Determinants of Adoption and Intensity of Organic Fertilizer Use Among Smallholder Farmers in Debark District, Ethiopia: Evidence from a Double-Hurdle Model

Banteamlak Abuhay[1], Workineh Yenewa[2] *, and Derjew Fentie[3]

Article History: *Received: 20 February 2025; Revised: 26 November 2025; Accepted: 16 April 2026*

Abstract

Despite its significance, the agricultural sector in Ethiopia is commonly known for its low productivity. To address this issue and promote overall economic development, the Ethiopian government has been working on increasing the use of organic fertilizers. However, adoption rates remain low across regions, including the study area. This research identifies factors influencing the adoption and usage levels of organic fertilizers among smallholder farmers. Primary data were gathered from 300 farmers in the Debark district of the Amhara region using a two-stage sampling method. The study used descriptive statistics and a double-hurdle model. Findings from Cragg's double-hurdle model indicate that livestock ownership, frequency of extension contacts, access to training, land size, and labor availability positively influence the decision to use organic fertilizer. Additionally, the intensity of organic fertilizer use is positively affected by labor availability, livestock numbers, the frequency of extension contacts, and access to training. On the other hand, annual income and the use of inorganic fertilizers negatively affect the decision to adopt organic fertilizers and educational status has a negative impact on usage intensity. Therefore, working on enablers and hurdles and encouraging farmers to adopt organic fertilizers is crucial. This can be facilitated by the government and other stakeholders through enhanced extension services and improved access to training on organic fertilizer practices. This study suggests tailored solutions for farmers with limited livestock and highlights the necessity of enhancing smallholder farmers' access to extension support and simplifying the dissemination of technical knowledge regarding organic fertilizer usage.

Keywords: Adoption; Organic Fertilizer; Determinants; Intensity; Double Hurdle Model.

JEL Classification: Q12; Q16; Q18

---

[1], [3] Department of Agricultural Economics, College of Agriculture and Natural Resources, Debre Markos University, Debre Markos, Ethiopia

[2] Ethiopian Institute of Agricultural Research, Fogera National Rice Research and Training Center, Bahir Dar, Ethiopia

1. Introduction

In sub-Saharan Africa, the rate of poverty has not decreased sufficiently to match the region's population growth, with an estimated 433 million Africans living in extreme poverty in 2018, an increase from 284 million in 1990. For many, subsistence agriculture serves as a primary source of both food and income (Larsen and Lilleor, 2014). Enhancing the agricultural sector's performance is considered the most effective strategy for alleviating poverty and raising incomes for the majority in this area (Dawson et al., 2016). Nevertheless, agricultural sectors in many sub-Saharan African countries struggle to enhance food security at both national and household levels (Bezu et al., 2014). Soil infertility poses a significant challenge for smallholder farmers in Sub-Saharan Africa (SSA), primarily due to the swift rise in population and the corresponding demand for food. The heightened demand for food leads to persistent and intensive agricultural practices, which in turn contribute to forest cover depletion and adverse environmental issues (Tittonell and Giller, 2013).

The rapid increase in population in both rural and urban regions of Ethiopia has resulted in a heightened demand for energy and food resources. Many households rely on animal by-products, such as manure, for fuel, while crop residues serve dual purposes as both fuel and animal feed. This reliance on such by-products has contributed to the limited adoption of organic fertilizers among smallholder farmers. Furthermore, swift population growth has intensified the need for arable land, prompting deforestation and increasing the risk of soil erosion (Gelgo et al., 2016). To sustain the burgeoning population, there is an urgent need to enhance productivity per unit area. The rising population density, coupled with a scarcity of alternative employment options in rural settings, has led to mounting pressure on land resources, resulting in smaller individual landholdings, fragmentation of existing plots, and encroachment into vulnerable and marginal lands. While improvements in productivity can be achieved through a consistent and balanced supply of nutrients, the ongoing decline in soil fertility remains a critical challenge for crop production and food security that has yet to be effectively addressed.

Food insecurity and poverty can be attributed to various factors, including demographic changes, the frequency of droughts, land degradation, the fragmentation of landholdings, ineffective policies, inadequate infrastructure, and suboptimal agricultural practices, among others. Land degradation, primarily resulting from soil erosion and nutrient depletion, poses a major environmental challenge that significantly jeopardizes the nation's food security objectives (Ketema and Bauer, 2011).

The agricultural sector plays a crucial role in enhancing the livelihoods of a significant portion of the rural population. Despite its vital importance, Ethiopia's agricultural sector is marked by low levels of production and productivity (Gelgo et al., 2016). To address this issue, the adoption of organic fertilizers has been pivotal in preserving soil fertility and directly improving agricultural crop production and productivity, particularly in developing countries where agriculture remains a major economic sector. Despite the detrimental impact of erosion on productivity in the Ethiopian highlands, the implementation of techniques aimed at enhancing soil fertility has been limited (Ketema and Bauer, 2011).

The reduction in soil fertility is associated with insufficient recycling of essential soil nutrients, which significantly contributes to the gradual loss of soil organic matter (Scotti et al., 2015). This decline adversely affects agricultural productivity, leading to increased levels of poverty. In Ethiopia, initial fertilizer adoption primarily focused on chemical options (Kassie et al., 2009), with scant attention paid to organic alternatives. Increased reliance on chemical fertilizers by smallholder farmers led to a gradual decline in soil health due to organic matter depletion. Consequently, the soil became compacted and impoverished, impairing its ability to retain nutrients and water, ultimately resulting in low productivity. The ongoing reliance on chemical fertilizers has further compromised soil fertility, diminished microbial activity, and disrupted environmental balance and ecological integrity (Girawale and Naik, 2016). Organic fertilizers are recognized as a viable alternative to chemical fertilizers for enhancing soil fertility and promoting sustainable agricultural practices. They also effectively complement chemical fertilizers, contributing to crop production systems while offering economic accessibility and fostering environmentally friendly farming practices (Girawale and Naik, 2016).

