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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Determinants and profitability of inorganic fertilizer use in smallholder maize production in Ethiopia

Mideksa Dabessa Iticha^{1*}, Moti Jaleta² and Fikadu Mitiku³

Abstract: Inorganic fertilizer is one of the key technologies that could enhance crop productivity. However, farmers are still using lower than the recommended rates and yet there are a lot of farmers who are not using fertilizers at all. In this study, we analyze determinants and profitability of fertilizer use using a survey data collected from 174 randomly selected maize producers in NonoBenja District, Ethiopia. The data were analyzed using descriptive statistics, Heckman's two-stage model, net profit analysis, and Kendall's coefficient of concordance. Results show that the sampled respondents on average applied 142.8 kg/ha inorganic fertilizer (NPS+Urea) which is only 71.5% of the recommended rate. Age of household head, farm income, and use of input credit affected the probability of fertilizer use positively. Education level of household head, livestock holding and frequency of contact with extension agent positively influenced both the probability and intensity of fertilizer use whereas perception on cost of production influenced both the use and intensity of use negatively. Off-farm income positively influenced the intensity of fertilizer use. Farmers applying the recommended and above the recommended rates of inorganic fertilizer in maize production were more profitable than those applying lower than the recommended rates. Results imply that smallholders



Mideksa Dabessa Iticha

ABOUT THE AUTHOR

Mideksa Dabessa joined the research system in Ethiopia in 2016. Since then, he has served as researcher and lecturer with capabilities. He has worked as Agricultural expert from 2009 to 2016 in the Ethiopia and then he join University. He did his MSc on the determinants and Profitability of inorganic fertilizer use in maize production in Ethiopia. This particular manuscript is one output of his MSc research project. His involvement and significant contribution resulted in capacity building and research specially adoption of agricultural new technologies (mainly common inorganic fertilizer, soybean, and improved forage). He also authored several publications in journal articles and review proceedings. Mideksa has been awarded for such outstanding accomplishment. Currently, he is served as lecture and researcher at Ambo University, Ethiopia.

PUBLIC INTEREST STATEMENT

Oromia region in Ethiopia is endowed with diverse agro-ecologies that are suitable for different farming systems found in the region. Mixed crop-livestock production is the typical farming system in Oromia region of Ethiopia. Maize is the main crop produced through the country. Inorganic fertilizer use in Maize production among the cereal crop is adapted by farmers in Nono Benja District of Oromia region in Ethiopia. However, despite importance of inorganic fertilizer use in improving the soil fertility through nutrient balancing and increasing yield, only very limited research and development efforts have been made to improve its use and intensity of use in Ethiopia particularly in Nono Benja District. Ascertaining constraints along the use and intensity use of inorganic fertilizer is important not only to use it as baseline information to setting up recommended national inorganic fertilizer use in maize production improvement programs, but also it ensures farmers profitability.

should be encouraged to use and enhance their use intensity of inorganic fertilizer in maize production for better productivity and profitability.

Subjects: Agriculture & Environmental Sciences; Soil Sciences; Food Chemistry

Keywords: Inorganic fertilizer; maize; profitability; smallholder farmers; survey

1. Background

Poor agricultural productivity is one of the main challenges to achieve food security and to reduce poverty in Sub-Saharan Africa and particularly in Ethiopia. Considering the fact that soil fertility is one of the biggest challenges, an obvious strategy is to increase inorganic fertilizer application at recommended level and to promote good agronomic practices to enhance productivity (Rashid et al., 2014). Although maize is one of the most productive crops in Ethiopia, it is not playing the expected potential role in ensuring food security due to various factors like poor soil fertility (lack of nutrient), low external input use and poor agronomic management (Abdulkadir et al., 2017).

In general, land degradation due to up slope cultivation, deforestation, flooding, soil acidity, and limited use of technologies are some of the major factors slowing agricultural productivity in Ethiopia. Low agricultural productivity combined with highly increasing population would put Ethiopia under a series challenge of food security. To tackle this and associated challenges, the government of Ethiopia put enhancing and sustaining agricultural productivity at the center of Ethiopia's development strategies. The country has consistently allocated more than 10% of its public spending on the agricultural sector (Mogues et al., 2008). In addition, more public spending was invested heavily in rural infrastructure and agricultural intensification with special attention to the extension services and fertilizer use (Byerlee et al., 2007; Mogues et al., 2008).

Despite the unreserved efforts of the Ethiopian government and other development organizations supporting agricultural transformation in the country, agricultural productivity growth remains low and majority of smallholder farmers practice low-input low-output production systems. Use of yield enhancing purchased inputs like fertilizer is very low (Fufa & Hassan, 2006). Studies show that only 30–40% of Ethiopian farmers use fertilizer and those who do use apply on average only 37–40 kg/ha(NPS+Urea), which is below the recommended rate (Hailu, 2016; Spielman et al., 2013). However, it is generally agreed that optimum use of fertilizer at farm level have the tendency of improving soil fertility leading to rise in agricultural productivity and the profitability of a given technology (Abubakar, 2014).

Improving productivity and profitability of smallholder farming is the main pathway out of poverty in using agriculture technology (World Bank, 2008). Improved agricultural productivity for smallholders can reduce poverty and improve household welfare (Abraham et al., 2014). However, in Ethiopia increased fertilizer prices and the concomitant decrease in output prices have been the most important factors associated with use of fertilizer (Fufa & Hassan, 2006).

