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Adoption Intensity of Inorganic Fertilizers in Maize Production: Empirical Evidence from Smallholder Farmers in Eastern Ethiopia

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Abstract

Evidences suggested that use levels of inorganic fertilizers are below the recommended rates in maize production. It is, therefore, necessary to investigate the reasons behind the failure to adopt the recommended rates of these fertilizers on maize production. This study analyzed determinants of intensity of adoption using a survey data collected from 383 randomly selected maize producing households. For this purpose, a two-limit Tobit model was applied. The econometric result revealed that variation in districts, family size, membership to cooperatives, distance to FTC, and livestock holding significantly affected smallholders' intensity of adoption of DAP in maize production. On the other side, variation in district, farming experience, farm size, membership to cooperatives, dependency ratio, and annual income significantly determined intensity of adoption of Urea. It is, therefore, necessary to give due emphasis to the indicated determinants in order to assist maize producing farmers by boosting maize productivity.

Keywords: adoption index, inorganic fertilizers, two-limit tobit, adoption intensity, Ethiopia

1. Introduction

The agenda of addressing food insecurity challenges has top priority in Sub Saharan African countries in general and in Ethiopia in particular. Apparently, agricultural production and productivity improvement strategies and policies have been set for poverty reduction and ensuring food security (Mucheru-Muna et al., 2007; Mugisha & Diiro, 2010).

Ethiopia, with its diversified agro ecology, is known for its suitability for agricultural production. The country has made remarkable efforts in increasing productivity of agricultural sector through various policies (Bachewe et al., 2015). Such strategies and policies are meant to improve agricultural performance through adoption of improved agricultural technologies. In line with this, information, input and output markets, labour markets, credit markets, and risks were among the variables addressed by the policies and strategies (Jack, 2011).

Despite these efforts, evidences depicted that improved technologies such as use of improved seed, fertilizer, improved agronomic practices and natural conservation measures are not widely adopted in the country (Million, 2010). Hence, efforts of feeding the growing population in Ethiopia remain to be a major challenge. Attempts in addressing this challenge resulted in expansion of land for agricultural production that eventually resulted in depletion of soil nutrient (Amsalu et al., 2007; Kindu et al., 2013; Lemenih et al., 2005). To surmount this, intensification could be an option.

Intensification of agriculture involves an efficient use of different farm inputs among which fertilizers are the major once as these improve agricultural productivity through improvements in soil fertility (Headey et al., 2014; Suri, 2011). The process of intensification requires the supply and use of sufficient external nutrients in order to harmonize the balance between nutrient removal during harvest and losses (Bekunda et al., 2010). In this regard, Ethiopia has implemented several cereal intensification programs in promoting the adoption of modern agricultural technologies like inorganic fertilizers and improved seed packages (Spielman et al., 2010).

By and large, adoption of improved agricultural technologies offers numerous potential benefits for smallholder farmers. This in turn increases agricultural production and contributes to income, food security, and poverty reduction (Asfaw et al., 2011; Kafle, 2010; Kassie et al., 2011). However, scholars indicated that the application rates of fertilizers in SSA are considered to be the lowest in the world (Xu et al., 2009) where Ethiopia is not an exception.

Maize is among the major food crops widely produced and consumed by smallholder farmers in Ethiopia in general and in Hararghe areas in particular. Area under maize during 2015/16 main cropping season in Ethiopia was about 2.1 million ha, which makes maize to be the second in area coverage out of cereals. During the same period, maize ranks first among cereals in terms of total production accounting for about 7.2 million tons. In West Hararghe and East Hararghe Zones, the area under maize production were about 42,044 ha and 49,980 ha, respectively, during the same period. Average productivity of maize in the zones were about 2.3 tons and 2.7 tones ha^{-1} in that order, which is below the national average of about 3.4 tones ha^{-1} (CSA, 2016a).

