Determinants of the Probability and Intensity of Improved Forage Crops Adoption in Oromia National Regional State

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ABSTRACT

The objective of this study was to investigate the determinants of the adoption rate and intensity of improved forage in Oromia National Regional State following multi-stage sampling procedure to collect primary data from a total of 1630 randomly selected smallholder dairy producers. Both descriptive analysis and Craggit econometric model were used to analyze the data. The overall adoption rate of improved forage crops in the region was only 10%. The intensity of adoption was also eight percent indicating a very low size of land allocated for the production of improved forage crops. Among the adopters, varietal level adoption rate indicated that 35% of them have commonly grown oat-vetch while 15% have grown elephant grass. The Craggit model result indicated that family size increased the probability of improved forage adoption while age of the household head increased the intensity of improved forage adoption. It also revealed that volume of milk production, land owned and the use of feed resources other than grazing were noted to have a positive impact on both the probability and intensity of improved forage adoption. Furthermore, access to extension services, relevant training, knowledge on improved feeds, access to big cities and experiences on food crop adoption were found have positive impact on the probability of improved forage adoption. Therefore, policies that target to enhance availability of improved forage seeds, knowledge and skills of family labor, experience sharing between older and younger farmers, relevant training, extension services and better infrastructure would have a positive impact on improved forage adoption. Raising awareness of the farmers on the importance of adopting improved forages would also help to allocate a plot of land for growing forage crops.

Keywords: Craggit model, forage, adoption

INTRODUCTION

The share of feed cost ranges from 40% to more than 70% of the total cost of dairy production depending on the region where the dairy farm operation is performed. In farms located in north Asia, Europe and North America, feed cost accounts for 40-50% of the total cost of milk production whereas it accounts for 50-70% of the total cost of milk production in most farms of Africa (Alqaisi *et al*., 2011). Recent studies in emerging economies such as Ethiopia show that the cost of feed accounts for as high as 80% of the total variable cost of milk production (Diro *et al*., 2019). One of the ways to reduce feed cost is by using the improved forage.

To avail improved forage that is usually disseminated as a package for improved dairy farms, national research institutes such as Ethiopian Institute of Agricultural

Research (EIAR), regional agricultural research institutes (RARIs), and international research agencies, such as International Livestock Research Institute (ILRI), generated several improved forage technologies and disseminated through various extension mechanisms. According to the report by Feyissa *et al.* (2015), 24 improved forage varieties were released and disseminated to the farmers until 2014. Out of these, 20 improved varieties of forage were reported to be in production (MoANR, 2018). The most commonly produced improved forage varieties included tree lucerne, elephant grass, Rhodes, panicum, trifolium, vetch, cow pea, pigeon pea, oats, sesbania, lupin, alfalfa, Pennisetum, perennial grass and d*esho* grass (MoANR, 2018). In the process of scaling up of these improved forages, marketing and commercializing of the improved forage seed and seedling is believed to be crucial.

Studies indicated that a strong forage market and commercialization is fundamental for the production of adequate amount of good quality improved forages, better adoption and transforming livestock and dairy sub-sectors in general, and forage sub-sector in particular (Lemma *et al*., 2010; Aranguiz and Creemers, 2019). However, forage marketing has remained informal, opportunistic and seasonal that has been controlled by traders and retailers, and characterized by underdeveloped commercialization (Aranguiz and Creemers, 2019). In Ethiopia, forage seed and planting material production, marketing and commercialization have been given less attention despite the potential to establish large scale seed production (Tolera *et al*., 2012). Furthermore, poor market orientation, shortage and poor-quality forage seed, high cost of feed resources, inadequate economic incentives of forage adoption, shortage of land, and lack of support services contributed to low level of improved forage adoption in Ethiopia (Gebremedhin *et al*., 2003; Lemma *et al*., 2010; Tolera *et al*., 2012).

Several other studies have also reported factors affecting forage technology adoption which broadly included household and farm characteristics, institutional factors and infrastructure. Household characteristics include sex, age, education of the head, family size and labor force (Abebe *et al*., 2018; Bashe *et al*., 2018; Bashir, 2014; Bassa, 2016; Gebremedhin *et al*., 2003; Jera and Ajayi, 2008; Martínez-García *et al*., 2013; Salo *et al*., 2017; Wambugu *et al*., 2011). Some other studies have also revealed the gender dimension that male household heads allocated more proportion of land to improved forage production than female headed households (Bashir, 2014). The same study has also reported that old age household heads are associated with high intensity of improved forage adoption (Bashir, 2014) while educational level of the household head has a positive impact on the adoption of improved forage (Bassa, 2016; Gebremedhin *et al*., 2003. Family size and adult male members of a household have a positive impact on the probability of adopting improved forage *(*Abebe *et al*., *2018;* Bashe *et al*., 2018; Martínez-García *et al*., 2013).

