1*	277	*8.6*
Freshly purchased OPV	13	*1.7*	45	*2.2*	16	*3.6*	74	*2.3*
Recycled OPV for ≤ 3 seasons	31	*4.0*	8	*0.4*	36	*8.2*	75	*2.3*
Recycled OPV for > 3 seasons	45	*5.9*	8	*0.4*	29	*6.6*	82	*2.5*
Local varieties	314	*41.0*	1,164	*57.8*	308	*70.0*	1786	*55.5*
Total	766		2013		440		3219	

Note: Maize potential is classified as mean productivity ± standard deviation at a district level (high potential >2.698 ton/ha; medium potential between 2.698 ton/ha and 1.103ton/ha; and low potential <1.403ton/ha)

Table 7. Number of improved maize varieties known by the sample households (Poisson Regression)

Explanatory variables	Both Hybrid and OPV maize Coef.(Std. Err.)	Hybrid maize varieties Coef.(Std. Err.)	Open Pollinated varieties (OPVs) Coef.(Std. Err.)
Sex of household head *(1=male, 0=female)*	0.168(0.063)***	0.168(0.066)**	0.171(0.196)
Age of household head *(years)*	-0.013(0.002)***	-0.013(0.002)***	-0.015(0.006)***
Education of household head *(years)*	0.015(0.004)***	0.018(0.005)***	-0.015(0.016)
Family size *(persons)*	0.043(0.006)***	0.044(0.006)***	0.036(0.019)*
Number of social networks a household head and spouse involved in	0.045(0.009)***	0.041(0.010)***	0.075(0.030)**
Land owned *(ha)*	-0.029(0.009)***	-0.030(0.009)***	-0.012(0.026)
Non-oxen livestock *(TLU)*	-0.009(0.004)**	-0.014(0.005)***	0.021(0.009)**
Total number of oxen owned	0.020(0.006)***	0.019(0.007)***	0.037(0.014)***
Dummy _own radio *(1=yes)*	-0.020(0.030)	-0.023(0.031)	0.038(0.096)
Dummy _own TV *(1=yes)*	0.086(0.091)	0.027(0.099)	0.485(0.236)**
Walking distance to main market *(minutes)*	0.000(0.000)	0.000(0.000)	0.000(0.001)
Walking distance to agro-dealers *(minutes)*	-0.001(0.000)	0.000(0.000)	-0.004(0.002)**
Years the HH head lived in a village *(years)*	0.006(0.001)***	0.005(0.001)***	0.015(0.005)***
Number of reliable relatives within a village	0.000(0.001)	0.001(0.001)	-0.001(0.005)
Number of reliable non-relatives within the village	0.000(0.001)	0.000(0.001)	0.000(0.005)
Number of reliable relatives in the village	-0.001(0.002)	-0.001(0.002)	-0.005(0.007)
Number of reliable non- relatives outside the village	0.004(0.002)**	0.004(0.002)**	-0.004(0.007)
Friend or relative in local leadership *(1=yes)*	0.071(0.029)**	0.087(0.031)***	-0.061(0.095)
Dummy_ confidence in the skill of extension agents *(1=yes, 0=no)*	-0.002(0.010)	-0.004(0.010)	0.008(0.032)
Dummy_ high potential *(1=yes)*	0.962(0.059)***	1.393(0.072)***	-0.927(0.138)***
Dummy_ medium potential *(1=yes)*	0.532(0.056)***	0.934(0.070)***	-0.943(0.107)***
Constant	-0.045(0.110)	-0.502(0.122)***	-1.285(0.323)***
Number of obs	*2289*	*2289*	*2289*
LR $Chi^2(20)$	*649.27*	*830.84*	*142.17*
Prob > Chi^2	*0.000*	*0.000*	*0.000*
Pseudo R^2	*0.076*	*0.099*	*0.052*
Log likelihood	*-3940.81*	*-3785.23*	*-1286.17*

Note: ***, ** and * are significant at 1%, 5%, and 10% level, respectively.