In Hararghe, farming is characterized by limited use of modern inputs such as improved seeds, fertilizers, irrigation, and others. Farmers usually apply both organic and inorganic fertilizer where the use of the latter is limited owing to its high prices and other factors (Ali et al., 2011; Endale, 2011; Haileslassie et al., 2007). Use levels of DAP (Di-Ammonium Phosphate) in maize production was about 78% and 83% in West Hararghe and East Hararghe zones, respectively. Only about 1% of land under maize production received Urea application in West Hararghe zone while it was about 12% in East Hararghe zone (CSA, 2016b).

On the other hand, the tendency to apply organic fertilizers is hampered by small livestock holdings especially in areas like Hararghe. In addition, crop residues are removed from field immediately after harvest as it is highly demanded for livestock feed and fire wood in the area (Nigussie et al., 2012). On top of these, study by Mengistu and Bauer (2011) depicted a negative reciprocal relationship between inorganic fertilizer use and manure applications.

Though boosting application of inorganic fertilizers beside the use of organic ones is necessary (Vanlauwe et al., 2011; Workneh, 2015), application of inorganic fertilizers in crop production in general and in maize production in particular is below the recommended rate in the study area.

Many factors are expected to contribute to the low levels of inorganic fertilizers use. Available evidences vary in explaining determinants of adoption of fertilizers. Some indicated that socioeconomic and institutional factors determine adoption (Duflo et al., 2008; Duflo et al., 2011; Yamano & Arai, 2010). Others add technical knowledge and household characteristics as determinants (Legese et al., 2009; Mengistu & Bauer, 2011). There are still other studies that revealed the effect of structural factors outweighing household characteristics in affecting adoption (Dadi et al., 2001). Technology related factors are also revealed as determinants (Doss, 2006; Kafle, 2010; Suri, 2011).

These indicated that the effects of the aforementioned determinants are not universal (Ogada et al., 2014; Rao & Debela, 2016). It is, therefore, necessary to investigate the specific factors that favour and hamper level of adoption of inorganic fertilizers in East Hararghe and West Hararghe zones. This study is, therefore, aimed at assessing determinants of adoption intensities of inorganic fertilizers, DAP and Urea, in maize production in five districts in eastern Ethiopia.

2. Methodology

2.1 Description of the Study Area

The study was conducted in five districts, Gurawa, Haramaya, Kombolcha, and Meta from East Hararge zone and Habro from West Hararghe zone in eastern Ethiopia.

Gurawa district: Gurawa is one of the districts in East Hararghe zone with high agricultural production potential. The altitude of the district ranges from 500 to 3230 meters above sea level (masl). The district has an estimated total population of 300,661 (CSA, 2013). The district is known for its production of staple crops (wheat, barley, and Irish potato) and fruit (apple) production (Nigussie et al., 2012).

Haramaya district: Haramaya is one of the districts of east Hararghe Zone. The district has an estimated total population of 352,031 according to CSA (2013). The altitude of this district ranges from 1400 to 2340 masl which enable the area to be categorized under the Ethiopian highlands. It is situated in the semi-arid tropical belt of eastern Ethiopia. The mean annual rainfall received ranges from 600 to 1260 mm with bimodal nature. The relative humidity varies between 60 and 80%. Minimum and maximum annual temperatures range from 6 °C to 12 °C and 17 °C to 25 °C, respectively. Mixed crop and livestock production system is practiced in the district. Crop production with the diverse cropping system is the dominant agricultural system where maize, sorghum, and vegetables production is common in the area.

Kombolcha district: Kombolcha is also one of the eighteen districts in East Hararghe Zone. The altitude of the district ranges from 1600-2400 masl. The district is strategically located between the two main cities Harar and Dire Dawa. In addition, due to its proximity to Djibouti, the district has access to potential markets in the area. The total population of Kombolcha district (CSA, 2013) is 178,058. Lowland and midland agro-ecological zones characterize the district's climate. Annually, the district receives mean annual rainfall of 600-900mm, which is bimodal and erratic in distribution. The major crops produced in the district include sorghum, maize, vegetables (potato, tomato, cabbage, onion, and carrot), khat, groundnut, coffee, and sweet potato.