Findings on the influence of farm characteristics on forage adoption have shown that the impact of land size is mixed. While some studies reported that land size had a positive impact on improved forage adoption (Jera and Ajayi, 2008; Martínez-García *et al*., 2013), others observed a negative impact (Bashe *et al*., 2018; Bashir, 2014). Farm characteristics such as dairy herd size (Bassa, 2016; Jera and Ajayi, 2008; Martínez-García *et al*., 2013), livestock ownership (Bashir, 2014; Martínez-García *et al*., 2013), and milk yield (Martínez-García *et al*., 2013) had a positive impact on the likelihood of improved forage adoption.

Institutional factors such as access to cooperative membership, credit, extension services and livestock training play important role in forage adoption. Membership of dairy cooperatives (Jera and Ajayi, 2008), access to extension service (Abebe *et al*., 2018; Bashir, 2014), access to credit service (Bashir, 2014) and livestock training (Abebe *et al*., 2018; Bassa, 2016) had a positive impact on the probability of improved forage adoption. Regarding the impact of infrastructure, studies have shown negative association between distance to development agents' office or farmers' training center and the likelihood of adopting improved forage (Abebe *et al*., 2018; Bashe *et al*., 2018; Bassa, 2016).

While several of the past studies on improved forage adoption are vital to serve as a guide for adoption study, they also had some limitations. Some of the past studies including that of Gebremedhin *et al*. (2003) conducted long time ago are rarely used to guide current policy making process related to forage improvement. Other studies including that of Abebe *et al*. (2018), Bashe *et al*. (2018), Bassa (2016), Bashir (2014), Jera and Ajayi (2008), and Martínez-García *et al*.(2013) had limited coverage focusing on one or two woredas[1] and hence had inherent limitation to represent wider areas. Furthermore, most of the past studies investigated the probability of adoption using a binary logit or probit model. However, both logit and probit models fail to capture the intensity of adoption which is as equally important as the probability of adoption. The exception is the study done by Bashir (2014) who investigated both the probability and intensity of improved forage adoption using double hurdle model and Gebremedhin *et al*. (2003) who investigated the intensity of adoption using Tobit model. The work of Bashir (2014) was limited to only one administrative zone in the northern part of the country in the Amhara National Regional State with limited sample size which will be difficult to make inferences and policy suggestions. Furthermore, the study of Gebremedhin *et al*. (2003) was not only limited to investigating the intensity of adoption, but also conducted long time ago which hardly helps to explain the recent situation.

The present study aimed to fill the stated gaps of past studies. Specifically, A Craggit double hurdle model that enables to investigate both the probability and the

[1] Woreda, also known as district, is the third-level of the administrative division of Ethiopia after zones and regions.

intensity of adoption solves the drawbacks of Tobit and Heckman two stage models. It also covers large area of land with reasonably large sample size. The objective of this paper is, therefore, to analyze adoption rates and the determinants of the probability and intensity of adoption of improved forage crops technologies in Oromia National Regional State.

METHODOLOGY

Scope of the Study

Improved forage is usually disseminated as a package with crossbred dairy technology. Therefore, the target population of this study is the households who owned cows. The study was conducted in Oromia National Regional State which possesses over 24 million cattle, accounting for 41% of the national cattle population (CSA, 2015). Eight Administrative zones that are believed to represent the region in dairy production were selected for the study including North Shewa, West Shewa, South West Shewa, East Shewa, West Hararghe, Arsi, Bale and West Arsi. Two woredas[1] were again selected from each of the zones based on their representativeness in dairy production along with associated packages, making a total of 16 woredas. From each of the woredas, two kebeles[2] were selected again based on representativeness in dairy production and package utilization practices making a total of 32 kebeles.

Data Collection Approaches

The required dataset and information were collected by employing blends of standard data collection methodologies. The major stages of data collection included desk review, qualitative and quantitative survey techniques. In the first stage, extensive desk review was made from electronic and print media including published and unpublished materials. Information obtained from desk reviews and qualitative approaches has helped to design survey instruments, such as structured questionnaire, at initial stages of the study. In the second stage, supplementary information and further details on specific parameters were collected through qualitative survey techniques, such as focus group discussions and key informant interviews. This approach has largely contributed to understand details of particular issues and learn more about dairy production technologies. Qualitative information was collected from selected farmers, Office of Agriculture representatives, senior livestock research and social science scientists and others. Information collected through this technique helped to describe and narrate quantitative findings. The third stage was devoted to collection of quantifiable data through quantitative survey approaches.

[2] Kebele is the lowest administrative unit in Ethiopia

This stage was fundamental to collect concrete and measurable data from randomly selected households using a structured and pre-tested questionnaire.

Sampling Frame and Sample Selection Techniques

Since the purpose of the study is to analyze the adoption status of improved forage technologies, the sampling frame was the population of households who owned dairy cows either local or crossbred. The complete list of households from where samples were drawn randomly was retrieved from Office of Agriculture. Once the list was secured, data was collected on the cow ownership status of each of the households along with kebele and village representatives. With this process, the sampling frame of the population of households who own cows was established. Out of this sampling frame, the sample of households was drawn randomly using systematic random sampling procedure.