In Ethiopia, majority of fertilizer is used for cereals production, mainly teff, maize, wheat, barley and sorghum. According to CSA (2015) estimates, 90% of fertilizers were applied to those first three major cereal crops. Teff holds the largest share in fertilizer use among the cereals (32%), maize (29%), and wheat (25%).

Several studies have been conducted to explain factors affecting the adoption and intensity of fertilizer use in Ethiopia at different places and times by using different models (e.g., Beshir et al., 2012; Ketema & Kebede, 2017; Negera & Bashargo, 2014; Yirga & Hassan, 2013). However, the currently available knowledge about the low adoption and low intensity of fertilizer use is not sufficient due the fact that the determinants are different from place to place. Also, previous studies could not show the relationship among use and intensity of fertilizer use in crop and its

profitability (Ketema & Kebede, 2017). This paper extended to fill this gap. NonoBenja is known for maize dominated cropping system, with heterogeneous farming community to get sample households with and without fertilizer use. This study is, therefore, aimed at assessing the determinants and profitability of fertilizer use in maize production among the smallholder maize farmers in NonoBenja district.

The remaining sections are structured as follows. Section 2 presents methodology including sampling procedures and method of data analysis. Results are presented and discussed in section 3, and section 4 presents conclusion and policy implications.

2. Methodology

2.1. Description of the study area

This study was conducted in NonoBenja district, Jimma zone, Oromia region, in Ethiopia. The district is located 156 km North of Jimma town and 263 km South West of Addis Ababa. The district experienced minimum and maximum mean temperatures of 14°C and 30°C yearly, respectively, and relative humidity between 80% and 90% that falls to about 40% in the dry season. The rainfall pattern is unimodal and it ranges from 780 to 2000 mm. The soil of the district was fine-textured heavy and loamy soil type with a pH of 6.0. Based on CSA (CSA (Central Statistical Agency), 2013), the total household of the district was 9909 (9641 male-headed and 268 female-headed). The economic base of the residents is mixed farming. Individual smallholder farmers are the sole and dominant production units. The agricultural sector is highly dependent on rain-fed cropping system.

2.2. Sampling methods and procedures

A two-stage sampling technique was used to select sample respondents. First, by considering maize production uniformity in all kebeles of the district and taking into consideration the time, budget and human resource necessary for the study, from the total of 19 rural kebeles, 4 kebeles namely; Abiyu Gibe, Wayu, Gurifat, and Ilu were randomly selected. In the second stage, a list of all smallholder maize farmers in the four kebeles were obtained and stratified into users and non-users of fertilizer in maize production. Then, 174 households (114 users and 60 non-users of inorganic fertilizer in maize production) were randomly selected from total 1899 households in these sampled kebeles in the district.

2.3. Data sources and methods of data collection

Both quantitative and qualitative data were collected from primary and secondary sources. The primary data were collected through structured interview schedule, focus group discussion and key informant interview. The quantitative data were collected using structured questionnaire implemented by trained enumerators who could speak the local language. The questionnaire was pre-tested on 20 similar farmers with the sampled household, but who were not included in the final survey. Finally, the questionnaire was translated from English to *AfaanOromoo* (local language of the study area) and implemented. Additional primary data were collected from key informants including district administrative bodies, experts from agricultural offices and cooperative offices; as well as from four focus groups (one from each kebele), each consisting of eight farmers. Secondary data were collected from published and unpublished materials.

2.4. Econometric model

In non-experimental data, where samples are selected randomly after the population in the sampling frame made their own decisions to participate in a program or not (i.e., self-selected themselves to participate or not), one cannot rule out self-selection bias of the program participants in the estimations to be made using these data. Thus, we use Heckman's selection model to control for the selection bias problem. According to Heckman (1979), sample selection bias may arise in practice for two reasons: first, there may be self-selection by an individual or data units being investigated; second, sample selection decision by analysts or data processors is much the same fashion as self-selection. In this study due to the first reason, we are forced to use

Heckman’s two-stage model. Some adoption studies in Ethiopia and East Africa used the Heckman’s selection model to identify the probability and intensity of different agricultural technologies in different locations (Atupokile, 2016; Jaleta et al., 2013; Yirga & Hassan, 2013).

Heckman’s selection model follows two step estimation procedure where in the first stage, an “adoption equation”, attempts to capture factors affecting the adoption decision and Inverse Mill’s Ratio (IMR) is obtained. In the second stage, the intensity of adoption is estimated using the IMR as one of the explanatory variables to correct for selection bias. The probability of adoption was estimated using Maximum Likelihood Probit model, from which the IMR was computed to control for self-selection bias into adoption. The specification for Heckman’s two-step model is stated as follows:

The adoption equation: The Probit model is specified as:

$$y_i^* = \beta_i X_i + \varepsilon_i$$

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where y_i^* is the latent dependent variable which is not observed and y_i is a binary variable that assumes 1 if the i^{th} household used chemical fertilizer, and 0 otherwise. β_i is a vector of unknown parameters to be estimated in adoption equation, X_i is a vector of explanatory variables in the probit regression model, and ε_i is a random error term that is assumed to be independently and normally distributed with zero mean and constant variance. From the adoption equation, λ_i (λ_i), which is the conditional probability that an individual household decides to adopt (given a set of independent variables), is determined by the formula.

$$\lambda_i = \frac{f(X_i\beta)}{1 - F(X_i\beta)} \exp\left[-\frac{f(X_i\beta)}{1 - F(X_i\beta)}\right] \quad (2)$$

where λ_i is the Inverse Mill’s Ratio (IMR), $f(X\beta)$ is the standard normal probability density function and $F(X\beta)$ is the cumulative distribution function for a standard normal random variable. Then, λ_i is used in the outcome equation to account for the potential self-selection bias.