Beyond the reliance on inorganic fertilizers, which have traditionally been the primary focus for extension workers, researchers, policymakers, and donors, Ethiopia faces broader soil fertility challenges. These interconnected challenges encompass the depletion of organic soil matter, loss of macro and micronutrients, erosion of topsoil, increased acidity and salinity, and degradation of physical soil properties. Despite the availability of abundant, often-wasted organic materials—such as compost, crop residues, and farmyard manure—particularly in Ethiopia's humid and sub-humid agro-ecosystems, these resources could be effectively utilized. While the adoption of practices like appropriate crop rotation and improved fallow is influenced by the socio-economic conditions of farming communities, the investment required for processing and applying organic fertilizers is comparable to that for inorganic fertilizers.

Smallholder farmers, however, show limited inclination to utilize organic fertilizers (Ketema and Bauer, 2011). This reluctance has hindered the advancement of agricultural production and productivity over the years. Recently, the Ethiopian government, along with development partners, has been actively promoting the adoption of organic fertilizers. The annual report from the Debark District Agricultural and Rural Development (DWARD) office for 2020/21 indicated that fewer than 35% of farmers in the district had adopted organic fertilizers. Consequently, this study seeks to explore the factors influencing the adoption and extent of organic fertilizer usage in the Debark district, located in the North Gondar zone of the Amhara region, Ethiopia.

2. Methodology of the Study

2.1. Description of the study area

This research was carried out in the Amhara National Regional State, specifically in the North Gondar zone, within the Debark district, located 830 km from Addis Ababa and 100 km from Gondar town. The geographical coordinates of the area are 13.08°N latitude and 37.54°E longitude. The district's elevation varies from 974 to 4,088 meters above sea level and encompasses all major agro-ecological zones, categorized as 2.84% wurch, 20.7% dega, 31.93% woina-dega, and 44.53% kola. The temperature in the district typically ranges from 7.5 to 25 degrees Celsius, while the annual rainfall averages between 900 and 1,800 mm (DWARD, 2017).

The district comprises 33 rural kebeles, encompassing an estimated total area of 157,971 hectares. This area includes 59,491.32 hectares of cultivated land, 16,369.1 hectares of forestland, 47,705.92 hectares of grassland, 24,410.24 hectares of shrub and bush land, 874.48 hectares designated for construction, and 9,119.96 hectares classified as miscellaneous land. The district's total population stands at 161,406, with males representing 49.5% and females accounting for 50.5% (DWARD, 2017).

2.2. Types and Sources of Data

To achieve the objectives outlined in this work, a combination of primary and secondary data was used.

Primary data was gathered through both qualitative and quantitative methods. Specifically, quantitative data was obtained from 300 farmers via face-to-face interviews using a structured questionnaire. This questionnaire was pre-tested with enumerators to ensure consistency and clarity, prevent duplication, and estimate the time needed for data collection. A team of trained data collectors was employed for this task.

Prior to the main study, a pilot survey was conducted with 15 randomly chosen households. Additionally, focus group discussions and key informant interviews were held to refine the research problem into a workable hypothesis.

Secondary data was sourced from various published and unpublished documents, research journals, and reports from the district agricultural development office.

2.3. Sampling techniques and sample size

The research employed a two-stage sampling technique. In the initial stage, three Kebeles—Mikara, Adagat, and Beles—were randomly selected from a total of 33 Kebeles with similar potential for organic farming, using a lottery sampling method.

For the second stage, simple random sampling was used to select participants from both adopter and non-adopter groups. Lists of adopters and non-adopters, assumed to be homogeneous, were obtained from the relevant kebele office. A random number table was then employed to identify the required number of respondents. The sample size was determined using the Yamane formula (Yamane, 1967), as the population size (the number of targeted individuals) was known in the study area.

$$n = \frac{N}{1 + N * (e)^2}$$

Where; n is sample size, N is the population size, e is allowable margin of error (level of precision) ranging from 0.05 to 0.1. Margin of error shows the percentage at which the opinion or behavior of the sample deviates from the total population. The smaller the margin of error the more the sample is representative to the population at a given confidence level. Therefore, for this study, allowing the smallest possible margin of error (e = 0.05), the total sample size became: $n = \frac{2745}{1 + 2745 * 0.05^2} = 300$.

Table 1: Distribution of sample size across the sample frame kebeles

Woreda	Kebele	Numberof House holds	Total adopter farmers	Sample taken from adopters	Total non-adopter farmers	Sample taken from non-adopters	Total sample taken
	Mikara	1099	365	40	734	80	120
Debark	Adagat	741	248	27	493	54	81
	Beles	905	302	33	603	66	99
Total		2745	915		1830		
	Sample households(total)			100		200	300

2.4. Specification of the econometric model

Most adoption studies have employed a binary variable to assess adoption, which has made the use of logit or probit models appropriate (Lapar and Pandey, 1999). While this modeling approach provides valuable insights into how various characteristics of farmers influence the likelihood of adopting organic fertilizer, it fails to convey the impact of these factors on the actual level of organic fertilizer adoption.

Furthermore, the adoption of organic fertilizer is inherently positive; farmers cannot engage in negative adoption practices. Given that this study aims to provide insights into the intensity of adoption, a discrete choice model is not suitable. Additionally, since the index measuring intensity is continuous, logit and probit models are not appropriate. The Tobit model is typically employed to address this issue; however, it has significant limitations in its parameterization. It assumes that the same stochastic process governs both the probability and the level of adoption, and it attributes all zero observations of the dependent variable to corner solutions (Moffatt, 2005). Therefore, this study has opted for the double-hurdle model as proposed by García (2013).

The double-hurdle model provides a framework in which various factors can influence both the decision to adopt and the intensity of using the product, allowing for the same variable to have differing effects on these two decisions. Consequently, factors influencing the utilization of organic fertilizer may exert distinct influences on farmers' adoption and usage decisions. For example, a particular factor might encourage the decision to adopt organic fertilizer while simultaneously discouraging the extent to which it is used. The double-hurdle model becomes particularly relevant when the decisions to adopt organic fertilizer and to determine the quantity to use are made independently. This model employs a probit regression for the adoption decision, utilizing all available observations, followed by a truncated regression for those instances where usage is greater than zero (García, 2013). By acknowledging that the decisions regarding adoption and usage intensity are not necessarily made in tandem and that the influencing factors may differ, the double-hurdle model effectively separates the likelihood of a farmer becoming a potential adopter from the intensity of their adoption.