To determine a representative sample size for the study, the following sample size determination formula by Kothari (2004) was used:

$$N = \frac{Z^2pq}{e^2} = \frac{(1.96)^2\ (0.5)(0.5)}{(0.025)^2} = 1537 \qquad (1)$$

Where N is the sample size needed, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, *e* is the desired level of precision, *p* is the estimated proportion of an attribute that is present in the population, and *q* = 1-*p*. The value of Z is found from the statistical table which contains the area under the normal curve of 95% confidence level. In the determination of sample size, setting the value of p=0.5 and hence q=0.5 yields the maximum optimum sample size while any other combination of the values of p and q yields less sample size using the Kothari formula. Therefore, using 0.5 for the values of p and q, and *e* = 0.025 the Kothari formula gives a total of 1537 samples to sufficiently represent the population in the selected study areas assuming a 95% confidence level and ±5% precision. However, assuming a response rate of 94%, additional 93 samples were added to have a total of 1630 samples.

Table 1. Sample sizes selected from each of the study zones in Oromia Region

Zones	Male	Female	Overall
North Shewa	167	57	224
West Shewa	175	60	235
South West Shewa	155	42	197
Arsi	130	42	172
Bale	140	60	200
West Arsi	138	61	199
East Shewa	140	58	198
West Hararghe	125	80	205
Overall average	1170	460	1630

Data Analysis

Both descriptive and econometric models were used to analyse the data. Econometric model used in this study was the Craggit model, the specification of which is given in subsequent section.

Empirical Model and Hypotheses

Farmers make two types of decisions: The first is whether or not to participate in adopting improved forage whereas the second is on the proportion of area allocated to grow improved forages out of the total land owned. Econometric models commonly used to handle such decisions can be Tobit (Tobin, 1958), Heckman two-stage (Heckman, 1979) and Craggit double hurdle (Cragg, 1971). The Tobit model has two shortcomings. First, it cannot separate the participation and intensity of participation decisions as it assumes both equations are affected by the same factors, which is not always true. Second, it assumes zero corner solution which may not hold true as the zero value of the intensity of participation equation may not be necessarily the corner solution but can be due to a discrete choice of not to participate in the adoption decision. Hence, Heckman two stage and the Craggit double hurdle models could be best candidates for this study.

The Heckman two-stage sample selection model solves the drawbacks of the Tobit because the participation and intensity of participation decisions are successively regressed in this modelling approach. In the Heckman selection model, the zero observations in the dependent variable are assumed to be discrete choices not to participate and only positive quantities are expected in the intensity (second) equation once a farmer decides to participate in adoption. That is, the second stage does not have a room for a corner solution in the intensity decision, which may not always be true. The Craggit model formulated by Cragg (1971) and further developed by Jones (1989) is more flexible and designed to solve the drawbacks of both the Tobit and the Heckman two stage models. However, to choose between the Tobit and the Craggit models, a log likelihood ratio test can be used. Based on Burke (2009), the specification of the Craggit double hurdle model that integrates the Probit model in the probability of adoption equation (to determine the probability of y > 0) and the truncated normal model for the intensity of adoption (given positive values of y) is given as:

$$f(w, y|x_1, x_2) = \{1 - \Phi(x_1\gamma\}^{1(w=0)}[\Phi(x_1\gamma)(2\pi)^{\frac{-1}{2}\sigma^{-1}}\exp\{-(y - x_2\beta)^2/2\sigma^2\}/\Phi(x_2\beta/\sigma)]^{1(w=1)} \quad (2)$$

Where w is a binary indicator equal to 1 if y is positive and 0 otherwise, x_1 and x_2 are the explanatory variables affecting the participation and the intensity equations, respectively, with no restrictions on the elements of x_1 and x_2 which means each decision may be determined by a different vector of explanatory variables altogether; Φ is the standard normal cumulative distribution function. In Craggit double hurdle model, the probability of y > 0 and the value of y, given y > 0, are determined by different mechanisms through the parameter vectors of γ and β, respectively.

From the Craggit model, the probabilities regarding whether y is positive are:

$$P(y_i = 0|x_{1i}) = 1 - \Phi(x_{1i}\gamma) \qquad P(y_i > 0|x_{1i}) = \Phi(x_{1i}\gamma) \tag{3}$$

The expected value of y, conditional on y > 0 can be given as:

$$E(y_i|y_i > 0, x_{2i}) = x_{2i}\beta + \sigma \times \lambda(x_{2i}\beta/\sigma) \tag{4}$$

Where λ (c) is the inverse Mills ratio (IMR) given as $\lambda(c) = \phi(c)/\Phi(c)$.