Table 8. Probability of growing improved maize varieties (Probit model)

Explanatory Variables	Improved maize variety		Hybrid maize variety		Improved OPV maize variety	
	Coeff. (Std. Err.)	Marginal Effects	Coeff. (Std. Err.)	Marginal Effects	Coeff. (Std. Err.)	Marginal Effects
Sex of household head *(1=male, 0=female)*	-0.078(0.120)	-0.025	0.027(0.149)	0.008	-0.269(0.183)	-0.031
Age of household head *(years)*	0.001(0.003)	0.000	-0.002(0.003)	0.000	0.003(0.005)	0.000
Education of household head (years)	0.020(0.010)**	0.006	0.023(0.013)*	0.007	-0.013(0.019)	-0.001
Family labor for farm (person days)	0.090(0.042)**	0.029	0.020(0.050)	0.006	0.030(0.076)	0.003
Number of social networks a household head and spouse involved in	0.024(0.023)	0.008	0.016(0.027)	0.005	0.030(0.038)	0.003
Predicted value of number of IMV known	0.247(0.089)***	0.079	0.185(0.101)*	0.054	0.330(0.496)	0.031
Farm size *(ha)*	-0.023(0.019)	-0.007	-0.008(0.022)	-0.002	-0.003(0.032)	0.000
Non-oxen cattle holding *(TLU)*	0.020(0.008)**	0.006	0.014(0.010)	0.004	0.015(0.012)	0.001
Number of oxen owned	-0.010(0.017)	-0.003	-0.023(0.022)	-0.007	0.014(0.026)	0.001
Weighted soil fertility of maize plots *(1=low, 2=medium, 3=high)*	0.186(0.054)***	0.059	0.233(0.069)***	0.069	0.002(0.100)	0.000
Weighted slope of maize plots *(1=flat, 2=gentle, 3=steep)*	-0.013(0.060)	-0.004	0.067(0.076)	0.020	-0.030(0.124)	-0.003
Weighted soil depth of maize plots *(1=shallow, 2=medium; 3=deep)*	0.137(0.040)***	0.044	0.154(0.050)***	0.045	0.188(0.074)**	0.018
Walking distance to main market *(minutes)*	0.000(0.000)	0.000	0.001(0.001)*	0.000	-0.002(0.001)*	0.000
Walking distance to agro-dealers *(minutes)*	0.000(0.001)	0.000	0.000(0.001)	0.000	-0.002(0.002)	0.000
Dummy_ good quality road to main market *(1=yes)*	0.044(0.074)	0.014	-0.078(0.089)	-0.023	0.110(0.120)	0.011
Number of reliable relatives within a village	0.003(0.004)	0.001	0.002(0.002)	0.001	0.000(0.003)	0.000
Number of reliable non-relative within a village	0.006(0.003)**	0.002	0.007(0.003)***	0.002	0.002(0.003)	0.000
Friend or relative in local leadership *(1=yes)*	0.033(0.064)	0.011	0.009(0.077)	0.003	-0.160(0.112)	-0.016
Dummy_ confidence in the skill of extension agents *(1=yes, 0=no)*	0.118(0.060)**	0.038	0.153(0.074)**	0.045	-0.007(0.111)	-0.001
Dummy_ needed and got credit for seed purchase *(1=yes)*	0.711(0.162)***	0.038	0.525(0.182)***	0.174	0.481(0.285)*	0.060
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	-0.172(0.163)	-0.053	-0.243(0.185)	-0.067	-0.036(0.276)	-0.003
Dummy _ high potential for maize *(1=yes)*	-0.136(0.200)	-0.043	0.632(0.333)*	0.209	-0.417(0.239)*	-0.033
Dummy _ medium potential for maize (*1=yes)*	0.149(0.125)	0.047	1.015(0.234)***	0.259	-0.649(0.211)***	-0.075
Constant	-2.365(0.248)***		-3.145(0.341)***		-1.481(0.466)***	
Number of observations	*2278*		*1602*		*1602*	
LR Chi^2(23)	*212.88*		*181.71*		*65.59*	
Prob > Chi^2	*0.000*		*0.000*		*0.000*	
Pseudo R^2	*0.0804*		*0.1004*		*0.0917*	
Log likelihood	*-1217.16*		*-813.80*		*-324.93*	

Note: ***, **, and * are significant at 1%, 5%, and 10% level, respectively.