The double-hurdle model is used for the analysis with the assumption that the status of adoption and the intensity of adoption are separately determined. To confirm the use of this model, a restriction test was carried out using the log-likelihood values obtained from separate estimations of Tobit, Probit, and Truncated regression models. Based on the values obtained, the following likelihood ratio statistic was computed using the formula below.

$$\lambda = 2(LLProbit + LLTruncated - LLTobi)$$

The test statistic (λ) has a chi-square distribution with degrees of freedom equal to the number of independent variables. The Tobit model is rejected in favor of the double-hurdle model if the test statistic (λ) exceeds the appropriate chi-square critical value (Burke, 2009). If this condition is met, the double-hurdle model would be used, as it can control the reciprocal relationship between the two factors: adoption decision and use intensity (Ketema and Bauer, 2011).

Based on the specification by Cragg (1971), the double-hurdle model contains two equations and assumes that a household head makes two independent and sequential decisions regarding the adoption and use intensity of technology.

2.4.1. First Hurdle adoption decision model

The study adopted the Probit regression model to measure the factors influencing the decision to adopt fertilizer. The Probit model was ideal due to its ability to constrain the utility value of the adoption decision variable between zero and one, and to resolve the problem of heteroscedasticity (Asante et al.,2011). Furthermore, the model allows the factors that determine the adoption decision and its intensity to differ independently (Temitayo and Kabir, 2016).

First hurdle adoption equation (Di): $di * = aixi + ui$

Where, ui~N(1,0), Di= $\begin{cases} 1 \text{ if } di * > 0 \\ 0 \text{ if } di * \leq 0 \end{cases}$

Where, di*is latent choice of the adoption by the smallholder farmers. αi is vector of unknown parameters, xi is a vector of explanatory variables which affect adoption decision, ui is normally distributed error term with zero mean and constant variance (σ2), i = 1, 2, … n, n is the number of observation and Di represents observable it farmers status to adopt organic fertilizer, 1 if adopt 0, other- wise.

2.4.2. Second Hurdle outcome model (intensity of adoption)

The second hurdle involves an outcome equation, which uses a truncated model to determine the level of adoption of organic fertilizer under study. This model excludes a portion of the sampled observations based on the value of the dependent variable. That is, the truncated regression uses observations only from farming households that reported positive values (i.e., greater than zero). The intensity of adoption is modeled as a regression truncated at zero, with a lower limit of zero and an upper limit of positive infinity (Yassin et al., 2016).

A dependent variable that has a zero value for a significant fraction of the observations requires a truncated regression model because standard OLS results in biased and inconsistent parameter estimates. The bias arises from the fact that if one considers only the observed data points and omits the others, there is no guarantee that the expected value of the error term would be zero (Terefe and Ahmed, 2016).

Truncated model expressed as follows: $Yi* = \beta Xi + ei$

Where, Ɛi~ N(0, σ2), $Yi = \begin{cases} yi * \text{ if } Di = 1 \text{ and } yi * \geq \mu \\ 0 \quad \text{if } Di \leq \text{ and } yi * < \mu \end{cases}$

Where: Yi* is the latent variable for observation i; β is a vector of parameters; and Xi is a vector of explanatory variables hypothesized to affect the intensity of technology adoption. μ represents the threshold, defined as the minimum use of organic fertilizer in the study area. This threshold is 8-10 tons per hectare, consistent with the recommended amount for compost, the primary organic fertilizer used in the study area (Fentaw, 2010).

2.5. Methods of data analysis

The gathered data were analyzed using descriptive and inferential statistics, and an econometric model. Descriptive statistics (percentages, means, and standard deviations) were used to summarize differences in socioeconomic and institutional factors between adopter and non-adopter groups. Additionally, t-tests and χ^2 tests were applied to assess socioeconomic disparities between these two groups for continuous and discrete variables, respectively. All quantitative data analysis was conducted using STATA version 14 software. Furthermore, a double-hurdle (DH) model was implemented to investigate the factors influencing both the adoption and intensity of organic fertilizer usage.

2.6. Multicollinearity test

There are different types of statistical problems that should be checked during analysis before executing the final model. Multicollinearity is one of the most common problems. Thus, in this study, all the hypothesized explanatory variables were checked for the existence of such a problem. Multicollinearity arises from the existence of a linear relationship between explanatory variables. The problem may cause the estimated regression coefficients to have incorrect signs, smaller t-ratios for many variables, and a high R^2 in the regression. It may also cause variances and standard errors to be high, with wide confidence intervals, thereby reducing the accuracy of estimating the impact of each variable (Gujarati, 2004; Greene, 2002).For this study, the Variance Inflation Factor (VIF) was used to identify collinear explanatory variables, which is given by the formula as shown below.

$$VIF = \frac{1}{1 - Rj2}$$

Where Rj2 is the R2 value that will find when the j^{th} continuous explanatory variable will regress on the remaining continuous explanatory variables (Gujarati, 2004). By the rule of thumb, if the VIF of a variable exceeds 10, that variable said to be highly collinear. Likewise, to identify the co linearity among the qualitative (dummy) explanatory variables contingency coefficients will compute using the formula shown below:

$$C = \sqrt{\frac{x2}{n + x2}}$$

Where, C= coefficient of contingency, $\chi 2$ = a Chi-square random variable and n =

total sample size. By the rule of thumb, there is no problem of multicollinearity if the CC of a variable less than 0.8.

3. Results and Discussion

3.1. Demographic and institutional characteristics of households

The dataset analyzed comprises 300 observations, revealing that 33.33% of farmers are adopters of organic fertilizer, while 66.67% are non-adopters. This indicates that a considerable number of smallholder farmers continue to forgo organic fertilizer in their agricultural practices. Furthermore, chi-square statistical analysis indicates significant differences between adopters and non-adopters regarding access to training, credit, and energy sources.

Approximately 27.33% of the households surveyed were headed by females, while 72.67% were male-headed. The findings indicate that male-headed households outnumbered female-headed ones in both the adopter and non-adopter categories of organic fertilizer. Nevertheless, the chi-square statistic revealed that the difference in the proportion of household heads by sex was not statistically significant between the two groups.