Where ϕ is the standard normal pdf (probability distribution function). The unconditional expected value of y is given as:

$$E(y_i|x_{1i}, x_{2i}) = \Phi(x_{1i}\gamma)\{x_{2i}\beta + \sigma \times \lambda(x_{2i}\beta/\sigma)\} \tag{5}$$

The partial effect of an independent variable, x_j, around the probability that $y > 0$, for a given observation is given as:

$$\frac{\partial P(y>0 \mid x_1)}{\partial x_j} = \gamma j\phi(x_1\gamma) \tag{6}$$

Where γ_j is the part of γ that represent the coefficient of x_j. The partial effect of an independent x_j on the expected value of y, given y > 0, is given as:

$$\frac{\partial E(y_i|y_i>0, x_{2i})}{\partial x_j} = \beta_j[1 - \lambda(x_2\beta/\sigma)\ \{x_2\beta/\sigma + \lambda(x_2\beta/\sigma)\} \tag{7}$$

Where β_j is part of β that represent the coefficient on x_j .

Finally, the partial effect of an independent x_j on the unconditional expected value of y is not straight forward because it depends on whether x_j is an element of x_1, x_2, or both. If it is an element of both x_1 and x_2, the partial effect is:

$$\frac{\partial E(y|x_1, x_2)}{\partial x_j} = \gamma_j\phi(x_1\gamma) \times \{x_2\beta/\sigma)\} + \Phi(x_1\gamma) \times \beta_j(1 - \lambda(x_2\beta/\sigma)\ \{\frac{x_2\beta}{\sigma} + \lambda(x_2\beta/\sigma)\}]\ \ if\ x_j \epsilon x_1, x_2 \tag{8}$$

However, if x_j is only determining the probability of y > 0, then β_j = 0, and the second term on the right-hand side of (8) is canceled. In contrast, if x_j is only determining the value of y, given y > 0, then γ_j = 0, and the first right-hand side term in (8) is canceled. In order to choose between the Tobit model and Craggit model, a likelihood ratio (LLR) test that compares the double hurdle model with the Tobit model was used. Following Greene (2012), the LLR can be given as:

$$LLR = 2 * [Log_{Craggitmodel} - Log_{Tobitmodel}]$$

Variables and Hypotheses

Dependent variables: The dependent variable in the first hurdle of the Craggit model is the dichotomous variable which takes the value of one if a farmer participated in improved forage production and 0 otherwise. During the survey period, ten improved forage varieties, namely: oat-vetch, elephant grass, tree lucerne, sesbania, alfalfa, fodder beet, rhodes grass, leucanea, cow pea, and pigeon pea were noted to be the major forage crops disseminated to the farmers. A farmer was considred as an adopter if s/he used at least one of the ten listed improved forage varieties. The dependent variable in the second hurdle (the intensity equation) is the percentage of land allocated to grow improved forage out of the total crop land owned by the farmer.

Explanatory variables and hypotheses: Based on economic theories and past empirical findings, relevant explanatory variables hypothesized to affect the participation and intensity equations are given in subsequent sections. However, some explanatory variables that are assumed to have less impact on the intensity equation were excluded from the second tier. Excluding some explanatory variables that are less likely to have extended impact on the intensity equation is a common practice in estimating the Craggit model to solve the difficulties of correctly identifying the parameters of the model (Newman *et al*., 2003; Shumeta *et al*., 2018).

Based on economic theories, past findings and field observation, major explanatory variables along with their definitions, measurements and expected sign of influence are presented in Table 2.

Table 2. Summary of explanatory variables included in the Craggit model

Variables	Definition and measurement	Expected sign
Age of HHH*	Age of the household head in years	+
Family size	Number of family members	+
Gender	Household type (Male=1)	+
Education of HHH	Elementary/junior education (Yes=1)	+
Number of cows	Number of total cows owned	+
Milk production	Milk yield in liters	+
Cow adoption	Adoption of crossbred cows (Yes=1)	+
Total land	Total land operated by the household (ha)	+-
Income	Household income (ETB/year)	+/-
Grazing feed	Feed source other than grazing (Yes=1)	-
Credit for dairy	Access to credit services for dairy (Yes=1)	+
Forage extension	No forage extension services (Yes=1)	-
Member of coops	Membership of milk cooperatives (Yes=1)	+
Access to big cities[3]	Within 100km radius from big cities (Yes=1)	+
Crop adoption	Adoption of improved crop varieties (Yes=1)	+
Feed problem	Availability of feed problem (Yes=1)	+
Training	Training on improved feeding practices (Yes=1)	+
Feed knowledge	Knowledge on feed technologies (Yes=1)	+

*HHH = Household head

[3] Milk-sheds supply milk to big cities are mainly located within the radius of 100kms.