Meta district: Meta is also one of the districts in the East Haraghe Zone. Meta district, apart from its stalk and small cereals (like wheat production), is known for its potentiality in cash crops like coffee. A projected total population of the district, for the year 2016, is about 318,458 (CSA, 2013).

Habro district: Habro is one of the 14 districts located in West Hararghe zone. The district has an estimated total population of 244,444 (CSA, 2013). The agro-ecology of the district comprises highland (19%), mid-altitude (50%) and lowland (31%) areas. The mean annual rainfall of the district is 1010 mm and the annual temperature ranges from 5-32 ^{o}C.

2.2 Sampling Procedure

A cross-sectional study design was used. Household survey questionnaire was administered to collect data from the smallholder farmers drawn from the study districts. Multistage sampling technique was employed. The steps involved were purposive selection of the five districts which are known for their maize production, followed by random selection of two representative *Kebeles* (Note 1) from each district making a total of ten *Kebeles*. As final respondents, a total of 383 household heads were randomly chosen from a population of maize growing farmers in the selected *Kebeles*.

2.3 Data Sources and Methods of Data Collection

Primary data on household socioeconomic characteristics, farm characteristics, institutional factors, use of inorganic fertilizers, and other variables were collected using structured questionnaire during 2015/2016 production year. Additional information on recommended inorganic fertilizer rates were collected from secondary sources.

2.4 Specification of Econometric Model

The selection of econometric model requires taking into account the nature of the dependent variable, among others. The dependent variable, the adoption index, is a continuous value between zero and one in this study. It is an index value ranging from 0 to 1, for which 0 indicates the non-adopter, 1 represents the full adopter of the inorganic fertilizer, and values lying in between 0 and 1 indicate the level of the adoption within the ranges of the two-limits. A dependent variable which bears a zero value for a significant portion of the observations requires a censored regression model (Two-limit Tobit model). Such censored regression is preferred because it uses data at the limit as well as those above the limit to estimate regression. Following the work of Maddala (1997), the Tobit model can be derived by defining a new random variable y^* that is a function of a vector of variables.

The equation for the model is constructed as:

$$y^* = X_i\beta_i + \varepsilon_i \tag{1}$$

Where, y^* is unobserved for values less than 0 and greater than 1 (called a latent variable) which represents an index for adoption of DAP and Urea fertilizer technologies; X_i represents a vector of explanatory variables; β_i is a vector of unknown parameters; and ε_i is the error term. By representing y_i (a particular agricultural technology adoption index) as the observed dependent variable, the two limit Tobit model can be specified as:

$$Y_i = \begin{cases} 0 \ if\ Y_i^* \leq 0 \\ Y^* \ if\ 0 < Y_i^* < 1 \\ 1 \ if\ Y_i^* > 1 \end{cases} \tag{2}$$

Censored regression models (including the standard Tobit model) are usually estimated by the Maximum Likelihood (ML) method. The log likelihood function is specified with an assumption that the error term ε follows a normal distribution with mean 0 and variance δ^2. The Tobit coefficients can be interpreted as coefficients of a linear regression model. Accordingly, factors that influence use intensity of inorganic fertilizers (DAP and Urea separately) was identified using Two-limit Tobit model.

Based on theoretical justifications and prior literature, a number of explanatory variables have been hypothesized to influence the adoption of agricultural technologies, inorganic fertilizers in particular. As a result, several hypothesized variables influencing the decision of intensity of adoption of inorganic fertilizers; DAP and Urea, were included.

2.5 Definition of Variables

2.5.1 Dependent Variable

The dependent variable was an index computed from the intensity of use of inorganic fertilizers. This variable is computed for DAP and Urea separately in order to run two-limit Tobit models. The index values are censored between 0 and 1. Accordingly, DAP use intensity index, the dependent variable in the first model is the ratio of the rate actually applied to that of the recommended DAP rate, where the actual rate is the ratio of total DAP applied on maize field to total area allocated for the crop. The same procedure was followed to compute Urea use intensity index.

