Estimating the impact of inorganic fertilizer adoption on sesame productivity: evidence from Humera, Tigray, Ethiopia

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Haileslasie Gereziher Hailu* and Giday kidu Mezgebo

Abstract: The major challenge in low-income countries is poor soil fertility that influences land productivity which results in food insecurity and poverty. To revert this inorganic fertilizer has been introduced in these countries to improve land productivity. However, how impactful is the application of this inorganic fertilizer towards improving sesame productivity depends on socio-economic, crop types, institutional, and environmental factors. Thus, this study aims at analyzing the impacts of inorganic fertilizer adoption on sesame productivity in the Humera district. A household survey was administered to collect micro-level evidence from randomly selected 393 households using face-to-face interviews. Endogenous switching regression and propensity score matching models were employed to estimate the impact of inorganic fertilizer adoption on sesame productivity. Adoption of inorganic fertilizer is significantly influenced by years of farming experience, total farm size, educational status, household size, land ownership, an area under sesame cultivation, the practice of land fallow as soil management methods, and access to the off-farm activity. Adoption of inorganic fertilizer improved the probability of Sesame productivity by 15% for adopters and 26.1% for non-adopters had households decided to adopt.

Subjects: Agricultural Development; Agricultural Economics; Agriculture and Food

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PUBLIC INTEREST STATEMENT
The sesame sector is one of Ethiopia’s widely cultivating and important sectors, both in terms of its foreign exchange earnings and source of income for million Ethiopians and in Tigray region as well. These sesames also providing cooking oil which is preparing traditionally and it is also serving as source of feed in the Tigray Region. Although there was an increase in average land cultivation for the past year, sesame productivity is still low compared to the land cultivated for sesame particularly in the Region. To overcome the above problem the government was introduced inorganic fertilizer adoption to increase sesame productivity, but it is not assessed its real impact yet. Therefore, this study will expect to provide primary information on the impact of inorganic fertilizer adoption on sesame productivity.

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Additional information is available at the end of the article
1. Introduction

The continuous degrading of soil nutrients in low-income countries has been mainly credited to insufficient use of inorganic fertilizers besides weak soil conservation practices. Severe climatic situations and related features, like limited access to evidence for fertilizer price and on how to use it, the high cost of fertilizer reduce land productivity (SANGINGA & WOOMER, 2009). Even though Africa is not poor in natural resource endowment, but the poor outlook towards soil conservation practice leads to a decline in land productivity. For those to restore and protect the fertility of soil, there is a big tendency to adopt agricultural inputs that enhance land productivity in the region (Minot & BENSON, 2009).

Many African countries sold inorganic fertilizer at the subsidized fees by centrally regulated input and delivery schemes. Thus, differences in the delivery scheme were applied in low-income African countries, such as Malawi, Zambia, Zimbabwe, Kenya, and Ethiopia until the 1990s (Jayne & RASHID, 2013). Inorganic fertilizer in Africa is mainly distributed by public sectors due to extreme regulation by plenty of taxes imposed on private investment and with a higher level of corruption. Consequently, inorganic fertilizer distribution is largely controlled by the public sectors’ interventions (Minot & BENSON, 2009). Therefore, low-income countries show a mixture of two problems the low soil nutrient and limited access to inorganic fertilizer adoption. The average intensity of fertilizer use in low-income countries is 7 kg/ha significantly lower than in other developing regions of the world (Kelly, 2005).

The intensity of inorganic fertilizer used in low-income countries in Africa compared to other regions has usually been greatest in the south part 16 kg/ha and east part 8 kg/ha and the lowermost in Sudan 4 kg/ha and central part of Africa 3 kg/ha (Kelly, 2005). A large part of inorganic fertilizer is being applied to cash crops, for Banana farm, oilseed crops, coffee, rubber, and circus. Inorganic fertilizer also used in contract farming, like cotton, and its tendency inorganic fertilizer use has been improved with other policy involvements, such as an improved seed package. A current study by TEKLU (2016) upon some countries in Africa implies that fertilizer across the only fertilizer using households is highest in Nigeria 310 kg/ha, followed by Malawi 188.8 kg/ha, Tanzania 95.6 kg/ha, Ethiopia 81 kg/ha, Uganda 37.5 kg/ha and Niger 26 kg/ha. Similarly, inorganic fertilizer uses across all households is highest in Malawi 146 kg/ha, followed by Nigeria 128 kg/ha, Ethiopia 45 kg/ha, Tanzania 16 kg/ha, Niger 4.5 kg/ha, and Uganda 1.2 kg/ha.