RESULTS AND DISCUSSION

Household Characteristics

The result shows that the average age of improved forage technology adopters was significantly higher (45 years) than their non-adopter counterparts (42 years) (Table 3). Likewise, the average family size of adopters was significantly higher (7.9 persons) than their counterparts (6.8 persons). Family size, especially those at economically working ages (15–64 years) is a vital factor for farming households as they largely depend on family labor for livestock management operations such as land preparation, planting, harvesting and collection of forage crops, and other dairy management activities. The practice of engagement on hired labor is limited for smallholder farmers for they largely depend on family labor. Age of the household head usually serves as a proxy for farming experiences which is noticed to have either positive or negative influences on adoption of agricultural technologies. In this study, if we assume that the household heads started farming at 20 years, they accumulated more than 20 years of faming experiences which is helpful for the management of forage crops and other farming practices in a better way than those with limited experiences. With increased age, the opportunity of farmers' exposure to new technologies and practices also increases.

Table 3. Mean difference between adopters and non-adopters of improved forage

	Adopter (n=159)	Non-adopter (n=1471)	Overall (n=1630)	t-value
Age of head (years)	44.75 (12.35)	42.48 (12.8)	42.7 (12.8)	2.2**
Family size (number)	7.86 (3.07)	6.80 (2.96)	6.90 (2.99)	4.3***
Total land (ha)	3.79 (3.23)	2.13 (1.92)	2.29 (2.14)	9.5***
Total number of cows	2.75 (2.13)	2.12 (2.09)	2.18 (2.10)	3.7***
Milk yield (L/cow/day)	5.63 (9.3)	2.39 (4.6)	2.7 (5.31)	7.5***
Income (1000 ETB)	30 (34.6)	26.0 (42.6)	26.4(41.9)	-1.2

Note: numbers in parenthesis are standard deviations

Table 4 also reveals that the proportion of households who attended primary and junior school was significantly higher for improved forage adopters (79%) than non-adopters (71%). Education enhances knowledge of the farmers which helps for informed decision making whether to adopt new technologies or not. It also helps to practice improved crop management practices which eventually contributes to increased production and productivity. Similarly, the proportion of households headed by male was significantly higher for adopters (89%) than non-adopters (84%). Male household heads are relatively better in their resource status than female heads of households which largely contributes to afford adoption of new practices and technologies.

Farm and Economic Characteristics

The findings further present the farm and economic characteristics of the adopters and non-adopters of improved forage. It was revealed that improved forage adopters owned significantly larger number of cows and land, and also produced larger volume of milk per annum than their non-adopter counterparts, on average. Land is important to adopt improved forage as it is a key factor to produce improved forages. Farmers who owned more dairy cows needed more feed including improved forages. More milk production would also generate more income that can partly be reinvested to adopt improved forage production. The results also show that there was no mean difference between income level of improved forage adopters and non-adopters.

Table 4. Percentage difference between adopters and non-adopters of improved forage (discrete variables)

	Adopter (n=159)		Non-adopter (n=1471)		Overall (N=1630)		Chi2 value
	Freq.	%	Freq.	%	Freq.	%	
Elementary and junior education (Yes=1)	125	78.62	1047	71.18	1172	71.90	3.93**
Household type (Male headed=1)	142	89.31	1240	84.30	1382	84.79	2.79*
Feed source other than grazing (Yes=1)	153	96.23	1299	88.61	1452	89.35	8.75***
Knowledge of improved feed practices (Yes=1)	84	52.83	666	45.28	750	46.01	3.3*
Adoption of crossbred cows (Yes=1)	76	47.80	384	26.10	460	28.22	33.34***
Adoption of food crop technologies (Yes=1)	150	94.94	1192	81.31	1342	82.64	18.46***
Perception of feed as a problem (Yes=1)	142	89.31	1285	87.36	1427	87.55	0.50
Access to trainings on improved feeds (Yes=1)	79	49.69	495	33.65	574	35.21	16.17***
Member of dairy coops (Yes=1)	23	14.47	102	6.93	125	7.67	11.49***
Dairy and forage related credit (Yes=1)	6	3.77	104	7.07	110	6.75	2.48
No extension services on forage (Yes=1)	22	13.84	391	26.58	413	25.34	12.32***
Close proximity to big cities (Yes=1)	109	68.55	745	50.65	854	52.39	18.45***

Improved Forage Related Technologies

The findings indicate that the proportion of households who reported to have feed sources other than grazing was significantly higher for improved forage crops adopters (96%) than non-adopters (88%). Households who adopted improved forage crops also owned crossbred bred cows which require additional feed resources other than grazing, such as concentrates, hay and pasture grass. Knowledge of improved feed practices was also significantly higher for adopters (53%) than non-adopters (45%). Adopter households also had better access to education which helped them gain more knowledge to make informed decision than non-adopters. The proportion of households who adopted crossbred cows was also significantly higher for adopters (48%) than non-adopters (26%). The farmers opt to grow improved forage crops to meet the high feed demands of crossbred cows. However, there is no significant difference between the two groups regarding the perception of feed problem for dairy production. Feed is a problem not only for adopters of improved forages but also for non-adopters. It is a common phenomenon that the farmers who own local breed cows also faced shortages.