2.5.2 Predictor Variables

Table 1 shows lists of predictor variables hypothesized to affect use intensity of inorganic fertilizers (DAP and Urea) in maize production.

Table 1. Summary of the predictor variables in use intensity of DAP and Urea

Variable	Type of Variable	Description of the variable	Expected sign
Independent variables			
District	Categorical	These are Gurawa, Haramaya, Kombolcha, Meta, and Habro	+/-
Sex of household head	Dummy	1 if the head is male, 0 otherwise	+/-
Age	Continuous	Age of household head (in years)	+
Education of household head	Dummy	1 if literate, 0 otherwise	+
Family size	Discrete	Number of individuals in a household	+/-
Farming experience	Continuous	Household head's farm experience in years	+
Distance from all-weather roads	Continuous	Distance from all-weather roads in Km	-
Distance from FTC	Continuous	Distance from FTC in Km	-
Access to extension	Dummy	1 if there is access, 0 otherwise	+
Access to credit	Dummy	1 if there is access, 0 otherwise	+
Total land size	Continuous	Total land size in ha	+
Number of plots	Discrete	Number of plots owned	+/-
Cooperative membership	Dummy	1 = if member, 0 otherwise	+
TLU	Continuous	Livestock holding in tropical livestock units	+
Dependency ratio	Continuous	The ratio of dependent members to active members	-
Annual income	Continuous	Annual income in ETB from crops, livestock, and off farm activities	+

3. Results and Discussion

3.1 Descriptive Results

On average, the family size in the study area is seven persons per household. The result shows that the mean family sizes in the study districts are relatively higher as compared to the national average. The average farming experience in the study area was about 19 years. Total average land holding is 0.51 ha. In terms of farm income, households in Kombolcha earn a higher income (about 25,070 Birr per year), followed by those in Habro (about 24,380 Birr per year) and Haramaya district (about 24,350 Birr per year).

In terms of membership to cooperative, about 53% of the respondent households were members. The average distance of the household from Farmers Training Centre (FTC) was found to be 1.78 kilometres. On average, livestock ownership in TLU was 3.95 per household. Dependency ratio is 1.33 indicating that one active member of a household supports more than one additional family member.

Farmers in the study area have used about 81% of the recommended rate of DAP where the recommended rate is 100 kg ha^{-1} in maize production. Likewise, the figure is about 69% for Urea utilization in maize production out of the urea recommended rate of 150 kg ha^{-1}. The result depicts that use levels of inorganic fertilizers in maize production in general falls below the recommended rates.

3.2 Determinants of Adoption of DAP and Urea in Maize Production

The two-limit Tobit models for both DAP and Urea showed a good fit at 1% level of significance. Moreover, the overall variance inflation factors (VIF) of all independent variables in the two-limit Tobit model is less than 10, indicating that multicollinearity was not a severe problem.

The model result for DAP use intensity showed that the socioeconomic factors including variation in district, family size, members to cooperatives, distance to FTC, and livestock holding in TLU were found to significantly determine the use of DAP in maize production. In the case of Urea use intensity, the result indicated that variation in district, farming experiences, farm size, members to cooperatives, dependency ratio, and annual income significantly determined its use level in maize production.

In concurrence with socio economic predictors, variations in district was found explaining the use intensity of DAP and Urea. This could be emanated from differences in potentiality of the districts in maize production resulting from differences in agro ecology and soil factors, among others. As a result, farmers in Gurawa as compared to those in Meta and Habro districts were found to use more DAP. For Urea use intensity, farmers in Haramaya district used more as compared to those living in Gurawa district (the result is significant at 1% significance level). The result exemplify that location matters in use level of DAP and Urea fertilizers in maize production. This result is consistent with prior studies (Mengistu & Bauer, 2011).

Family size explained DAP adoption intensity negatively and significantly. The result shows that as family size increases, use level of DAP declines. This could be due to the limited capacity in affording DAP fertilizer given the extra living expenses required for the family members. This result is against earlier findings that indicated adoption of new technology requires more labour inputs (Feleke & Zegeye, 2006; Molla, 2008).