Educational achievement of the household head is anticipated to enhance the capacity to acquire, analyze, and utilize information pertinent to the adoption of advanced agricultural technologies, particularly organic soil fertilizers. According to survey findings on the educational backgrounds of sampled household heads, 23% of respondents were illiterate, while 77% were literate. Among organic fertilizer adopters, 21% were illiterate, and 79% were literate. Conversely, among non-adopters, 24% were illiterate, and 76% were literate. This suggests that a higher proportion of literate farmers, possessing reading and writing skills, tend to adopt organic fertilizers, potentially reflecting the influence of better educational opportunities. Nevertheless, chi-square statistical analysis revealed that the differences in educational levels between adopters and non-adopters were not statistically significant.

Table 2: Demographic and institutional characteristics of respondents (dummy variables)

Variable	Category	Adopters	Non adopters	Total	Chi square
		Frequency	Frequency	Frequency	
Education	**Illiterate**	**21**	**48**	**69**	**0.33**
status	Literate	79	152	231	
Sex	Female	28	54	82	0.03
	Male	72	146	218	
Access to training	No	18	104	122	31.93***
	Yes	82	96	178	
Health status	Unhealthy	51	95	146	0.32
	Healthy	49	105	154	
Access to credit	No	72	50	122	61.03***
	Yes	28	150	178	
Transport access	No	35	74	109	0.115
	Yes	65	126	191	
Energy source	No	72	57	129	51.46***
	Yes	28	143	171	

Source: Own survey data, 2021 *, **and *** indicates significance at 10, 5 and 1 % level respectively

Engagement in training plays a crucial role in raising awareness among target groups and facilitating their ability to utilize technologies effectively. The study's findings revealed that 59.33% of all respondents had participated in training related to organic fertilizer, while 40.67% had not. Notably, among adopters, 82% attended training sessions, whereas only 48% of non-adopters participated. Conversely, 18% of adopters and 52% of non-adopters did not engage in training regarding organic fertilizer utilization. This highlights a significantly higher proportion of trained individuals among adopters compared to non-adopters. The chi-square test further confirms a statistically significant difference in training participation between the two groups at a 1% significance level.

Credit plays a crucial role in financing the adoption of agricultural technology. Regarding credit accessibility, approximately 59.33% of the surveyed individuals had access to credit, while around 40.67% did not, primarily due to factors such as high interest rates and inadequate credit services. Interestingly, among organic fertilizer adopters, about 72% of households lacked access to credit, in contrast to 28% who did have access. Conversely, for non-adopting households, around 25% were without credit access, while the remaining 75% were able to secure credit. The results of the chi-square test reveal a statistically significant difference in credit access between the two groups at a 1% significance level.

The study results indicate that 63.67% of the total respondents had the means to transport organic fertilizer to their farms, while 36.33% did not. Among organic fertilizer adopters, 35% lacked transportation access, whereas 65% were able to transport the fertilizer to their fields. In contrast, among non-adopters, 37% reported not having access to transport organic fertilizer, while 63% did have access. Despite a slight numerical difference, the chi-square statistical analysis revealed that the difference in transportation access between adopters and non-adopters was not statistically significant.

Survey findings indicate that 57% of the total respondents utilized crop residues and animal byproducts as their primary domestic energy sources, while the remaining 43% relied on alternatives such as electricity, charcoal, firewood, and solar energy. Among organic fertilizer adopters, 72% did not use crop residues and animal byproducts for domestic energy, while 28% did. Conversely, among non-adopters, 71.5% utilized crop residues and animal byproducts as their energy source, with 28.5% opting for other alternatives. This suggests that farmers who depend on different energy sources are more inclined to adopt organic fertilizers. It is noteworthy that animal byproducts and crop residues are primary components of organic fertilizers. Furthermore, the chi-square test results reveal a statistically significant difference in the distribution of energy sources between the two groups at a 1% significance level.

3.2. Socio-economic characteristics of respondents

A t-statistic analysis revealed significant differences in livestock ownership, land size, household size (in man equivalent), use of inorganic fertilizers, and frequency of extension contact between organic fertilizer adopters and non-adopters. Generally, adopters showed higher average values for these variables, with the exception of the age of household heads and inorganic fertilizer usage. The average age squared of household heads in the sample was 2351.49 years (SD = 897.65), with 34.7% of household heads being over 48 years old. As shown in Table 3, the mean age squared for organic fertilizer adopters was 2182.44 years (SD = 709.95), while for non-adopters it was 2436.02 years (SD = 897.65). This indicates that adopters were, on average, younger than non-adopters, a difference confirmed to be statistically significant at the 5% level by the t-test.

Furthermore, the average household size (in man equivalent) among the sample household heads was 5.21 (SD = 1.88). Of the total sample, 31.67% of household heads had a household size exceeding this average. According to Table 3, the mean household size in man equivalent for adopters was 6.27 (SD = 2.41), compared to 4.68 (SD = 1.25) for non-adopters. This indicates that adopters had a larger household size (in man equivalent) than non-adopters, a difference that the t-test further demonstrated to be statistically significant at the 1% level.

The average land area held by the sample household heads was 0.94 hectares (SD = 0.37). Within the total sample, 46.67% of household heads held land exceeding this average. As shown in Table 3, the average land sizes for organic fertilizer adopters and non-adopters were 0.99 hectares (SD = 0.28) and 0.91 hectares (SD = 0.41), respectively. This indicates that adopters possessed a larger average land size than non-adopters.

The average livestock holding among the sampled household heads was 4.55 Tropical Livestock Units (TLU), with a standard deviation of 1.98. Notably, 36.67% of households held livestock exceeding this average. As illustrated in Table 3, the mean livestock holdings for organic fertilizer adopters stood at 5.90 TLU, while non-adopters averaged 3.87 TLU, with standard deviations of 2.59 and 1.08, respectively. This indicates that adopters had a higher average livestock holding compared to non-adopters. Furthermore, the t-test results revealed a statistically significant difference in the mean age between the two groups at the 1% significance level.