The intensity equation (OLS Regression): Outcome model is specified as:

$$Y_i = \alpha Z_i + \mu \lambda_i + \eta_i \quad (3)$$

where Y_i is the intensity of fertilizer use, α_i is a vector of unknown parameters to be estimated in the intensity of fertilizer use equation, Z_i is a vector of explanatory variables determining the intensity of fertilizer use, μ is the parameter that helps to test whether there is a self-selection bias in the use of fertilizer, λ_i is the IMR and η_i is the error term.

Before running the Heckman’s model, all the hypothesized explanatory variables were checked for the existence of multicollinearity problem. There are two methods that are often suggested to test the existence of multicollinearity: Variance Inflation Factor (VIF) for association among the continuous explanatory variables and Contingency Coefficients (CC) for dummy variables. Following Maddala (1992) and Gujarati (1995), both VIF and CC were applied to the multicollinearity test and no problem was identified for the variables used in the model.

2.5. Definition of variables

2.5.1. Dependent variable

The dependent variables in this study are “inorganic fertilizer” use, which is a dummy variable, and “intensity of fertilizer” use, which is a continuous variable. For the continuous dependent variable, the values potentially range between 0 and 200 kg/ha, i.e., the maximum recommended fertilizer

Table 1. Explanatory variables and their expected sign along with references

Variables	Type/Unit	Description	Expected sign	References
AGEHH	continuous (Year)	Age of Household head	-	Debebe, 2016
SEXHH	Dummy	Sex of household head (1 = male&0 = Female)	+	Mesfin, 2005; Taha, 2007
ADLE	Discrete (number)	Number of adult equivalent labor within household	+	Abrha, 2015
EDLHH	Continuous (year)	Education level of household head	+	Yirga & Hassan, 2013
FMTCMH	Continuous (birr)	The income household head obtain from their farm	+	Negera & Bashargo, 2014
OFFINC	Continuous (birr)	The off-farm income obtained by household head	+	Beshir et al., 2012
PRPIO	Categorized(in degree of feeling)	The perception of household head on input-out price (1 = low 2 = high)	-	Fufa & Hassan, 2006
FARMS	Continuous (ha)	Total land hold & contract for crop by household head	+	Hedeto, 2011
LVSH	Continuous(TLU)	Total livestock hold by household head	+	Yirga & Hassan, 2013
USCP	Dummy	Application of compost on crop land (1 = yes; 0 = no)	-	Tedla, 2011
FCWEA	Continues(day/mo)	Number of days/month extension agent contacts	+	Milkias & Abdulahi, 2018
UITCRD	Dummy	Use of credit by household head (1 = yes; 0 = no)	+	Ketema & Bauer, 2011
DFIM	Continuous(hour)	Distance household walks from house to input market.	-	Negera & Bashargo, 2014
MCPS	Dummy	Being the member of cooperative (1 = yes; 0 = no)	+	Ketema & Kebede, 2017

use in maize production in the study area, 100 kg NPS (nitrogen (N) phosphorus (P) sulfur (S) fertilizer), and 100 kg Urea per ha. In this study, user/adopter is defined as smallholder maize producer who applied any amount of chemical fertilizer component in maize production during the survey period. Intensity of adoption refers to index indicating farmer's level/extent of fertilizer use in maize production at the period of the survey.

Non-adopter is defined as a farmer who did not use any amount of inorganic fertilizer component in maize production during the survey period. For multiple practices, there are two options of measuring adoption; (i) adoption index: measures the extent of adoption at the time of the survey or (ii) adoption quotient: measures the degree or extent of use with reference without taking time into consideration. In this study, the first option was employed. Accordingly, adoption index which shows to what extent the respondent farmer has adopted the whole set of packages was calculated by employing the formula following:

$$AI = \left(\frac{e_1}{p_1} + \frac{e_2}{p_2} \right) * 100 \quad (4)$$

where e_1 is the extent of NPS use,

e_2 is the extent of Urea use, p_1 and p_2 are the potential (recommended) doses of NPS and Urea, respectively.

In the first stage of the Heckman's selection model, a dichotomous household level fertilizer use in maize production (1 for users and 0 for non-users) is used in estimating the probability of fertilizer adoption. In the second stage, household level intensity of fertilizer use in maize production is used as a dependent variable in the OLS regression.

2.5.2. Independent variables

Depending on different literature on use and intensity of use of improved agricultural technologies, key explanatory variables that are expected to determine the use and intensity of fertilizer use in maize production at study area are summarized in [Table 1](#).

2.6. Estimating profitability of mineral fertilizer use in maize production

Following earlier studies assessed the profitability of technology use in cereal production (Gedefa, 2016; Takele, 2010)) we adopted net profit analysis method where all inputs and expenses required to produce the specific crop (in our case, maize) were considered and costs are estimated based on market prices. The unit of analysis is a hectare of crop land. Revenue from crop production is obtained using market prices and actual crop production data collected for each surveyed plot. Net profit is given as:

$$NetProfit = TR - TC = PQ - \sum_i^N w_i X_i \quad (5)$$

Where TR and TC are total revenue and total cost per ha, respectively, P is farm-gate price of maize (Birr/kg),¹ Q is household level average maize productivity (kg/ha), w_i and X_i are the unit price and amount of input i used in maize production, respectively.