The result for distance to FTC was positive in explaining DAP fertilizer use intensity in maize production. FTC is among major sources of information where technologies can be demonstrated to farmers, to the wider community, and to stakeholders. However, the result was against the expectation. A kilometre increase in households distance from FTC results in an increases in use intensity of DAP in maize production by a factor of 0.056, keeping other factors constant. This might be because FTC's did not give due attention in demonstrating and disseminating technologies related to fertilizer use in maize technology, probably giving more focus to other commodities. This is an indication that these centres need to consider maize related technologies in their future endeavour. Basically, the history of FTC establishment in Ethiopia dated back to the PASDEP plan that outlined to assign at least three DAs (specializing in crop production, livestock, and natural resources) in each *Kebele* (Bachewe et al., 2015), where farmers would have access to participatory demonstrations for improved technologies and new farming systems. However, the lesson from the negative influence of FTC on DAP from this finding could provide a clue that this potential plan is not realized in the context of maize technology adoption, specifically in the case of inorganic fertilizer adoption in the study area.

Urea use in maize production was negatively influenced by farm size, farming experience, and dependency ratio. The result indicates that farmers with relatively smaller land holding have more probability to use urea in maize production. Similarly, farmers with more years of experience are found to be less users of urea as compared to those with less experience. This could be because experienced farmers more likely use organic fertilizer sources as a substitute for urea. Likewise, household with more dependent family size are found to be less users of urea in maize production as this could happen as a result of giving more priority to financially support the livelihood of the dependent family members instead of buying urea.

Membership to cooperative, on the other hand, positively affected use intensity of DAP and Urea. Keeping other factors constant, being member of a cooperatives was found to favour the farmers' likelihood of adoption of DAP and urea in maize production by the factor of 0.051 and 0.079 respectively. The result could reveal the strongest institutional role played by cooperatives in the use of these fertilizers in maize production. This is in line with prior finding that reported the positive influence of cooperative membership in agricultural technology adoption (Ahmed, 2015).

Livestock holding (in TLU) was found a significant determinant of DAP use. This could be due to the fact that households with more number of livestock holding do minimize the capital constraints to purchase agricultural inputs as well as to capacitate their risk taking behaviour to use technologies like DAP. This is against the finding that explained a negative influence of livestock holding on inorganic fertilizer use where farmers with more livestock preferred utilizing manure to inorganic fertilizer (Mengistu & Bauer, 2011).

Annual income was found to significantly and positively determine urea use intensity in maize production. Accordingly, farmers with higher annual income tend to use more urea in maize production. This could be due to the fact that availability of more income reduces financial limitation for the purchase and use of inorganic fertilizers. The result is consistent with prior studies (Negash, 2007).

Table 2. Parameter estimates of the Two-limit Tobit model

Predictor variables	**DAP**			**Urea**		
	Coefficient	SE (Robust)	t-value	Coefficient	SE (Robust)	t-value
District (*Gurawa* is a reference)						
Haramaya	-0.087	0.113	0.77	0.313***	0.077	4.08
Kombolcha	0.039	0.124	0.31	0.116	0.070	1.65
Metta	-0.236**	0.112	2.11	-0.112*	0.067	1.67
Habro	-0.337**	0.145	2.32	-0.164*	0.085	1.93
Sex	0.107	0.104	1.02	0.102	0.071	1.44
Age	0.005	0.008	0.65	0.006	0.005	1.13
Education status	-0.030	0.082	0.36	-0.018	0.051	0.35
Family size (number)	-0.041**	0.017	2.38	-	-	-
Farming experience (years)	0.001	0.009	0.12	-0.009*	0.005	1.74
Distance to all weather road (km)	-0.005	0.027	0.18	0.026	0.016	1.65
Distance to FTC (km)	0.056**	0.028	2.03	0.017	0.016	1.02
Access to extension service	-0.115	0.349	0.33	-0.006	0.354	0.02
Access to credit	-0.074	0.102	0.73	-0.033	0.066	0.50
Farm size (ha)	-0.064	0.119	0.53	-0.114*	0.066	1.73
Number of plots	0.006	0.038	0.16	0.020	0.022	0.90
Membership to cooperative	0.151**	0.075	2.01	0.079*	0.046	1.73
Livestock ownership	0.034*	0.019	1.79	0.006	0.009	0.61
Dependency ratio	0.012	0.036	0.33	-0.059**	0.024	2.41
Annual income (‘000’ Birr)	0.003	0.002	1.46	0.002*	0.011	1.74
Constant	0.967**	0.443	2.18	0.622	0.391	1.59
Log likelihood	-268.06			-221.03		
LR Chi2 (19) (18)	2.07***			6.78***		
Number of observations (N)	383			383		
Pseudo R^2	7.43%			**19.83%**		