In Ethiopia, due to fast population growth and resulting high demand for food, energy, and housing have considerably transformed land-use practices and severely degraded the countries forest and land. Furthermore, the practices of old-style soil protection have caused poor soil productivity, and the forest resources have been declining in coverage. Soil fertility conservation practice in Ethiopia is not optimum that affects crop productivity (TEKLU, 2016). In Ethiopia, the adoption rate of inorganic fertilizer is low which is 45 kg/ha. The content of soil nutrient exhaustion in smallholder farms is one of the important biophysical causes of decreasing crop productivity in Ethiopia. The exhaustion rate of soil nutrient for N, P, K is 122 kg/ha, 13 kg/ha and 82 kg/ha, respectively (HAILESLASSIE et al., 2005). The inorganic fertilizer adoption per hectare of some crop types in Ethiopia is 57 kg for Wheat, 41 kg for Sesame, 40 kg for Teff, 29 kg for Maize, 22 kg for Barley, 3 kg for Sorghum (AMARE et al., 2019). However, studies assert that there is an imbalance regarding soil nutrients for entire crops in Ethiopia. These statistics indicate that the national level intensity of fertilizer use is still lower than the recommended rate of 200 kg/ha (ENDALE, 2011).

In Ethiopia, due to an increase in mining activity, the soil nutrient depletion rate also rising. Thus, there is a big threat to both land productivity and decreasing of poverty. Even though there is an inorganic fertilizer distribution by the government. They are inefficient compared to the demand of
the farmers on the ground. The price of inorganic fertilizer by itself is unaffordable for the poor farmers which highly influence the farmers’ decision to, or not to use inorganic fertilizer (KENEA et al., 2019). Setit Humera district among the potential area of sesame farming in Ethiopia has been facing many farming problems, such as yearly variability of rainfall, reduced soil fertility, and market fluctuation mainly for Sesame. Land degradation, low land productivity, food insecurity, and poverty are the most common and interconnected challenges in the Tigray region and the Humera district in particular (VAN DER VEEN & GEBREHIWOT, 2011). Due to the expansion of extensive farming and deforestation in the district has been produced serious land degradation, soil erosion, poor soil fertility, and reduce the productivity of the land. To increase Sesame productivity and reduce the level of food insecurity in the Humera district, numerous involvements to address the above problems have been applied yet.

Among the interference which focuses on reducing the problem of low Sesame productivity encompasses the Ethiopia Strategy Support Program II, Farmer's Cooperative Union, Improving Productivity and Market Success, Farmer Training Centers, Agricultural Value Chain Project, and the government are also is a big supplier of fertilizer. Those are the programs that have been implemented in the district. Despite, there is a soil conservation practice in the district, there is limited evidence regarding its impact on Sesame productivity. Studies indicating that government inorganic fertilizer’s supply and the above project’s success are crucial for the sustained use of inorganic fertilizer in the district. Hence, this study aims to fill the knowledge gap and offer empirical evidence that notifies the policy dispute regarding the adoption of inorganic fertilizers to smallholder farmers to enhance sesame productivity. The results of the study are important to policymakers and literature. Firstly, it provides micro-level empirical evidence regarding inorganic fertilizer adoption that alters therefrom. Secondly, this finding will help to the literature by identifying whether or not this adoption is improving Sesame productivity. Hence, no studies have been conducted yet in the district.

In general, in low-income countries, Some studies (De Brauw et al., 2016; MATSUMOTO & YAMANO, 2010; NGWIRA et al., 2013) have been assessed the effect of inorganic fertilizer adoption on cash crops. Furthermore, a study by Sheahan and Barrett (2017) stated that fertilizer adoption in Ethiopia, Malawi, Niger, Nigeria, Tanzania, and Uganda is not equally low across those countries. However, those studies were basically focused on adoption rate with limited evidence of its impact on land productivity. Those studies indicated that the adoption of inorganic fertilizer can be improved by introducing high-value crops, reducing the period of land fallow, intercropping crops and trees, minimize the establishment costs, and introducing higher-value by-products.

Despite, inorganic fertilizer in Ethiopia is adopting for Sesame to improve its productivity, no study has been conducted on the impact of inorganic fertilizer adoption on Sesame productivity in the Humera district. Humera district makes a motivating area for this study given with the inorganic fertilizer is newly introduced in the district, the volume of sesame produces, and the high level of poverty. Eventually, evidence of an inorganic fertilizer impact on Sesame productivity will inform policymakers and experts to adopt a sounder approach in implementing future interventions. Thus, this study was focused on the sesame productivity using propensity score matching and endogenous switching regression.