Table 3. Socio-economic and institutional characteristics of respondents (continuous variables)

Variables	Adopters		Non adopters		Total		Mean difference	t- value
	Mean	SD	Mean	SD	Mean	SD		
age square	2182.44	709.95	2436.02	897.65	2351.49	847.06	253.58	2.43**
household size	6.27	2.41	4.68	1.26	5.21	1.88	-1.59	7.51***
Land size	0.99	0.28	0.92	0.41	0.94	0.37	-0.08	1.77*
Livestock	5.90	2.59	3.87	1.08	4.55	1.98	-2.03	9.55***
Extension frequency	4.49	1.73	3.70	1.03	3.96	1.35	-0.78	4.90***
Inorganic fertilizer	99.25	43.58	169.37	73.51	146	72.95	70.12	8.79***

Source: Own survey data, 2021 *, **and *** indicates significance at 10, 5 and 1 % level respectively.

Regarding extension contact, the average frequency reported by the sample household heads was 3.96 times, with a standard deviation of 1.35. Among the total sample, 50.67% of household heads experienced more than four instances of extension contact. According to Table 3, the mean frequency of extension contact for organic fertilizer adopters was 4.49 times, compared to 3.70 times for non-adopters, with standard deviations of 1.73 and 1.03, respectively. This data indicated that adopters engaged in extension contact more frequently than non-adopters. Additionally, the t-test results confirmed that the difference in mean frequency of extension contact between the two groups was statistically significant at the 1% significance level.

The average usage of inorganic fertilizer among the sampled household heads was 146 kilograms, with a standard deviation of 72.95. Notably, 62.67% of these household heads reported using more than 146 kilograms. As illustrated in Table 3, the average inorganic fertilizer usage for organic fertilizer adopters was 99.25 kilograms, while non-adopters averaged 169.37 kilograms, with standard deviations of 43.58 and 73.51, respectively. Interestingly, the mean usage of inorganic fertilizer among adopters was lower than that of non-adopters. The results of the t-test indicated that the difference in mean inorganic fertilizer usage between the two groups was statistically significant at the 1% significance level.

Type of organic fertilizer used and area coverage in the studied area

In the study area, the six-year total fertilizer use trend, as indicated in Table 4, showed that overall fertilizer use declined by 80.32% over the study period.

Secondary data collected

from the Woreda agricultural and rural development office revealed that organic fertilizer use decreased by 83.07%, while chemical fertilizer use increased by 29.91%. This implies that chemical fertilizer use is increasing at an accelerating rate, with the amount in the final year being approximately five times that of 2008. In contrast, organic fertilizer use declined year after year. This decline may be because organic fertilizer is labor-intensive to prepare and use. Therefore, farmers may be substituting chemical fertilizer for organic fertilizer.

Table 4: Six years trend of fertilizer utilization in land area coverage.

Year(G.C)	Compost	FYM	Sum(OF)	CF	Sum(OF+CF)
2008	678654	334035	1012689	4567	1017256
2009	545678	316550	862228	9345	871573
2010	436789	318889	755678	13450	769128
2011	235670	287987	523657	18765	542422
2012	195670	276890	472560	25765	498325
2013	145670	25689	171359	28768	200127
Average	373,021.8	260,006.67	633,028.5	16,776.67	649,805.17

Source: DWARD[3] (Unpublished)

FYM=Farm Yard Manure, OF= Organic Fertilizer, CF= Chemical Fertilizer

Secondary data collected from the Woreda agricultural and rural development office revealed that farmers predominantly use chemical fertilizer without mixing it with organic varieties. This practice may stem from the need to cover large areas of land with fertilizer and to reduce overall fertilizer costs. When organic fertilizers are utilized, however, farmers frequently mix compost with farmyard manure. This mixture, while extending coverage, can be of lower quality and may not release sufficient nutrients due to its slow action. While compost itself offers better quality, its preparation is labor-intensive. Consequently, farmers combine compost and farmyard manure to cover larger areas and enhance the general quality of their organic fertilizers

[3] Debark Woreda Agricultural and Rural Development

beyond what farmyard manure alone would provide. Indeed, using farmyard manure solely does not improve soil fertility as effectively as compost. As indicated in Table 5, the total area of land covered by fertilizer over six successive years shows only about a 4% increment. Currently, fertilizer covers only about 27.8% of the total cropping land. Of this fertilized land, a large proportion is covered by chemical fertilizer. However, the continuous use of chemical fertilizer presents disadvantages for soil fertility. This implies that a significant portion of land remains unfertilized. Yet, fertilizer remains a crucial input for increasing crop production and productivity.

Table 5: Area of land covered by each fertilizer in the previous 6 year

Year (G.C)	Compost	FYM	CF	FYM+COM	FYM+CF	COM+CF	Total	% of land covered
2008	5938.223	835.0875	2283.5	4860.23	0	0	13917.04	23.3934
2009	4774.683	791.375	4672.5	4280.982	0	0	14519.54	24.40615
2010	3821.904	797.2225	6725	3936.211	0	0	15280.34	25.68499
2011	2062.113	719.9675	9382.5	3025.466	0	0	15190.05	25.53321
2012	1712.113	692.225	12882.5	2805.822	0	0	18092.66	30.41227
2013	1274.613	64.2225	14384	685.37	0	0	16408.21	27.58084

Source: DWARD (2021)

3.3. Econometric analysis

3.3.1. First Hurdle: Factors determining adoption decision of organic fertilizer

The initial phase of the double hurdle model focuses on the decision-making process regarding the adoption of organic fertilizer. Farmers were categorized as adopters (assigned a value of one) if they utilized organic fertilizer, and non-adopters (assigned a value of zero) otherwise. In examining the factors influencing the adoption of organic fertilizer during this first stage, six explanatory variables emerged as statistically significant. These variables include household size (measured in man equivalents), the number of livestock owned, the frequency of extension contacts, access to training, the use of inorganic fertilizers, and the size of landholdings, all of which significantly influenced the decision to adopt organic fertilizer. The coefficient estimates aligned with expectations, indicating that household size, livestock units, frequency of extension contact, access to training, and land size positively influenced the adoption of organic fertilizer among smallholder farmers. Conversely, the use of inorganic fertilizers was found to have a statistically significant negative effect on the adoption of organic fertilizer in this demographic.