Note. ***, ** and * implies statistical significance at 1, 5, and 10% levels, respectively.

4. Conclusion and Policy Implications

The study analyzed determinants of adoption intensity of inorganic fertilizers taking in to account DAP and urea application in maize production. Data collected from a total of 383 farmers selected from Gurawa, Haramaya, Kombolcha, Meta, and Habro districts were analyzed using Tobit model.

Descriptive results revealed that about 81% of the recommended DAP rate (where recommended rate is 100 kg DAP ha^{-1}) was applied by the sampled farmers. Similarly, about 69% of recommended urea use level was applied in maize production (recommended rate is 150 kg urea ha^{-1}). These results indicated that underutilization of inorganic fertilizers is observed in the study districts.

Tobit model results revealed that variation in district, family size, membership to cooperatives, distance to FTC, and livestock holding were found to significantly determine adoption intensity of DAP while variation in district; farming experience, farm size, membership to cooperatives, dependency ratio, and annual income were found to significantly determine adoption intensity of urea in maize production.

Membership to cooperatives plays an enormous role in disseminating technologies such as fertilizers and other agricultural inputs. Moreover, cooperative is among the sources of information for farmers in order to disseminate technologies. It is, therefore, necessary to encourage participation of farmers in cooperative institutions for enhancing application of inorganic fertilizers and other agricultural technologies.

Uses of inorganic fertilizers are still lagging behind the recommended levels in maize production. Therefore, farmers should be encouraged to increase use levels of these fertilizers in order to optimize the productivity of the crop. Furthermore, the study revealed the importance of taking in to account location differences while advising and distributing inorganic fertilizers to farmers in various maize producing districts. This can further maximize the benefit obtained from the application of such fertilizers. In addition, it is necessary to strengthen farmers training centres for enabling them to properly demonstrate available technologies and at the same time to capacitate farmers on technology utilization by offering training.

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References

Ahmed, M. H. (2015). Adoption of multiple agricultural technologies in maize production of the Central Rift Valley of Ethiopia. *Studies in Agricultural Economics, 117*, 162-168. https://doi.org/10.7896/j.1521

Ali, K., Munsif, F., Zubair, M., Hussain, Z., Shahid, M., Din, I. U., & Khan, N. (2011). Management of organic and inorganic nitrogen for different maize varieties. *Sarhad J. Agric., 27*(4), 525-529.

Amsalu, A., Stroosnijder, L., & de Graaff, J. (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. *Journal of Environmental Management, 83*(4), 448-459. https://doi.org/10.1016/j.jenvman.2006.04.010

Asfaw, S., Shiferaw, B., Simtowe, F., & Haile, M. G. (2011). Agricultural technology adoption, seed access constraints, and commercialization in Ethiopia. *Journal of Development and Agricultural Economics, 3*(9), 436-447. Retrieved from https://ssrn.com/abstract=2056976

Bachewe, F. N., Berhane, G., Minten, B., & Taffesse, A. S. (2015). *Agricultural growth in Ethiopia (2004-2014): Evidence and drivers*. International Food Policy Research Institute (IFRPI), Ethiopia Strategy Support Program (ESSP), Background Paper Prepared for this Report.