Institutional and Infrastructural Factors

Institutional factors such as access to trainings on improved feeds, dairy cooperative membership, access to dairy and forage related credits, availability of forage related extension services and distances from big cities are expected to influence the adoption of improved forage crops. The result indicates that the proportion of improved forage adopters had higher chance of participation in trainings (50%) than non-adopters (34%). Access to trainings has created awareness on improved technologies, including improved forage crops, and also contributed for enhanced knowledge and skills. Similarly, improved forage adopter households (14%) have better chances of participation in dairy cooperatives than non-adopters (7%). This has helped them get the required inputs, such as concentrate feeds and seeds of improved forages, through cooperatives at reasonable prices for their dairy cows.

It was also recognized that the proportion of households who are situated at a distance closer to big cities was higher for adopters (69%) than non-adopters (51%). Adopters of improved forages are also adopters of crossbred cows who produce milk and sale to the nearby towns. Accessibility to woreda and zonal towns, and capital cities is one of the favorable conditions to adopt dairy technologies including improved forages for it creates easy access to markets of perishable products, such as milk. In contrast, the proportion of households who did not receive extension services on improved forages was significantly lower for adopters (14%) than non-adopters (27%). This might be because, adopters had better exposure to formal schooling where they go basic knowledge and may not necessarily rely on the knowledge obtained from extension services. The result also indicates that there was no significant difference between the proportion of the two groups regarding access to dairy and forage related credit services. Non-adopters also require access to credit especially to purchase oxen.

Overall Adoption Rates and Intensity of Adoption of Improved Forage Crops

The overall adoption rate of improved forage crops in Oromia National Regional State was 10% (Table 5). This is regional level adoption rate from the perspective of all the samples taken in this study. Among the study zones, improved forage crops were most adopted in North Shewa zone (23%) followed by South West Shewa (16%) and Arsi (14%) zones. In response to increased demands for crossbred cow technologies and feed shortage problems, adoption of improved forage crops is expected to grow over time. Tens of improved forage crop varieties have also been generated through research and released to beneficiaries. Strengthening promotion and dissemination of these varieties is also expected to enhance adoption of improved forage crops. FGD and KII discussants have also indicated that improved forage seeds need to be available at reasonable cost to help them increase the adoption status.

Intensity of adoption of improved forages is defined as the size of farmland allocated for growth of improved forage crops. The findings revealed that the sample households have allocated eight percent of their farmlands on average for the growth of improved forage crops. Some of the adopter households, such as those in Arsi zone, allocated as high as 10% of their farmlands for the growth of improved forage crops while other adopters, such as those in South West Shewa zone, allocated five percent. Conventionally, the farmers tend to allocate more area of farmlands for the production of food than forage crops. This is partly because of limited landholding and attitudes of the farmers who perceived that animals can get feed freely from elsewhere and it is a waste of land to allocate a plot for the production of forage crops.

Table 5. Adoption intensity of improved forage crops in the study zones of Oromia Region

The study zones	Adoption rates			Adoption intensity		
	Total sample (N)	Number of improved forage growers (n)	Adoption rates of improved forages (%)	Improved forage growers mean farm size (ha)	Area allocated for improved forage (ha)	% of area allocated for improved forage
North Shewa	224	51	23	5.1	0.44	8.6
West Shewa	235	23	10	3.6	0.25	6.9
South West Shewa	197	32	16	3.1	0.15	4.8
Arsi	172	24	14	3.5	0.36	10.3
West Arsi	199	15	7.5	3.5	0.23	6.6
East Shewa	198	3	1.5	2.8	0.16	5.7
West Hararghe	205	0	0	0	0	0
Overall	1630	159	10	3.8	0.31	8
		X^2=98.6106, df=7, P<0.001		F=3.93 df=6 P=0.0011	F=4.96 df=6 P<0.001	F=3.09 df=6 P=0.007

Varietal Level Adoption Rates of Improved Forage Crops

Until 2014, a total of 24 improved varieties of forage crops were officially released for different agro-ecological zones of Ethiopia (Fekede Feyissa *et al*., 2015). Various stakeholders were engaged in the promotion of these forage crops, such as Offices of Agriculture, Agricultural Research Institutes, Higher Learning Institutes, special purpose projects, such as 4th Livestock Project, ILRI (the then ILCA) projects, and Smallholder Dairy Development Projects.

Households are said to be improved forage crop adopters if they grow at least one of the improved forage varieties. Accordingly, oat-vetch was relatively most grown improved forage variety with adoption rate of 35% followed by elephant grass (15%) (Table 6). On the otherhand, pigeon pea (0.2%), cow pea and Leucanea (1% each) were the least adopted improved forage varieties. The major reasons behind the less adoption rates of improved forage crops was associated with shortage of farmlands and the consequent interest of the farmers to give priority for food than forage crops.