2.7. Determining constraint rankings

The main constraints hindering the use and intensity of fertilizer use in maize production at the study area were identified and grouped into 12 categories through focus group discussion. Following farmers' ranking in terms of their importance as a challenge in intensifying maize production, the constraints were arranged from severe to mild constraint: high cost of fertilizer, lack of credit service, high interest rate on credit, low return on fertilizer use, lack of uniform rain fall distribution, perception of having fertile land, absence of choice packaging amount, inefficient distribution of fertilizer, distance of residence from fertilizer marketing, late arrival of fertilizer, poor quality of fertilizer, and lack of knowledge on fertilizer.

Table 2. Households' characteristics by use of fertilizer (for continuous variables)

Variables	User(N = 114)		Non-user(N = 60)		t-value	Total sample(N = 174)	
	Mean	Std. D	Mean	Std. D		Mean	Std.D
Age of household	44.05	6.664	45.204	5.854	-1.124	44.454	6.405
Education level	2.053	1.823	0.752	1.145	5.033***	1.632	1.734
Adult equivalent ²	5.184	1.331	5.174	1.343	0.0430	5.175	1.332
Farm size (ha)	3.641	2.051	3.113	1.314	1.834*	3.463	1.844
Livestock (TLU) ¹	7.482	3.183	4.601	2.242	6.253***	6.504	3.233
Farmincome (Birryear ⁻¹)	10,130	5899.8	3682.8	3389	7.872***	7907.29	6008
Off-farm income (Birryear ⁻¹)	1894.6	2814.5	114.1	383.3	4.871***	1280.61	2438.15
Extension/Frequency per month)	2.051	1.034	1.023	1.151	6.013***	1.743	1.181
Distance from market (hour)	1.101	0.442	1.234	0.728	-1.434	1.154	0.563

*** and *significant at 1% and 10% respectively.

¹Tropical Livestock Unit (TLU) is calculated based on Storck et al., (1991).

²Adult equivalent is calculated based on Storck et al., (1991).

Table 3. Households' characteristics by use of fertilizer (for dummy explanatory variables)

Variables	Non-user		User		χ ²	Total sample	
	N	%	N	%		N	%
Perception on cost of production	3	5	31	27.212	23.291***	34	19.513
	57	95	83	72.831		140	80.534
Use of compost	11	18.33	14	12.332	2.662	25	14.432
	49	81.67	100	87.713		149	85.621
Member of cooperative	21	35	51	44.741	1.531	72	41.431
	39	65	63	55.261		102	58.631
Use of credit	4	6.7	53	46.631	28.301***	65	37.412
	56	93.312	61	53.434		109	62.612

***Significant at 1% level

Table 4. Parameter estimates of Heckman's two steps for the likelihood of fertilizer use in maize production (Probit estimation) and its marginal effect

Variables	Coef.	Std. Err.	t-ratio	Marginal effect
Age of household head	0.103	0.063	1.68*	0.005
Sex of household head	0.226	1.257	0.18	0.011
Education level of household head	0.801	0.214	3.74***	0.040
Adult equivalent labor	-0.021	0.256	-0.08	-0.001
Farm size holding	-0.228	0.169	-1.35	-0.011
Livestock holding	0.517	0.185	2.79***	0.026
Farm income	0.001	0.008	2.53**	9.68e-06
Perception on input-output price	-1.122	0.402	-2.79***	-0.056
Off-farm income	0.000	0.001	0.42	5.61e-06
Use of compost	0.054	0.688	0.08	0.003
Frequency of contact with extension agent	0.893	0.323	2.77***	0.044
Member of cooperative	-0.702	0.754	-0.93	-0.035
Distance to input market	-0.582	0.483	-1.20	-0.029
Use of input credit	2.094	0.855	2.45**	0.105
Constant	-5.259	3.611	-1.46	
Number of obs = 174 Wald chi2(13) = 138.32 Prob > chi2 = 0.0000				

***, ** and* shows the values of statistically significant at 1%, 5%, and 10 level of significance respectively.

Table 5. Parameter estimates of Heckman’s two step for intensity of fertilizer use in maize production (kg/ha) (OLS estimation)

Variables	Coef.	Std. Err.	t-ratio
Sex of household head	0.906	7.400	0.12
Education level of household head	4.941	0.888	5.56***
Adult equivalent labor	-1.090	1.909	-0.57
Farm size holding	1.968	1.206	1.63
Livestock holding	1.876	0.784	2.39**
Farm income	0.000	0.001	0.92
Perception on input-output price	-7.353	2.385	-3.08***
Off-farm income	0.002	0.001	1.97**
Use of compost	-2.069	6.606	-0.31
Frequency of contact with extension agent	6.483	1.272	5.10***
Member of cooperative	-5.521	5.146	-1.07
Distance from input market	2.079	4.992	0.42
Use of input credit	7.019	4.537	1.55
Constant	112.407	15.722	7.15***
Inverse mill ratio (Lambda)	16.513	7.795	2.12**

Number of obs. = 174 Wald chi2(14) = 138.32 Prob > chi2 = 0.0000
 Censored obs. = 60 Uncensored obs. = 114