Table 9. Tobit estimation on the intensity of improved maize varieties grown per household (ha /household)

Explanatory Variables	Improved maize varieties (Hybrid + OPV) Coef.(Std. Err.)	Hybrid Coef.(Std. Err.)	Improved OPV Coef.(Std. Err.)
Sex of household head *(1=male, 0=female)*	-0.587(0.620)	-0.423(0.807)	-1.442(1.094)
Age of household head *(years)*	0.007(0.015)	-0.006(0.019)	0.016(0.029)
Education of household head *(years)*	0.099(0.054)*	0.138(0.070)*	-0.072(0.114)
Family labor for farm *(person days)*	0.265(0.217)	0.067(0.267)	0.216(0.446)
Number of social networks a household head and spouse involved in	0.065(0.121)	0.091(0.145)	0.174(0.229)
Predicted_ no. of improved maize varieties known *(total, hybrid, OPV)*	1.557(0.449)***	1.248(0.591)**	2.226(2.988)
Farmland holding *(ha)*	0.199(0.092)**	0.328(0.113)***	0.007(0.187)
Non-oxen livestock *(TLU)*	0.155(0.039)***	0.148(0.050)***	0.112(0.073)
Total number of oxen owned	-0.018(0.087)	-0.084(0.108)	0.097(0.151)
Weighted soil fertility of maize plots *(1=low, 2=medium, 3=high)*	1.138(0.282)***	1.508(0.375)***	-0.032(0.595)
Weighted slope of maize plots *(1=flat, 2=gentle, 3=steep)*	-0.014(0.313)	0.121(0.409)	-0.359(0.748)
Weighted soil depth of maize plots *(1=shallow, 2=medium; 3=deep)*	0.933(0.213)***	0.805(0.275)***	1.273(0.451)***
Walking distance to main market *(minutes)*	0.001(0.002)	0.004(0.003)	-0.009(0.005)*
Walking distance to agro-dealers *(minutes)*	0.000(0.005)	0.002(0.006)	-0.018(0.013)
Dummy_ good quality road to main market *(1=yes)*	0.318(0.379)	-0.312(0.488)	0.834(0.709)
Number of reliable relatives within a village	0.005(0.007)	0.005(0.007)	0.001(0.015)
Number of reliable non-relatives within a village	0.029(0.010)***	0.026(0.012)**	0.016(0.020)
Friend or relative in local leadership *(1=yes)*	-0.315(0.331)	-0.274(0.414)	-1.048(0.668)
Number of traders known in the village	0.072(0.034)**	0.043(0.044)	-0.114(0.132)
Dummy_ confidence in the skill of extension agents *(1=yes, 0=no)*	0.607(0.310)*	0.716(0.397)*	0.001(0.657)
Dummy_ needed and got credit for seed purchase *(1=yes)*	2.749(0.802)***	2.452(0.973)**	2.793(1.732)
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	-0.155(0.804)	-0.662(0.989)	-0.166(1.667)
Dummy _ high potential for maize *(1=yes)*	-1.944(1.035)*	2.992(1.902)	-3.008(1.434)**
Dummy _ medium potential for maize *(1=yes)*	-0.116(0.650)	5.147(1.338)***	-4.214(1.299)***
Constant	-12.94(1.340)***	-17.940(1.970)***	-8.701(2.895)***
Number of observations	*2141*	*1602*	*1602*
LR $Chi^2(24)$	*222.19*	*198.33*	*79.44*
Prob > Chi^2	*0.000*	*0.000*	*0.000*
Pseudo R^2	*0.0429*	*0.054*	*0.0717*
Log likelihood	*-2478.3*	*-1738.38*	*-514.60*

Note: ***, **, and * are significant at 1%, 5%, and 10% level, respectively.

Table 10. Heckman's selection model estimation on intensity of improved maize area (2009/10 production year)