Table 2. Varietal level adoption rates of improved forage crops in the Oromia Region

S.No.	Improved forage variety	% of aware hh N=1630	Years since awareness	Adoption rate (%) N = 1630
1	Oat-vetch	53	9.5	35
2	Elephant grass	43	4.7	15
3	Tree Lucerne	19	8.3	7
4	Sesbania	14	5.1	6
5	Alfalfa	11	4.6	2
6	Fodder beet	9	6.0	2
7	Rhodes grass	7	8.7	1.3
8	Leucanea	5	6.4	1
9	Cow pea	4	4.4	1
10	Pigeon pea	2	5.6	0.2

Determinants of Improved Forage Technology Adoption

The Craggit double hurdle model was used to investigate the factors affecting the probability and intensity of improved forage technology adoption. Before deciding to run the Craggit model, the Tobit model was tested. Accordingly, the null hypothesis which states ‘the Tobit model fits for the data at hand against the alternative Craggit model’ was rejected (the calculated value of the LLR = 70 while the tabulated value using loglikelihood ratio test with a value of 70.12 compared to the tabulated value at 95% level of signficnance and 13 degree of freedem is 22.36).

Older household heads were positively associated with the intensity of improved forage crop adoption. As age of the household head increases by one year, the conditional level of area allocated to improved forage inceased by 0.2% on average, cetires paribus (Table 7). This could be because older farmers accumulated more experiences and knowledge on the importance of improved forages than youths. Another posible explanation is that older farmers usually have more access to land, out of which some can be allocated to improved forage. In contrast, the youth is constrained by access to land as witnessed by FAO (2014). According to this report, access to land is one of the six challenges of youth to participate in agriculture. In addition, studies show that younger generation is losing interest in subsistence and traditional agriculture and try to run away from farming in developing countries (White, 2012). The migration is commonly from rural areas to urban centers, which is also happening in Ethiopia.

Table 7. Results of Cragg's double hurdle regression model for determinants of improved forage adoption

Variables	1st hurdle (participation)	2nd hurdle (intensity)	Probabilities $\frac{\partial P(y > 0 \mid x_1)}{\partial x_j}$	Unconditional $\frac{\partial E(y \mid x_1, x_2)}{\partial x_j}$	Conditional $\frac{\partial E(y_i \mid y_i > 0, x_{2i})}{\partial x_j}$
	Coef. (Std. Err.)	Coef. (Std. Err.)	APE	APE	APE
Age of head	-0.0001 (0.004)	0.006*(0.003)	0.000	0.000	0.002
Family size	0.041** (0.02)	0.001 (0.014)	0.006	0.002	0.000
Gender	0.18 (0.15)	-0.14 (0.14)	0.026	0.002	-0.051
Education of head	0.098 (0.12	-0.02 (0.10)	0.014	0.003	-0.009
Total cows owned	-0.025 (0.025)	0.025 (0.02)	-0.004	0.00	0.009
Milk production (liters)	0.03***(0.009)	0.01* (0.005)	0.004	0.001	0.004
Crossbred cow adoption	0.163 (0.12)	-0.145 (0.10)	0.024	0.001	-0.053
Total land (ha)	0.11*** (0.02)	0.07***(0.01)	0.016	0.008	0.026
Income (Birr)	-0.000 (0.000)	-0.000 (0.000)	0.000	0.00	0.000
Feed other than grazing	0.44** (0.21)	0.82** (0.40)	0.065	0.054	0.301
Credit access for dairy	-0.37* (0.22)	-0.03 (0.23)	-0.054	-0.017	-0.01
Access to big city	0.24** (0.10)	-0.23** (0.1)	0.036	0.001	-0.084
Feed problem	0.08 (0.15)	-0.19 (0.13)	0.012	-0.005	-0.07
Member of coops	0.14 (0.16)		0.02	0.006	
Crop adoption	0.43** (0.18)		0.063	0.018	
No forage extension	-0.39*** (0.13)		-0.058	-0.017	
Access to training	0.22** (0.10)		0.032	0.009	
Had feed knowledge	0.193**(0.098)		0.028	0.008	
Constant	-3.25*** (0.38)	-0.8 (0.49)			
Sigma					
Constant		0.33*** (0.04)			

Observations = 1,619, Wald chi2 (18) = 123.34, Log likelihood = -388.21, Prob > chi2 = 0.0000; Note: APE=Average partial effect

Family size was also found to have a positve impact on the probability of improved forage adoption. As family size of able persons (15-64 years) increases by one person, the probabilty and unconditional (overall) level of adopting improved forage increases by an average of 0.2 and 0.6%, respectively. Family is the main source of labor in rural setting, because of which a positive relationship is usually expected. Previous findings also confirmed this positive relationship (Abebe *et al*., 2018; Bashe *et al*., 2018; Martínez-García *et al*., 2013).