***and ** show the values of statistically significant at 1% and 5% level of significance respectively.

This subsection used the Kendall’s Coefficient of Concordance (W) in determining whether there is an agreement in the respondents’ ranking of the constraints associated with the use and intensity of fertilizer use among the maize-growing smallholder farmers in the study area. Following Salaam (2016), the Kendall’s Coefficient of Concordance (W) analysis is statistical technique that is used to rank a given set of identified constraints from the most critical to the least critical one and measures the degree of agreement between these constraints. The constraint with the least sum score or mean is ranked as the most critical while the one with the highest sum score or mean is ranked as the least critical. The formula for Kendall’s Coefficient of Concordance was used to test the degree of agreement among smallholder maize farmers on the constraints identified. The formula is specified as follows:

$$W = 12 \frac{[\sum T^2 - (\sum T^2)/n]n}{nm^2(n^2 - 1)} \tag{6}$$

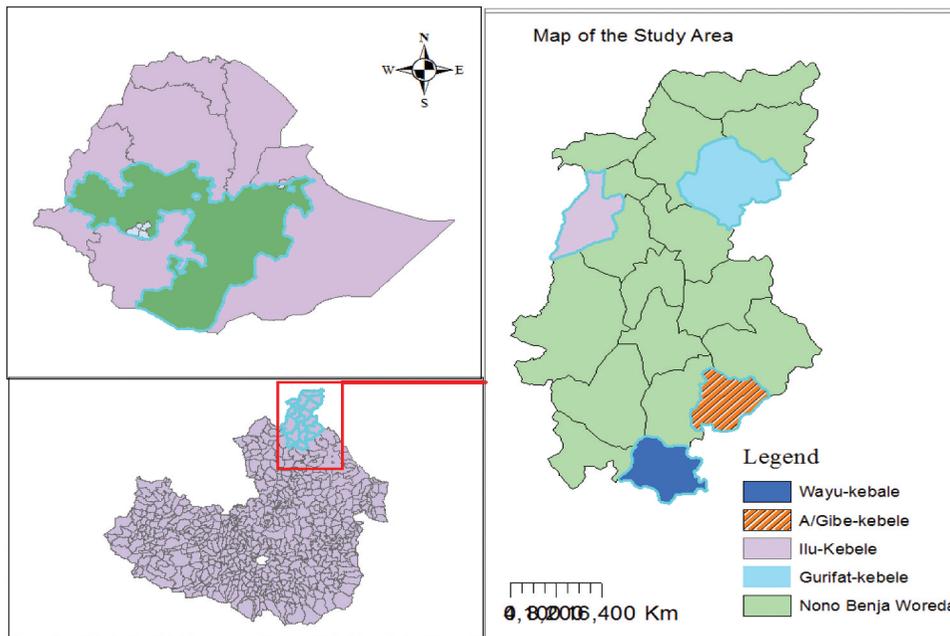
Where, W is Kendall’s Coefficient of Concordance, T is the sum of ranks for constraints being ranked, m is the total number of respondents, n is the total number of constraints being ranked (Anang et al., 2011).

Hypothesis Testing for Kendall’s Coefficient of Concordance:

H_0 : There is no significant agreement between the rankings of constraints of use and intensity of fertilizer use among smallholder maize farmers in the study area [Figure 1](#).

Figure 1. Map of study area.

Source: Adopted from GIS



H_1 : There is a significant agreement between the rankings of constraints of use and intensity of fertilizer use among smallholder maize farmers in the study area.

3. Results and discussion

3.1. Descriptive results

Table 2 presents the results of descriptive statistics and compares the inorganic fertilizer users and non-users based on different factors. Accordingly, about 87.4% of the sample households were male headed. More than 67% and 54.5% of the male and female headed households, respectively, were chemical fertilizer users. The sample households on average utilized 82.8 kg/ha of NPS and 60.1 kg/ha of Urea in maize production. The result indicated that fertilizer application in maize production in general falls below the recommended rate. The result of this study is in line with the findings of Ketema and Kebede (2017).

The overall average age and education of the sample respondents were 44.5 and 1.6 years, respectively. There is no significant difference between the mean age of non-users (45.2 years) and users (44.1 years) whereas users were more educated than the non-users (i.e., 2.1 and 0.8 years of schooling, respectively). The average family size was 5.2 in adult equivalent, which is equal for users and non-users (Table 2).

The average farm size and livestock holding of the respondents were 3.46 ha and 6.5 TLU (Tropical Livestock Unit) respectively. Users hold significantly larger farm size (3.64 ha) than non-users (3.11 ha). Similarly, users hold large number of livestock (7.5TLU) than non-users (4.6TLU). The average annual farm and off-farm income were 7,907.3 and 1,280.6 Birr per household, respectively. The mean farm income was larger for users (10,130.7 Birr) than that of the non-users (3,682.8 Birr). Likewise, the average off-farm income was also larger for users (1,894.58 Birr) than for the non-user (114.08 Birr). The average frequency of contacts with extension agents was 1.7 days per month during production season. Users contacted extension agents more frequently (2.05 days per month) than non-users who contacted extension agents for only 1.02 days per

Table 6. Gross margin analysis of fertilizer use in maize production

Items	Plots with Fertilizer (N = 114)		Plots without Fertilizer (N = 60)		Mean Difference
	Mean	Std.Dev	Mean	Std.Dev	
(A) Revenue					
Maize yield (t/ha)	2.91	0.844	1.20	0.544	1.708*
Price of maize (Birr/ton)	4973.15	0.220	4973.15	0.22	
Revenue from maize (Birr/ha)	14,471.87	0.401	596.78	0.302	13,875.09***
(A) Costs					
Seed cost (Birr/ha)	863.31	0.135	349.44	0.230	513.87***
NPS Fertilizer use (kg/ha)	82.85	0.152	0	0	82.85***
UREA fertilizer use (kg/ha)	60.08	0.307	0	0	60.08***
Cost of fertilizer (Birr/ha)	1823.61	0.473	0	0	1823.61***
Total labor cost (Birr/ha)	4196.14	0.273	2976.86	0.526	1219.28***
Total animal draft power cost	2105.09	0.115	1953.40	0.050	151.69***
Cost of pesticide (Birr/ha)	446.40	0.827	0	0	446.40***
Cost of interest on capital (Birr/ha)	1319.72	0.309	0	0	1319.72***
Total Variable cost (Birr/ha)	10,754.27	0.612	5279.71	0.431	5474.56***
Total land cost (Birr/ha)	1500.65	0.105	1500.65	0.105	0
Total cost (Birr/Ha)	12,254.92	0.120	6780.36	0.895	5474.56***
Return to land	1.5		-4.120		
Return to labor	0.533		-0.0340		