	Improved maize	Hybrid maize	OPV maize
Explanatory Variables	Coef.(Std. Err.)	Coef.(Std. Err.)	Coef.(Std. Err.)
Dependent variable: Intensity of maize area under improved maize(ha)			
Sex of household head *(1=male, 0=female)*	-0.661(0.438)	-0.179(0.141)	0.152(0.753)
Age of household head *(years)*	-0.011(0.010)	-0.002(0.003)	-0.011(0.021)
Education of household head *(years)*	0.032(0.036)	0.014(0.011)	0.061(0.107)
Family labor for farm *(person days)*	0.072(0.146)	0.037(0.042)	0.029(0.360)
Number of social networks a household head and spouse involved in	0.098(0.079)	0.014(0.024)	-0.160(0.194)
Farmland holding *(ha)*	0.647(0.072)***	0.190(0.021)***	0.072(0.197)
Non-oxen livestock *(TLU)*	0.068(0.031)**	0.022(0.009)**	0.043(0.068)
Total number of oxen owned	0.255(0.083)***	0.061(0.024)**	0.339(0.214)
Weighted soil fertility of maize plots *(1=low, 2=medium, 3=high)*	0.588(0.215)***	0.150(0.067)**	-0.150(0.462)
Weighted slope of maize plots *(1=flat, 2=gentle, 3=steep)*	-0.321(0.227)	-0.094(0.069)	0.122(0.640)
Weighted soil depth of maize plots *(1=shallow, 2=medium; 3=deep)*	0.221(0.177)	-0.007(0.055)	0.461(0.372)
Walking distance to main market *(minutes)*	0.000(0.002)	0.000(0.000)	-0.002(0.005)
Walking distance to agro-dealers *(minutes)*	0.005(0.003)	0.001(0.001)	-0.016(0.011)
Dummy_ good quality road to main market *(1=yes)*	-0.216(0.256)	-0.084(0.079)	0.559(0.504)
Number of reliable relatives within a village	0.001(0.003)	0.000(0.001)	-0.010(0.058)
Number of reliable non-relatives within a village	-0.003(0.006)	-0.002(0.002)	0.020(0.038)
Friend or relative in local leadership *(1=yes)*	-0.418(0.232)*	-0.079(0.071)	-0.239(0.513)
Number of traders known in the village	0.197(0.040)***	0.066(0.012)***	-0.046(0.104)
Dummy_ confidence in the skill of extension agents *(1=yes, 0=no)*	-0.097(0.224)	-0.057(0.068)	-0.260(0.501)
Dummy_ needed and got credit for seed purchase *(1=yes)*	-0.317(0.586)	-0.117(0.182)	-0.443(2.001)
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	0.926(0.546)*	0.321(0.179)*	0.624(1.880)
Dummy _ high potential for maize *(1=yes)*	-1.402(0.533)***	0.233(0.334)	-2.447(0.979)**
Dummy _ medium potential for maize *(1=yes)*	-1.452(0.472)***	0.218(0.338)	-1.170(0.909)
Constant	2.671(1.585)*	0.177(0.599)	5.649(2.833)**
Dependent Variable: Probability of growing improved maize varieties			
Sex of household head *(1=male, 0=female)*	-0.082(0.122)	0.020(0.149)	-0.277(0.183)

Age of household head *(years)*	0.001(0.003)	-0.001(0.004)	0.003(0.005)
Education of household head *(years)*	0.019(0.010)*	0.021(0.013)	-0.013(0.019)
Family labor for farm *(person days)*	0.068(0.043)	0.018(0.050)	0.022(0.076)
Number of social networks a household head and spouse involved in	0.022(0.024)	0.014(0.027)	0.025(0.038)
Predicted_ no. of improved maize varieties known *(total, hybrid, OPV)*	0.255(0.090)***	0.207(0.102)**	0.572(0.500)
Farmland holding *(ha)*	-0.021(0.019)	-0.007(0.022)	-0.003(0.032)
Non-oxen livestock *(TLU)*	0.020(0.008)**	0.015(0.010)	0.012(0.013)
Total number of oxen owned	-0.012(0.018)	-0.023(0.022)	0.008(0.026)
Weighted soil fertility of maize plots *(1=low, 2=medium, 3=high)*	0.175(0.055)***	0.231(0.069)***	0.003(0.101)
Weighted slope of maize plots *(1=flat, 2=gentle, 3=steep)*	-0.017(0.060)	0.065(0.076)	-0.009(0.124)
Weighted soil depth of maize plots *(1=shallow, 2=medium; 3=deep)*	0.138(0.041)***	0.154(0.050)***	0.189(0.074)**
Walking distance to main market *(minutes)*	0.000(0.000)	0.001(0.001)*	-0.001(0.001)*
Walking distance to agro-dealers *(minutes)*	0.000(0.001)	0.000(0.001)	-0.002(0.002)
Dummy_ good quality road to main market *(1=yes)*	0.063(0.074)	-0.073(0.089)	0.125(0.120)
Number of reliable relatives within a village	0.003(0.004)	0.002(0.002)	0.000(0.003)
Number of reliable non-relatives within a village	0.006(0.003)**	0.007(0.003)**	0.002(0.003)
Friend or relative in local leadership *(1=yes)*	0.051(0.065)	0.006(0.077)	-0.158(0.112)
Dummy_ confidence in the skill of extension agents *(1=yes, 0=no)*	0.113(0.060)*	0.152(0.074)**	-0.012(0.111)
Dummy_ needed and got credit for seed purchase *(1=yes)*	0.668(0.165)***	0.525(0.182)***	0.434(0.286)
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	-0.153(0.166)	-0.249(0.186)	-0.031(0.276)
Dummy _ high potential for maize *(1=yes)*	-0.158(0.204)	0.574(0.336)*	-0.347(0.239)
Dummy _ medium potential for maize *(1=yes)*	0.151(0.127)	0.988(0.235)***	-0.581(0.210)***
Constant	-2.358(0.250)***	-3.156(0.341)***	-1.587(0.466)***
Lambda	*-0.464(0.527)*	*-0.139(0.144)*	*-1.299(1.161)*
Number of observation	*2255*	*1602*	*1602*
Censored observation	*1668*	*1198*	*1508*
Uncensored observation	*587*	*404*	*94*
Wald $Chi^2(23)$	*269.28*	*276.44*	*43.72*
Prob > Chi^2	*0.000*	*0.000*	*0.0057*
Log likelihood	*-2572.93*	*-1204.26*	*-515.79*