Bekunda, M., Sanginga, N., & Woomer, P. L. (2010). Chapter Four: Restoring Soil Fertility in Sub-Sahara Africa. *Advances in Agronomy, 108*, 183-236. https://doi.org/10.1016/S0065-2113(10)08004-1

CSA (Central Statistical Authority). (2013). *Population Projection of Ethiopia for All Regions at Wereda Level from 2014-2017*. Central Statistical Agency, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). (2016a). *Agricultural Sample Survey 2015/16* (Volume I). Report on Area and Production of Major Crops for Private Peasant Holdings, Meher Season. Statistical Bulletin 584, Central Statistical Agency, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). (2016b). *Agricultural Sample Survey 2015/16* (Volume III). Report on Farm Management Practices for Private Peasant Holdings, Meher Season. Statistical Bulletin 584, Central Statistical Agency, Addis Ababa, Ethiopia.

Dadi, L., Burton, M., & Ozanne, A. (2001). Adoption and intensity of fertilizer and herbicide use in the central highlands of Ethiopia. *Agrekon, 40*(3), 316-333. https://doi.org/10.1080/03031853.2001.9524956

Doss, C. R. (2006). Analyzing technology adoption using micro studies: Limitations, challenges and opportunities for improvement. *Agric. Econ., 34*, 207-219. https://doi.org/10.1111/j.1574-0864.2006.00119.x

Duflo, E., Kremer, M., & Robinson, J. (2008). How high are rates of return to fertilizer? Evidence from field experiments in Kenya. *The American Economic Review, 98*(2), 482-488. Retrieved from http://www.jstor.org/stable/29730068

Duflo, E., Kremer, M., & Robinson, J. (2011). Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya. *American Economic Review, 101*, 2350-2390. https://doi.org/10.1257/aer.101.6.2350

Endale, K. (2011). *Fertilizer consumption and agricultural productivity in Ethiopia* (No. 003). Retrieved from http://www.edri.org.et/Resources/Working_Papers/EDRI_WP003_Fertilizer_Consumption.pdf

Feleke, S., & Zegeye, T. (2006). Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy, 31*(5), 442-457. https://doi.org/10.1016/j.foodpol.2005.12.003

Haileslassie, A., Priess, J. A., Veldkamp, E., & Lesschen, J. P. (2007). Nutrient flows and balances at the field and farm scale: Exploring effects of land-use strategies and access to resources. *Agricultural Systems, 94*(2), 459-470. https://doi.org/10.1016/j.agsy.2006.11.013

Headey, D., Dereje, M., & Taffesse, A. S. (2014). Land Constraints and Agricultural Intensification in Ethiopia: A village-level analysis of high-potential areas. *Food Policy, 48*, 129-141. https://doi.org/10.1016/j.foodpol.2014.01.008

Jack, B. K. (2011). *Constraints on the adoption of agricultural technologies in developing countries*. White paper, Agricultural Technology Adoption Initiative, Boston: J-PAL (MIT) and Berkeley: CEGA (UC Berkeley).

Kafle, B. (2010). Determinants of adoption of improved maize varieties in developing countries. *Review. Inter. Res. J. Appl. Basic. Sci., 1*, 1-7.

Kassie, M., Shireraw, B., & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development, 39*(10), 1784-1795. https://doi.org/10.1016/j.worlddev.2011.04.023

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2013). Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. *Remote Sensing, 5*(5), 2411-2435. https://doi.org/10.3390/rs5052411

Legese, G., Langyituo, S. A., Mwangi, W., & Jaleta, M. (2009). *Household resource endowment and determinants of adoption of drought tolerant maize varieties: Double-hurdle approach* (pp. 1-22). Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22.

Lemenih, M., Karltun, E., & Olsson, M. (2005). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, Ecosystems & Environment, 105*(1), 373-386. https://doi.org/10.1016/j.agee.2004.01.046

Maddala, G. S. (1997). *Limited Dependent and Quantitative Variables in Econometrics*. Cambridge University Press.

Mengistu, K., & Bauer, S. (2011). Determinants of Manure and Fertilizer Applications in Eastern Highlands of Ethiopia. *Quarterly Journal of International Agriculture, 50*(3), 237-252.