***Significant at 1%. The following market prices were used to estimate revenue and costs: Maize grain (4973.15Birr/ton), Maize seed(46.174Birr/kg)NPS(14.412Birr/kg, Urea(10.479Birr/kg).

month. On the average, a farmer walks 1.15 hours to reach the nearest market which is 1.1 hours for users and 1.23 hours for non-users with no statistically significant difference (Table 2).

Ninety-five percent of the non-users and 72.8% of the users had perceived that the cost of maize production was high. The chi-square (χ^2) test indicated that there was statistically significant difference in perception on cost of maize production among fertilizer users and non-users at 1% level (Table 3).

Table 3 shows that only 14.37% of the total respondents prepared and applied compost to their farmland. Slightly more proportion of non-users (18.33%) prepared and applied compost than the fertilizer users (12.3%), but the difference was not statistically significant. It is better if the users and non-users are prepared and apply compost in maize production. About 40% of the sample respondents were member of any form of cooperative. Only 35% of the non-users and 44.74% of

Table 7. Rankings of constraints of use and intensity of fertilizer use

Constraints	Mean Rank	Overall rank
High cost of fertilizer	1.41	1 st
Lack of credit for input use	2.36	2 nd
High interest rate on credit	3.79	3 rd
Low return on fertilizer use	5.24	4 th
lack of uniform rain fall distribution	5.29	5 th
Perception of having fertile land	6.81	6 th
Absence of choice packaging amount	6.84	7 th
Inefficient fertilizer distribution	7.94	8 th
Distance of fertilizer marketing	8.45	9 th
Late arrival of fertilizer	8.89	10 th
Poor quality of fertilizer	10.34	11 th
Lack of knowledge on fertilizer use	10.64	12 th

users were members of a cooperative without any significant difference between the two categories. About 62.6% of the respondents did not use credit for agricultural production. Only 6.7% of the non-users and 46.6% the users used input credit. The chi-square (χ^2) test shows statistically significant association between using input credit and using inorganic fertilizer at 1% level (Table 3).

3.2. Estimation results

3.2.1. Determinants of inorganic fertilizer use in maize production

Table 4 presents the estimation results of the Heckman's selection model for the factors affecting household's inorganic fertilizer use in maize production. Results show that age of the household head was found to be positive and significantly ($p < 0.093$) influenced the probability of adopting fertilizer. The result indicates that, as the average age of the household head increases by one more year, the probability of using fertilizer in maize production increases by 0.5%. Older farmers might gain knowledge and experience of input use. Moreover, older farmers may accumulate more wealth than younger and so older ones may still be intensive fertilizer users even as they grow older. The result of this study was consistent with the findings by Beshir et al. (2012) and Debebe (2016).

Education level of household head was found to be positively and significantly influencing the probability of fertilizer use in maize production at 1% ($P < 0.000$) level. The result indicated that the increase in the number of years of formal schooling of the household head by one more schooling year would lead to increase in the probability of fertilizer use in maize production by 4.01%. This implies that, education improves the ability to use information, process and interpret about agricultural technology. Our finding is consistent with the findings in Negera and Bashargo (2014).

Livestock holding was found to be positively influencing (at 1% $P < 0.005$) the probability to use fertilizer. The result shows that, as livestock holding increases by a TLU, the probability that a farmer uses fertilizer in maize production increases by 2.6%. This implies that as the number of livestock increases smallholder farmers usually become more wealthy and able to purchase fertilizer. The study is consistent with the findings of Ketema and Bauer (2011) and Yirga and Hassan (2013).

Farm income has positive and significant influence on the use of fertilizer in maize production. Accordingly, an increase in 1000 Birr of farm income leads to a 1% increase in the probability of fertilizer use in maize production. The result of the study implies that smallholder farmers who got income from their annual agricultural production could invest some proportion of the income to buy fertilizer as well as to purchase other agricultural inputs. The result of this study is consistent with findings of Ketema and Kebede (2017).

Perception on cost of production had a negative and statistically significant, at 1% ($P < 0.005$) level, effect on households' use of fertilizer. The result implies that, the more the farmers perceive that cost of production is high, is the less likely they use fertilizer in maize production. The result of this study was consistent with the findings of Fufa and Hassan (2006).

Frequency of contact with extension agents has a positive and statistically significant, at 1% ($P < 0.006$) level, influence on the likelihood of farmers' fertilizer use in maize production. The result revealed that, as frequency of household head's contact with extension agent increases by a day per month, the probability of using fertilizer in maize production increases by 4.4%. This result implies that contacting extension agents frequently could enhance farmers' exposure to new and improved technologies and practices in crop production, and also increases acquiring updated information on the agricultural technologies. A result in this study is consistent with finding of Derso et al. (2016).

Use of input credit has a positive and statistically significant influence, at 5% ($P < 0.014$) level, on the probability of farmer's fertilizer use in maize production. The result indicated that farmers who used input credit have higher probability of fertilizer use in maize production by 10.5%. The result implies that credit is key in relieving capital constraints faced by smallholder farmers. This result was consistent with the findings by Ketema and Bauer (2011) and Jaleta et al. (2013).