This research revealed that smallholder farmers possessing a large number of livestock are more inclined to utilize organic fertilizer. The analysis indicated a positive and statistically significant coefficient for households with larger livestock holdings, with a significance level of 1%. The marginal effect analysis showed that an increase of one Tropical Livestock Unit (TLU) raised the likelihood of adopting organic fertilizer by approximately 14.49%, assuming other variables remain constant. Given that livestock manure is a primary component of compost and a significant source of organic fertilizer, having a larger livestock holding enhances the likelihood of adopting organic fertilizer. Thus, households with a substantial number of livestock are more likely to generate more manure, facilitating the adoption of organic fertilizer. These findings align with the conclusions drawn by Terefe et al. (2013), who noted that households with greater livestock ownership are better positioned to adopt organic fertilizer due to their increased capacity to produce animal manure.

This research revealed that smallholder farmers who engage more frequently with extension services are more inclined to adopt organic fertilizers. The analysis indicated a positive and statistically significant coefficient for households with increased extension contact (at a 1% probability level) in relation to their decision to utilize organic fertilizers. The marginal effect analysis demonstrated that each additional contact with extension agents raised the probability of adopting organic fertilizers by approximately 9.46%, while controlling for other variables. A crucial function of extension services is to enhance farmers' understanding of agricultural productivity by providing essential information regarding the adoption of agricultural technologies. Consequently, the findings of this study support the notion that improved information dissemination through extension workers can facilitate the adoption of organic fertilizers by increasing awareness of the benefits associated with new technologies. Therefore, households with frequent contact with extension workers are likely to have a greater propensity for adopting organic fertilizers. This finding aligns with results from various other studies, including those conducted by Ali et al. (2018), Eba and Bashargo (2014), and Nazziwa-Nviiri et al. (2017), which suggest that farmers who maintain regular contact with agricultural experts are more motivated to adopt agricultural technologies due to the comprehensive information they receive from these professionals.

This research also revealed that smallholder farmers who utilize higher amounts of inorganic or chemical fertilizers are less inclined to adopt organic fertilizers. The analysis indicated a negative and statistically significant coefficient for households with increased use of inorganic/chemical fertilizers, with a significance level of 1% regarding their decision to embrace organic fertilizers. The marginal effect analysis demonstrated that a one-unit increase in chemical fertilizer usage corresponds to an approximate 0.38% decrease in the adoption of organic fertilizers, assuming other variables remain constant. This trend may be attributed to the substitutive relationship between the two types of fertilizers. This finding aligns with the observations made by Ketema and Bauer (2011), who noted a negative correlation between the decisions to use fertilizers and manure. While fertilizers are often expensive and limited in availability, they require less labor for application. In contrast, manure is typically more accessible at no cost but demands significant labor for both transportation and application.

Table 6: Results of double hurdle model (probit output) on the determinants of decision of organic fertilizer

Variables	dy/dx	Coef.	Std. Err.	P>z
Sex	-0.1011	-0.3493	0.2917	0.231
Educstat	-0.0043	-0.0157	0.3370	0.963
Household size	0.0597	0.2199	0.0773	0.004
Land size	0.3657	1.3482	0.3666	0.000
Livestock own	0.1449	0.5342	0.0830	0.000
Training	0.2834	1.1595	0.2945	0.000
Extfrequency	0.0946	0.3489	0.1249	0.005
Inorganic fert	-0.0038	-0.0141	0.0025	0.000
Credit use	-0.1634	-0.5780	1.0173	0.570
Healthstat	0.0174	0.0642	0.2591	0.804
Transport access	0.0617	0.2342	0.3004	0.436
Energy sources	-0.1271	-0.4569	1.0123	0.652
age square	2.93	0.0	0.0002	0.946
_cons		-5.0837	1.1768	0.000

Number of obs= 300

LR chi2 (13) 255.69

Prob > chi2 0.0000

Log likelihood = -63.106934 Pseudo R2 = 0.6695

Source own survey data, 2021 *, **and *** indicates significance at 10, 5 and 1 % level respectively. dy/dx is marginal effect.

Finally, this research revealed that smallholder farmers who received training were significantly more inclined to utilize organic fertilizer. The coefficient estimate for households with access to training was found to be both positive and statistically significant at the 1% probability level, indicating its influence on the decision to adopt organic fertilizer among these farmers. The marginal effect analysis indicated that farmers with training were 28.34% more likely to adopt organic fertilizer compared to those without training, while controlling for other variables. This suggests that training enhances farmers' understanding and technical skills regarding organic fertilizer.

The study also revealed that smallholder farmers with larger land holdings were more likely to adopt organic fertilizer. Supporting this, the coefficient estimate for households with greater land holdings was positive and statistically significant ($p < 0.01$), underscoring the role of land size in this decision. Specifically, marginal effect results showed that a one-hectare increase in land holding corresponded to a 36.57% rise in organic fertilizer adoption. This positive correlation likely stems from economies of scale on larger farms, where organic fertilizer may be more cost-effective than inorganic alternatives. Such cost-effectiveness could motivate farmers in the study area to prefer organic options. These findings align with observations by Martey et al. (2014), who noted that an increase in cultivated land often correlates with financial constraints for smallholder farmers in Ghana, thereby hindering the adoption of chemical fertilizers. This suggests that for larger landholdings, organic fertilizer may be a more economically viable alternative.

3.3.2. Second Hurdle: Factors affecting use intensity of organic fertilizer

In the study area, the majority of households utilize various forms of organic fertilizer, particularly compost, and its quantity is straightforward for farmers to measure. Those who employ compost typically measure it in quintals, which is equivalent to 100 kg, both during preparation and when transporting it to their fields. Consequently, farmers are more familiar with the application levels of compost compared to other organic fertilizers, such as crop residues and green manure. As a result, compost was used as a reference point in the second stage of the analysis to assess the factors influencing the intensity of organic fertilizer usage.

The analysis revealed that several factors significantly impact the intensity of organic fertilizer use, including the education level of the household head, the number of livestock owned, the frequency of extension contacts, access to training, and household size. The coefficient estimates aligned with expectations, indicating that household size (measured in man equivalents), livestock ownership, frequency of extension interactions, and access to training positively and significantly influence the intensity of organic fertilizer use among smallholder farmers. Conversely, the education level of the household was found to have a statistically significant negative effect on the intensity of organic fertilizer usage by these farmers.