Table 11. Multinomial Probit estimation results on determinants of the type of maize seed used per plot

Explanatory Variables	Freshly purchased hybrid seed	Recycled hybrid seed	Freshly purchased OPVs	Recycled OPVs for ≤ 3 seasons	Recycled OPVs for > 3 seasons
	Coef.(Std. Err.)	Coef.(Std. Err.)	Coef.(Std. Err.)	Coef.(Std. Err.)	Coef.(Std. Err.)
Sex of household head *(1=male, 0=female)*	-0.289(0.192)	0.202(0.249)	0.030(0.325)	-0.085(0.349)	-0.174(0.341)
Age of household head *(years)*	-0.012(0.003)***	-0.007(0.004)*	0.002(0.006)	0.004(0.006)	-0.010(0.006)
Education of household head *(years)*	0.033(0.012)***	0.012(0.015)	0.007(0.025)	0.030(0.025)	-0.018(0.025)
Family labor for farm *(person days)*	0.193(0.046)***	-0.034(0.061)	0.251(0.079)***	0.033(0.099)	0.103(0.088)
No. of social networks a household head and spouse involved in	0.180(0.025)***	0.068(0.032)**	0.170(0.047)***	0.114(0.051)**	0.102(0.049)**
Farmland holding *(ha)*	-0.123(0.023)***	0.010(0.024)	-0.097(0.047)**	-0.152(0.058)***	0.008(0.034)
Non-oxen livestock *(TLU)*	0.030(0.009)***	0.012(0.011)	0.040(0.013)***	0.004(0.023)	-0.005(0.022)
Number of oxen owned	0.045(0.021)**	0.069(0.022)***	0.029(0.043)	0.060(0.033)*	0.069(0.030)**
Dummy_ Plot is own *(1=yes)*	-0.164(0.097)*	-0.266(0.121)**	0.010(0.195)	-0.115(0.192)	0.209(0.217)
Dummy_ Plot is women managed *(1=yes)*	-0.793(0.236)***	-0.107(0.281)	0.664(0.329)**	-0.511(0.461)	-0.549(0.444)
Plot distance from homestead *(minutes)*	0.005(0.002)***	0.001(0.002)	0.008(0.003)***	0.007(0.003)***	0.007(0.003)**
Soil fertility of maize plot *(1=low, 2=medium, 3=high)*	0.399(0.060)***	-0.055(0.078)	0.352(0.113)***	0.008(0.125)	-0.073(0.121)
Slope of maize plot *(1=flat, 2=gentle, 3=steep)*	-0.013(0.068)	-0.088(0.089)	-0.454(0.161)***	0.020(0.140)	-0.028(0.136)
Soil depth of maize plot *(1=shallow, 2=medium; 3=deep)*	0.229(0.048)***	0.255(0.058)***	0.306(0.091)***	0.426(0.099)***	0.346(0.092)***
Dummy_ needed and got credit for seed purchase *(1=yes)*	0.591(0.198)***	-0.103(0.267)	0.828(0.340)**	0.278(0.418)	0.455(0.330)
Dummy_ needed and got credit for fertilizer purchase *(1=yes)*	0.315(0.160)*	0.376(0.194)*	-0.430(0.331)	-0.130(0.337)	0.350(0.275)
Dummy _ high potential for maize *(1=yes)*	2.083(0.189)***	0.633(0.149)***	0.115(0.229)	0.207(0.183)	0.416(0.177)**
Dummy _ medium potential for maize *(1=yes)*	1.822(0.179)***	-0.014(0.134)	-0.151(0.187)	-1.258(0.208)***	-1.135(0.202)***
Constant	-3.445(0.340)***	-1.942(0.390)***	-3.938(0.588)**	-3.034(0.600)***	-2.623(0.594)***
No. of observations	*3177*				
Wald $Chi^2(90)$	*716.6*				
Prob>Chi^2	*0.000*				
Log likelihood	*-3219.57*				

Note: ***, **, and * are significant at 1%, 5%, and 10% level, respectively.