The annual quantity of milk production was found to have a positive impact on both the probability and intensity of improved forage adoption. A liter increase in milk production would result in a mean increment of a 0.4% probability of adoption, 0.1% overall (unconditional) and 0.4% conditional levels of improved forage adoption. This could be because high milk production helps to generate more income that can be reinvested for purchase of improved forage seeds to meet feed demands and sustain higher milk production. This result is in line with the findings of Martínez-García *et al*. (2013) who found a positive relationship between milk production per herd and improved grassland management by small scale dairy farmers in central Mexico.

As expected, total land owned was also found to have a positive impact on both the probability and intensity of improved forage adoption. As the land owned increases by one hectare, the probability of adopting improved forages increases by 1.6% on average while the overall (unconditional) and conditional levels of adoption increased by 0.8 and 2.6%, respectively. This is because land is a key resource to grow improved forage crops. This finding is in conformity with the past findings (Gebremedhin *et al*., 2003; Jera and Ajayi, 2008; Martínez-García *et al*., 2013).

The result also indicates that households who have feed sources other than grazing were positively associated with both the probability and intensity of improved forage adoption. Compared to households who totally depend on grazing as a feed source, households who have other feed sources than grazing had 6.5% higher probability of adopting improved forages. Likewise, the overall (unconditional) and conditional level of improved forage adoption of households who have more feed sources than grazing was 5.4 and 30% higher than their counterparts. The plausible explanation for this could be acute feed shortages where households opt to depend on different sources including improved forages to ensure adequate supplies especially for their crossbred animals.

Contrary to our expectation, credit for dairy was found to have a negative impact on the probability of adopting improved forages. Households who had access to credit were less likely to adopt improved forage by 5.4% with an overall (unconditional) level of adoption of 1.7%. This result is in contrast with the past findings (Bashir, 2014). This might be because of more dependence of households on purchased feed resources than planting and managing of forage crops. With increased access to money, they would like to depened on purchased feeds, such as green and dry feeds, or concentrates.

Close vicinity to big cities was also found to have a positive impact on the probability but a negative impact on the intensity of improved forage adoption. The probability of a household who is living within 100kms radius of big cities had 3.6% higher probability and 0.1% overall (unconditional) level of improved forage adoption but 8.4% conditional level of adoption.

The result also reveals that experience on crop technology adoption was found to have a positive impact on the probability of adopting improved forage. As compared to the households who did not have experiences in food crop technology adoption, the probability and unconditional (overall) level of improved forage adoption of households who have experience of food crop technology adoption was high by 6.3 and 1.8%, respectively. This is because, households have already developed exposure to technologies and also realized the importance from improved food crops which has also driven them to adopt new technologies such as improved forage crops.

Unavailability of forage extension service was found to have a negative impact on the probability of improved forage adoption. The probability and unconditional (overall) level of improved forage technology adoption of households with no exposure to extension services were lower by 5.8 and 1.7%, respectively, as compared to those who have exposure. This finding is consistent to the reports of past findings (Abebe *et al*., 2018; Bashir, 2014).

The results also indicated that the training and knowledge of improved forages were found to have a positive impact on improved forage technology adoption. The probabilities of households who had access to training on improved forages and those who have knowledge on improved forages were higher by 3.2 and 2.8%, respectively, as compared to their peers. The overall (unconditional) level of adoption of improved forage of households who had access to training and had knowledge of improved forage were 0.9 and 0.8%, respectively, compared to their counterparts. Past studies also reported that access to trainings had a positive impact on the probability of improved forage adoption (Abebe *et al*., 2018; Bassa, 2016).

CONCLUSION AND POLICY IMPLICATION

This study investigated determinants of the probability and intensity of improved forage technology adoption in Oromia National Regional State. The adoption rate of improved forage crop was generally low standing at only 10% of the surveyed households. These households also allocated eight percent of the land for the production of improved forage crops, which reveals the very low intensity of adoption. The low adoption rates are indications that tens of improved forage crop varieties generated and released through research have not yet been well promoted and disseminated. Not only that awareness levels were low, but also limited availability of improved forage variety seeds has contributed to the low adoption rate and intensity. The attitude is still persistent that farmers marginalized allocation of a plot of land to growth of forage crops which largely contributed to limited intensity of adoption.

The Craggit model result indicated that family size increases the probability of improved forage adoption while age of the household head increases the intensity of improved forage adoption. It also revealed that volume of milk production, land owned and diversifying feed sources were also found to have a positive impact on both the probability and intensity of improved forage adoption. Furthermore, access to extension services, relevant training, knowledge on feed, access to big cities and experience on food crop adoption were found have positive impacts on the probability of improved forage adoption. Therefore, policies that target to improve sustainable knowledge and skills of family labor, experience sharing between older and younger farmers, relevant training and better infrastructure would have a positive impact on improved forage adoption. Qualitative analysis has also suggested increased availability of improved forage seeds at reasonable costs. Awareness should be raised further to change attitude of the farmers and help them allocate a plot of land for the growth of forage crops. Since technology adoption is a dynamic phenomenon, this paper suggests conducting nationwide research on improved forage adoption trends and investigating impact of adoption on farmers' wellbeing as a future research direction.

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