A unit increase in household size, measured in man equivalents, correlates with an approximate rise of 10.75 quintals per hectare in the intensity of organic fertilizer usage, assuming all other variables remain unchanged. This finding underscores the positive impact of household size on the application intensity of organic fertilizers, with the effect being statistically significant at the 1% probability level. The beneficial influence of household size on organic fertilizer usage may stem from the fact that the preparation of organic fertilizers, such as composting, requires considerable time and labor. Consequently, households with more members are more likely to engage in preparing organic fertilizers, which are not only more economical but also easily produced without significant costs.

Furthermore, results from the truncated regression model indicate that a one-unit increase in Tropical Livestock Unit (TLU) in livestock holdings leads to an increase of 8.71 quintals per hectare in the intensity of organic fertilizer usage, while controlling for other variables. This suggests that livestock holdings positively influence the intensity of organic fertilizer application, with the effect also being significant at the 1% probability level. Farmers with large livestock holdings are more inclined to utilize organic fertilizers, as these are generally less expensive than inorganic alternatives, especially given their enhanced access to livestock manure.

Households that experience more frequent extension interactions are more likely to increase their organic fertilizer usage. This suggests that as smallholder farmers engage more frequently with extension services, they are inclined to apply greater amounts of organic fertilizers on their farms. Extension services play a crucial role in providing farmers with essential information, thereby empowering them to adopt relevant agricultural technologies that can enhance their productivity. This finding aligns with results from various studies, including those by Eba and Bashargo (2014), Obuobisa-Darko (2015), Nazziwa-Nviiri et al. (2017), and Ali et al. (2018).

Findings from the truncated regression model indicate that literacy among households is associated with a reduction in the intensity of organic fertilizer usage by approximately 36.63 quintals, assuming other variables remain constant. This suggests that a higher education level negatively impacts the intensity of organic fertilizer application. The effect of education on organic fertilizer use is statistically significant at the 5% probability level. The negative coefficient implies that households headed by literate individuals are less inclined to utilize organic fertilizers compared to those headed by illiterate individuals. This inverse relationship may primarily stem from literate households often having opportunities for non-farm employment, allowing them to earn additional income that they may prefer to allocate towards purchasing chemical fertilizers instead.

Table 7: Results of crags double hurdle model (truncated output) on factors affecting intensity of organic fertilizer adoption

Variable	dy/dx	Coef.	Robust Std. Err.	P>z
Sex	17.3957	17.3957	18.2522	0.341
Educstat	-36.6358	-36.6358	17.5339	0.037**
Household size	10.751	10.751	3.4086	0.002 ***
Land size	14.4576	14.4576	32.1412	0.653
Livestock own	8.7106	8.71061	3.2873	0.008 ***
Training	51.047	51.047	24.8244	0.040***
Extfrequency	24.7026	24.7026	4.3168	0.000***
Inorganic fert	-0.0624	-0.0624	0.1780	0.726
Credit use	-42.9622	-42.9622	91.2881	0.638
Healthstat	-7.7699	-7.7699	16.5844	0.639
Transport access	6.2231	6.2231	16.6835	0.709
Energy sources	-37.2956	-37.2956	91.2658	0.683
age square	0.0158	0.0158	0.0104	0.128
_cons		-60.4614	75.2553	0.422
/sigma		66.6069	4.7012	0.000

Truncated regression
Limit: lower = 0
Number of obs = 100
Upper = +inf
Wald chi2 (13) = 98.84
Log likelihood = -557.37981 Prob > chi2 = 0.0000

Source: **O**wn survey data, 2021 *, **and *** indicates significance at 10, 5 and 1 % level respectively. dy/dx is marginal effect

4. Conclusion and Recommendations

Despite government efforts to improve soil fertility, organic fertilizer adoption in Debark district remains low. This study examined the factors influencing both the decision to adopt and the intensity of organic fertilizer use. Descriptive results showed that adopters generally had more livestock, larger landholdings, higher income, more labor, and more frequent extension contact than non-adopters. A Chi-square test further indicated that access to training, credit, inorganic fertilizer, and energy sources significantly affected adoption. Econometric analysis confirmed that annual income, land size, livestock ownership, labor availability, training access, extension contact, and inorganic fertilizer use shaped adoption decisions. Most factors had positive effects on adoption, while income and inorganic fertilizer use were negatively associated. Usage intensity increased with labor, livestock, training, and extension contact but declined with higher education levels.

Access to technical training and extension services emerged as key drivers for both adoption and intensity. Strengthening these services through better funding, regular engagement, and improved training centers is essential. Engaging unemployed youth in compost production could boost supply and create jobs.

Livestock ownership strongly influenced adoption and use; thus, farmers with limited livestock need support through credit, technical assistance, and incentives for livestock rearing. Land size also positively affected adoption, suggesting that land consolidation could improve productivity.

Overall, improving access to training and extension services, supporting livestock ownership, and enhancing organic fertilizer production can significantly enhance soil fertility and agricultural productivity. Targeted policies addressing these factors will help smallholders adopt and use organic fertilizers more effectively.

Therefore, for smallholder farmers to benefit from organic fertilizer adoption, policymakers should take the following important issues into consideration:

- **Strengthen and expand extension services:**

Increase both the frequency and quality of farmer-extension interactions. While each kebele has assigned development agents, many farmers still receive limited support. Ensure that development agents actively engage all farming households and provide consistent, needs-based advisory services.

- **Promote organic fertilizer commercialization:**

Farmers with limited livestock struggle to access organic fertilizer. To address this, government and development partners should invest in processing facilities and develop supply chains to make organic inputs widely available.

- **Support livestock ownership and large-scale farming:**

As livestock ownership strongly drives organic fertilizer use, policies should expand access to credit, technical assistance, and incentives for livestock rearing. To further enhance adoption, policies should also promote large-scale farming and provide training on efficient organic fertilizer use.

- **Improve access to training and farmer education:**

Training is essential for technology adoption. Establish and fund farmer training centers and ensure regular, hands-on training by extension agents and district experts on organic fertilizer production and use.

- **Promote organic fertilizer for income generation:**

Organic fertilizer use can significantly boost farm income. Encourage its adoption among smallholder farmers through awareness programs, financial incentives, and integration into broader rural development strategies aimed at improving livelihoods and food security.