3.2.2. Determinants of intensity of inorganic fertilizer use in maize production

The parameter estimates of Heckman's two-step models for intensity of fertilizer use in maize production are given in Table 5. Results show that six variables were found to be significant determinants of the intensity of fertilizer use by households in maize production.

Inverse mill ratio: According to the model output, inverse mill ratio (Λ) for the intensity of fertilizer use was significant, at 5% ($P < 0.034$) level, indicating that selection bias would have affected the intensity of fertilizer use had it been calculated without taking into account the decision to use fertilizer. Hence, this justifies the relevance of using Heckman's two-step procedure. The positive sign suggests that the error terms in the adoption equation and intensity of adoption are positively correlated. This shows that those unobserved factors that determine households' use of fertilizer in maize production are likely to be positively associated with household intensity of fertilizer use in maize production.

Education level of household head: It had a positive and statistically significant, at 1% level ($P < 0.000$), effect on intensity of fertilizer use by households in maize production. The coefficient of variable shows that as the household head gets one more year of formal education, the intensity of fertilizer use in maize production increases by 4.94 kg, keeping other variables constant. This presumably arises from a better understanding of the usefulness of fertilizers and it may also imply better crop management. The result of this study is in harmony with the findings of Tedla (2011) and Yirga and Hassan (2013).

Livestock holding: It had a positive and statistically significant, at 5% level ($P < 0.017$), influence on intensity of fertilizer use by households in maize production. The coefficient of the variable shows that as the household head's livestock holding increases by one TLU, the intensity of fertilizer use in maize production increases by 1.87 kg, keeping other variables constant. This implies that, households with larger livestock holding may have the opportunity to get financial ability by selling their livestock. The result of this study was consistent with the finding of Ketema and Kebede (2017).

Perception on cost of production: It is shown that it has negative and statistically significant, at 1% level ($P < 0.002$), effect on intensity of fertilizer use in maize production. The negative relationship indicated that the more a household perceives the cost of production is high, the less amount of fertilizer it uses in maize production. This result is in line with the findings of Muthyalu (2013).

Off-farm income: It has positive and statistically significant, at 5% level ($P < 0.049$), influence on intensity of fertilizer use in maize production. The coefficient of the variable indicated that as the average income a household earns from off-farm activities increases by 1Birr, the intensity of fertilizer use in maize production increases by 0.002 kg, keeping other variables constant. Cash generated from off-farm activities increase the farmers' liquidity to purchase yield enhancing agricultural technologies. The result is consistent with the findings in Beshir et al. (2012).

Frequency of contact with extension agent: This variable has a positive and statistically significant, at 1% ($P < 0.000$) level, influence on the intensity of fertilizer use in maize production. The coefficient of the variable indicated that as the frequency of extension agent contact with the head of household increases by one more day per month the intensity of fertilizer use in maize production increases by 6.5 kg, keeping other variables constant. The result implies that frequency of contact with extension agent for technical advice and information enhances the intensity of fertilizer use in maize production. The result of the study is in line with the finding by Yirga and Hassan (2013).

3.3. Profitability of inorganic fertilizer use in maize production

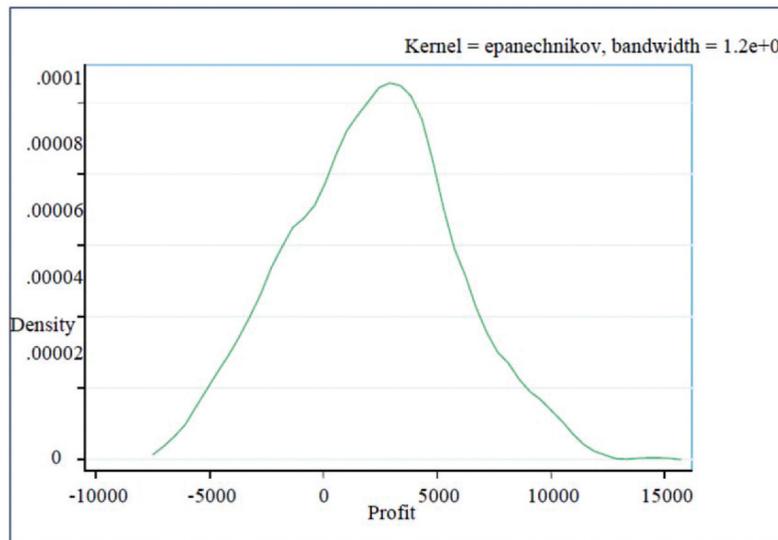
Table 6 presents the results of Gross income from maize production, cost of maize production, and net profit from using inorganic fertilizer. The result shows that the average maize yield for fertilizer users was 2.9 ton/ha and the average gross income generated by these farmers was 14,471.87 Birr/ha. This average maize productivity is below the national average for the same year, i.e., 3.66 ton/ha (CSA, 2016/2017). The results also indicated that the average total cost per hectare used for maize production was 12,254.92 Birr/ha. Labor cost (wage value of labor) accounts for the highest share of the total cost (34.3%) followed by material input cost (22%) and animal draft power cost (17.2%). Opportunity cost of land takes the least share (12.1%) of the total cost and other costs account for 14.4% of the total cost of production. The finding reveals that the total revenue earned by the sample respondents who use inorganic fertilizer in maize production was 14,471.87 Birr/ha whereas their total cost incurred for maize production was 12,254.92 Birr/ha. Therefore, after covering all the costs incurred in maize production, the average net profit of inorganic fertilizer use was 2,216.95Birr/ha. This result implies that the use of fertilizer in maize production in study area was profitable. In the study area, even though the existing maize productivity and price level makes the use of fertilizer in maize production profitable, the net profit obtained by sampled producers was low.