Million, T. (2010). *Essay on contracts, Risk coping and Technology Adoption in Ethiopia* (PhD Thesis, p. 193). Department of Economic and Resource Management, Norwegian University of Life Science.

Molla, D. K. (2008). *Social networks and diffusion of agricultural technology: The case of sorghum in Metema Woreda, North Gondar, Ethiopia* (MSc thesis, p. 131). Rural Development and Agricultural Extension, Haramaya University, Haramaya, Ethiopia. Retrieved from https://cgspace.cgiar.org/handle/10568/645

Mucheru-Muna, M., Mugendi, D., Kung'u, J., Mugwe, J., & Bationo, A. (2007). Effects of organic and mineral fertilizer inputs on maize yield and soil chemical properties in a maize cropping system in Meru South District, Kenya. *Agro forestry Systems, 69*(3), 189-197. https://doi.org/10.1007/s10457-006-9027-4

Mugisha, J., & Diiro, G. (2010). Explaining the adoption of improved maize varieties and its effects on yields among smallholder maize farmers in eastern and central Uganda. *Middle-East Journal of Scientific Research, 5*(1), 6-13.

Negash, R. (2007). *Determinants of adoption of improved haricot bean production package in Alaba special Woreda, Southern Ethiopia* (MSc thesis, p. 137). Rural Development and Agricultural Extension, Haramaya University, Haramaya, Ethiopia. Retrieved from https://cgspace.cgiar.org/handle/10568/682

Nigussie, D., Mengistu, K., Haile, D., Wole, K., Tamiru, A., Olkaba, B., … Samuel, T. (2012). *Participatory Rural Appraisal for Gurawa, Haramaya, Kombolcha, and Habro Districts (Woredas) of East and West Hararghe Zones in Ethiopia*.

Ogada, M. J., Mwabu, G., & Muchai, D. (2014). Farm technology adoption in Kenya: A simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agricultural and Food Economics, 2*(1), 1. https://doi.org/10.1186/s40100-014-0012-3

Rao, P. N., & Debela, G. D. (2016). An Economic inquiry in to the Empirics of the Determinants of demand for technology: An Explorative research. *International Journal of Business Quantitative Economics and Applied Management Research, 3*(1), 15-23.

Spielman, D. J., Byerlee, D., Alemu, D., & Kelemework, D. (2010). Policies to promote cereal intensification in Ethiopia: The search for appropriate public and private roles. *Food Policy, 35*(3), 185-194. https://doi.org/10.1016/j.foodpol.2009.12.002

Suri, T. (2011). Selection and comparative advantage in technology Adoption. *Econometrica, 79*(1), 159-209. https://doi.org/10.3982/ECTA7749

Vanlauwe, B., Kihara, J., Chivenge, P., Pypers, P., Coe, R., & Six, J. (2011). Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant and Soil, 339*(1-2), 35-50. https://doi.org/10.1007/s11104-010-0462-7

Workneh, B. (2015). *Compost and Fertilizer - Alternatives or Complementary? Management Feasibility and Long-Term Effects on Soil Fertility in an Ethiopian Village* (Doctoral Thesis, p. 72). Department of Soil and Environment, Faculty of Natural Resources and Agricultural Sciences, Swedish University of Agricultural Sciences, Uppsala. Retrieved from http://pub.epsilon.slu.se/12825

Xu, Z., Burke, W. J., Jayne, T. S., & Govereh, J. (2009). Do input subsidy programs "crowed in" or "crowed out" commercial market development? Modelling fertilizer demand in a two-channel marketing system. *Agricultural Economics, 40*(1), 79-94. https://doi.org/10.1111/j.1574-0862.2008.00361.x

Yamano, T., & Arai, A. (2011). *Fertilizer policies, price, and application in East Africa. In Emerging Development of Agriculture in East Africa* (pp. 39-57). Springer Netherlands. https://doi.org/10.1007/978-94-007-1201-0_3

Notes

Note 1. *Kebele* is the smallest administrative units in Ethiopia.

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