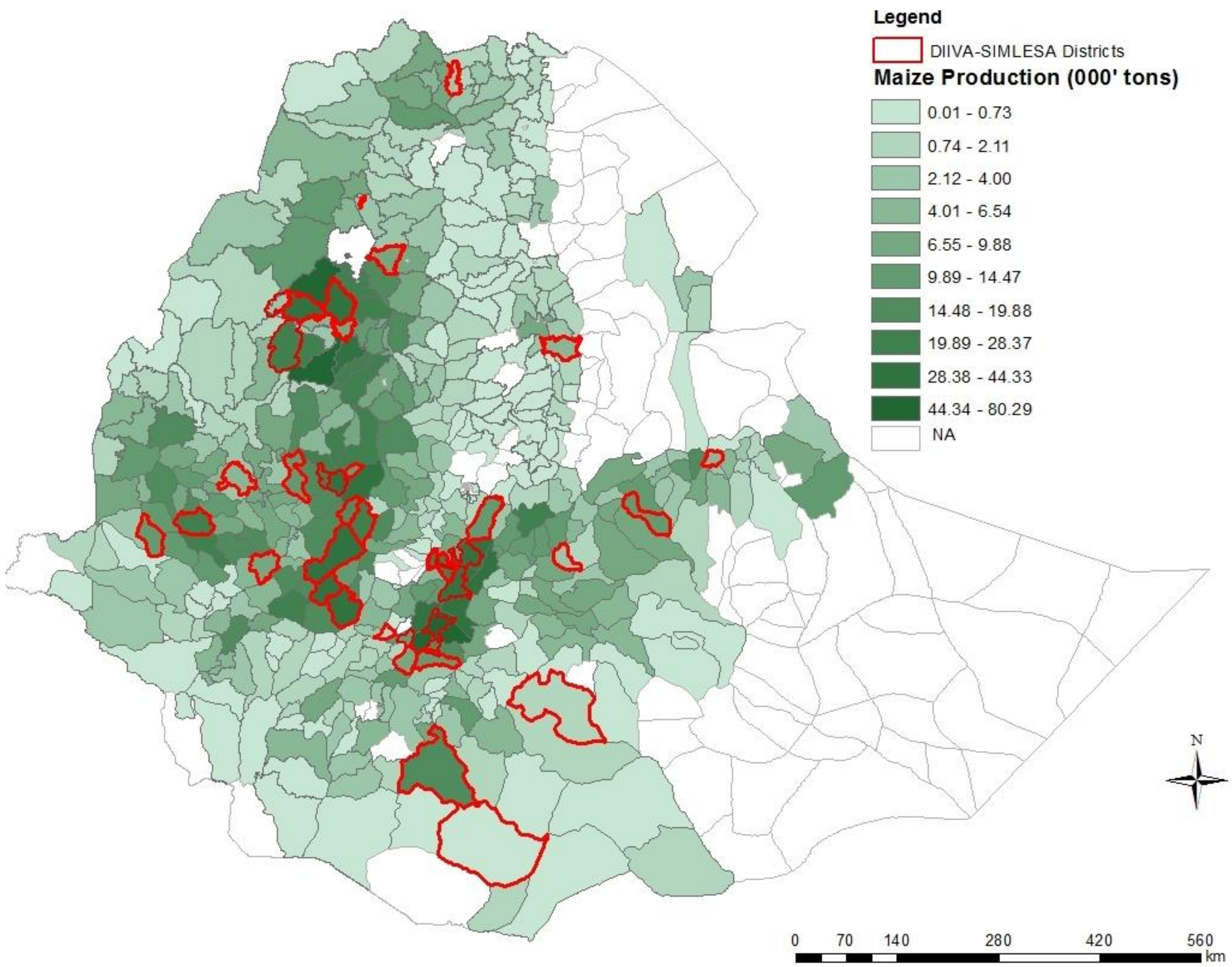

Figure 1. Distribution of sample districts where the survey was conducted.