On the other hand, Figure 2 gives the Kernel density estimates of the distribution of inorganic fertilizer user respondents by their respective profit per ha of maize produced. The figures indicate that most of the user respondents were profitable and distributed at the profit area and some farmers were more profitable from fertilizer use in maize production. This might be due to high productivity achieved by those farmers relative to others. Although farmers on average make positive profit, fertilizer use is not always reflecting a profit as some considerable farmers are still making some loss in maize production. Therefore, the low or negative profit arises due to improper use of inputs like fertilizer and improved seed, poor agronomic practice, and low price of maize grain.

In Table 6, the average maize productivity without using fertilizer was 1.2ton/ha and the average gross income generated from this was 5,967.78 Birr/ha. This shows that low productivity of maize without fertilizer use implies a negative profit (-3,807.78Birr/ha).

Figure 2. Kernel density estimate of distribution of respondents by their respective profit.

Note: Kendall's W = 0.680, M = 174, n = 12, $\chi^2 = 1301.109$, Asympt.sign = 0.000, df = 11



3.4. Ranking constraints in fertilizer use

Table 7 presents the result of the Kendall's coefficient of concordance, which was 0.680 (68%). Hence, the result shows that the respondents were in agreement with each other on the ranking of the constraints in the study area. Thus, we rejected the null hypothesis (H_0), which states that there was no agreement among the respondents over the ranking of the constraints of use and intensity of fertilizer use. Hence, H_1 was accepted and there was agreement among the respondents on the ranking of the constraints. Therefore, the main constraints put into the following orders based on the identification and rankings by the sampled respondents.

High cost of fertilizer was ranked at first and found to be the most important constraint to use and intensity fertilizer use in maize production followed by lack of credit, high interest rate on credit, lack of return on fertilizer use, lack of uniform rainfall distribution, perception of having fertile land, absence of choice of packaging amount; inefficient fertilizer distribution, distance of fertilizer marketing from residence, late arrival of fertilizer, poor quality of fertilizer and lack of knowledge on fertilizer application in order of importance (ranked from second to twelfth).

4. Conclusions and recommendations

Use of inorganic fertilizer is essential in cereal-based systems to enhance agricultural production and productivity. This study analyzed determinants of fertilizer use and its profitability in maize production using data collected from a total of 174 farmers randomly selected from NonoBenja district. Results revealed that farmers who used inorganic fertilizer applied 142.8 kg/ha, on average, which is far below the recommended rate (200 kg/ha). Results also showed that age and education of the household head, farm income, livestock holding, frequency of contact with extension agent, use of input credit and perception on fertilizer cost were found to be significantly determining the use of fertilizer while variation in education level of household head, livestock holding, frequency of contact with extension agents, perception on cost and off-farm income were found to significantly influencing the intensity of fertilizer use in maize production. Net profit analysis indicated that fertilizer users made a positive profit, 2,217 Birr/ha, after covering all costs incurred in maize production. It can be concluded that inorganic fertilizer use increases the profitability of maize production in the study area. However, given that high cost of fertilizer and factors hindering farmers' access to inorganic fertilizer are raised as the main constraints for inorganic fertilizer use. Thus, it is important to design a mechanism that eases farmers' access to inorganic fertilizer in the study area.

The extent of inorganic fertilizer use in maize production is still lagging behind the due to different factors recommended rates. Therefore, farmers should be encouraged to use fertilizer and intensify their use in order to enhance crop productivity and protect soil fertility lose. Also, the farmer should have to give more emphasis on the use organic fertilizers. Furthermore, the study revealed the importance agricultural extension services in advising and distributing fertilizers to farmers in various maize producing districts. This can further maximize the benefit obtained from the application of inorganic fertilizer. Furthermore, it is recommended to strengthen farmers' training centers to enable them to properly demonstrate technologies and at the same time to capacitate farmers on technology utilization through trainings.

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Note

1. Birr is Ethiopian currency and 1USD was equivalent to 27.8 Birr at the time of this study.

Abbreviations

CC: Contingency coefficients; CSA: Central Statistical Authority; ETB: Ethiopian Birr; Ha: Hectare; IMR: Inverse Mill's Ratio; Kg: Kilogram; NPS: Nitrogen phosphate Sulfate; OLS: Ordinary Least Square; TLU: Total Livestock Unit; VIF: Variance inflation factor

Ethics approval and consent to participate

We hereby declare that this thesis represents our own work which has been done after we were identified the problem in the study area, and has not been previously included in a study conducted in the country. We have read the current research ethics guidelines, and accept responsibility for the conduct of the procedures in accordance with the research. We have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and safety approval, and acknowledged our obligations and the rights of the participants. Thesis in whole or in part when in his or her judgment the proposed use of the material is in the interest of scholarship, permission must be obtained from the author of the Thesis.

Availability of data and materials

The data used for this article is currently not available publicly but could be made available upon request, with permission from the project team leaders.

Competing interests

The author(s) declare that they have no competing interests.

Author's contributions

The research idea was originally conceived by MDI. The authors searched for the existing literature together. They equally contributed together in estimating the empirical models and analyzing the econometric results. They also discussed the results and contributed to the final manuscript. All authors read and approved the final manuscript.

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