References

Abebe, Gedefaw, & Debebe Sisay. (2019). Factors affecting use of organic fertilizer among smallholder farmers in Sekela district of Amhara region, Northwestern Ethiopia. Cogent Food & Agriculture, 5(1), 1669398.

Ali, Ernest Baba, Awuni, Joseph A, & Danso-Abbeam Gideon. (2018). Determinants of fertilizer adoption among smallholder cocoa farmers in the Western Region of Ghana. Cogent Food & Agriculture, 4(1), 1538589.

Asante, B. O., Afari-Sefa, V., and Sarpong, D. B. (2011). Determinants of small-scale farmers' decision to join farmer based organizations in Ghana. *Afr. J. Agric. Research*, vol. 6, pp. 2273-2279.

Bezu, Sosina, Kassie, Girma T., Shiferaw, Bekele, & Ricker-Gilbert Jacob. (2014). Impact of improved maize adoption on welfare of farm households in Malawi: A panel data analysis. World Development, 59, 120-131.

Burke, W. J. (2009). Fitting and interpreting Cragg's Tobit alternative using Stata. *The State Journal,* vol. 9, pp. 584-592.

Carswell, G. (1997). Agricultural intensification and rural sustainable livelihoods: A 'think piece'. Working Paper. England: Institute of Development Studies.

Cragg, J. (1971). Some Statistical Models for Limited Dependent Variables with Applications to the Demand for Durable Goods. *Econometrica* 39(5), 829 – 844.

Dawson Neil, Martin Adrian, & Sikor Thomas. (2016). Green revolution in sub-Saharan Africa: implications of imposed innovation for the wellbeing of rural smallholders. World Development, 78, 204-218.

Eba Negera, & Bashargo Getachew. (2014). Factors affecting adoption of chemical fertilizer by smallholder farmers in Guto Gida district, Oromia regional state, Ethiopia. Science, *Technology and Arts Research Journal*, 3(2), 237-244.

Fentaw Ejigu. (2010). Bio-slurry in Ethiopia: what is it and how to use it, Institute for Sustainable Development (ISD) and National Biogas Program Ethiopia Coordination Office. Addis Ababa, Ethiopia.

García Bruno. (2013). Implementation of a double-hurdle model. *The Stata Journal*, 13(4), 776- 794.

Gelgo Biru, Mshenga P, & Zemedu L. (2016). Analysing the determinants of adoption of organic fertilizer by smallholder farmers in Shashemene District, *Ethiopia. Journal of Natural Sciences Research*, 6(19), 35-44.

Girawale V. B., & Naik R. M. (2016). Adoption of Organic Fertilizer: A Way to Eco-friendly Agriculture. Advances in Life Sciences, 5, 8118-8120.

Greene, W. (2002). *Econometric Analysis*, Fifth edition. New Jersey, Prentice Hall.

Gujarati, D. (2004). *Basic Econometrics*, Fourth Edition. New York: McGraw-Hill.

Kassie Menale, Zikhali Precious, Manjur Kebede, & Edwards Sue. (2009). Adoption of sustainable agriculture practices: Evidence from a semi-arid region of Ethiopia.

Paper presented at the Natural resources forum.

Ketema Mengistu, & Bauer Siegfried. (2011). Determinants of manure and fertilizer applications in eastern highlands of Ethiopia. *Quarterly Journal of International Agriculture,* 50(3), 237-252.

Lapar Ma Lucila A, & Pandey Sushil. (1999). Adoption of soil conservation: the case of the Philippine uplands. Agricultural Economics, 21(3), 241-256.

Larsen Anna Folke, & Lilleør Helene Bie. (2014). Beyond the field: The impact of farmer field schools on food security and poverty alleviation. World Development, 64, 843-859.

Martey Edward, Wiredu Alexander, Nimo Etwire, Prince M, Fosu Mathias, Buah SSJ, Bidzakin John, Kusi Francis. (2014). Fertilizer adoption and use intensity among smallholder farmers in Northern Ghana: A case study of the AGRA soil health project. Sustainable Agriculture Research, 3(1).

Moffatt Peter G. (2005). Hurdle models of loan default. *Journal of the Operational Research Society*, 56(9), 1063-1071.

Nazziwa-Nviiri, Lydia Van Campenhout, Bjorn, & Amwonya, David. (2017). Stimulating agricultural technology adoption: Lessons from fertilizer use among Ugandan potato farmers (Vol. 1608): Intl Food Policy Res Inst.

Norris Patricia E, & Batie Sandra S. (1987). Virginia farmers' soil conservation decisions: An application of Tobit analysis. *Journal of Agricultural and Applied Economics*, 19(1), 79- 90.

Scott, R, Bonanomi Gianluca, Scelza R, Zoina A, & Rao M. A. (2015). Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. *Journal of soil science and plant nutrition*, 15(2), 333-352.

Tedla Teame Hailemariam. (2011). Factors determining fertilizer adoption of the peasant farm sector in northern Ethiopia, Tigray region.

Temitayo, A. A. and Kabir, K. S. (2016). Dynamics of observable use of family planning methods in rural Nigeria: A double hurdle model approach. *Journal of Humanities and Social Science*, vol. 21, pp. 33-43.

Terefe, T. and Ahmed, H. (2016). Adoption and extent of use of organic fertilizer in Arsi Negelle District, Oromia Regional State of Ethiopia. *Advanced Journal of Agricultural Research*, vol. 1.

Terefe T, Ahmed H, & Gebremariam G. (2013). Adoption and extent of use of organic fertilizer in Arsi Negelle District, Oromia Regional State of Ethiopia: What are the sources. *Advanced Journal of agricultural Research*, 1(004), 061-071.

Tittonel, Pablo, & Giller Ken E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. Field Crops Research, 143, 76-90.

Yamane T. (1967). Statistics: *An Introductory Analysis*, 2nd edition, New York: Harper and Row.

Yassin, E., Adam, B., and Mengistu, K. (2016). Determinants of level of Smallholder farmers participation In potato sales in Kofele district, Oromia region Ethiopia. *Journal of Agricultural Science and Research*, vol. 3, pp. 23-30