2. Materials and Methods

2.1. Description of the study area
This study was conducted in Setit Humera district of the Western Zone of the Tigray region in northwestern Ethiopia, which is located between 36° 27’ 5” to 37° 33’ 7” east longitudes and between 13° 39’ 46” to 14° 26’ 35” north latitudes. The total land surface of the district is 4,542.33 square kilometers. The average annual temperature of the district is 27°C with annual rainfall is 510 millimeters. It is bordered in the west by Sudan, in the north by Eritrea, in the south of Kafa
Humera district, and in the east by the Kafta Humera district. Based on the 2007 national-level census conducted by the Central Statistical Agency of Ethiopia (CSA) the district has a total population of 92,167, of whom 47,909 are men and 44,258 are women with the population density of 20.29, which is total 23,449 households were counted in the district. The total land devoted to sesame cultivation is 2764.91 square kilometers and 68.8% of the farmers are growing both crops and livestock, while 27.97% only grow crops and 3.23% only raise livestock (NEGASH & Swinnen, 2013) (Figure 1).

2.2. Sampling techniques
A three-stage sampling technique was employed in this study. In the first stage, the Setit Humera district was purposively selected from the two districts in the western Tigray region based on the amount of sesame produced, accessibility and the district is new adopters of inorganic fertilizer. Second, there are four kebeles in Setit Humera district and three kebeles were randomly selected. Finally, 393 Sesame producer’s households were selected by stratified random sampling method. Using Yamane (1967), the required sample size was determined, where ndonates sample size, Ndonates the total population of the district and edonates the margin of error of the sample size 5% (implying 95% confidence level).

2.3. Data source and collection methods
For this study, both primary and secondary sources of data were adopted. Cross-sectional data contained socio-economic and demographic characteristics of smallholder sesame producer farmer’s fertilizer adopter and non-fertilizer adopter, amount of land devoted to sesame cultivation and other crop types, total amount of sesame production, crop rotation system access to extension services were collected through preparing a semi-structured questionnaire which was administered to randomly selected sesame growing farmers. The primary data was conducted through face-to-face interviews with farmers as the majority of the farmers were not able to read and write. The two-day training was given to the data collector regarding the volume of the survey to collect valid and reliable data from the households. To triangulate the primary data secondary data consisted of sesame production, study area description, and production characteristics were collected from the Agricultural office of the district, related book chapters, annual reports, and government documents.
2.4. Data analysis

Data on the socio-economics profile and demographic characteristics of the respondents were presented using frequency distribution of tables, t-test, means, standard deviation and local polynomial smoothing graph also employed to analyze the relationship between the total sesame produced versus total farm size cultivated for Sesame and land productivity versus total hectare cultivated by adopters and non-adopters. The propensity score matching was used to estimate the potential determinants of fertilizer adoption in the district. Furthermore, the propensity score matching control for selection bias and provides unbiased estimates through controlling for observed confounding factors, but not the unobserved biased (AAKVIK et al., 2005; ABADIE et al., 2004; IMBENS & Wooldridge, 2009; Lee, 2005; ROSENBAUM & Rubin, 1983) were employed. Finally, to analyze both the observed and unobserved bias in estimating the impact of inorganic fertilizer adoption on sesame productivity Endogenous Switching Regression model was employed. Based on different kinds of literature most study regarding impact evaluation that depends on cross-sectional data have used similar estimation model (DI FALCO et al., 2011; FUGLIE & Bosch, 1995; KLEEMANN & ABDULAI, 2013; NEGASH & Swinnen, 2013; NOLTZE et al., 2013).

3. Results and discussion

3.1. Descriptive statistics of variables

(Table 1 and 2) showed that the summary statistics of sampled sesame producing farmers. The result implied that there was a significant difference for both an outcome and repressor variables regarding adoption status. The farmers who used inorganic fertilizer were designated as adopters and they contain 60% of the total sampled households. The data result presented indicated that there was no statistically significant difference between adopters and non-adopters in land productivity. The variables that were found to be statistically significant for adopters were the age of farmers, household size, educational status of farmers, the practice of crop rotation, economically active household members, access to extension services, and proportion of male adults in the household. One important information observed that adopters of inorganic fertilizer had extra years of farming experience compared to the non-adopters, but the rest of the variables were not statistically significant. The advantage of having a long-time experience in farming operations helps farmers to adopt newly introduced agricultural inputs. Household size and proportion of male adults in the household also had a crucial role in supporting family labor in the adoption of soil furtherance inputs.

According to the result young household with high educational status adopt inorganic fertilizer than older and illiterate households. This implied that age and education play a significant role in sesame productivity. Access to extension service contributes a crucial role for the dissemination of agricultural inputs to farm households and the findings indicated that adopters had more frequent visits than non-adopters of inorganic fertilizers. The land ownership also plays a great role in increasing land productivity. According to AZUMAH and ZAKARIA (2019), owning farmland has an important contribution to the adoption of agricultural technologies.

| Table 1. Distribution of sampled households by kebeles |
|------------------------------------------------------|
| Sampled Kebeles | Total households | Total sample size | Adaptors | Non-adopter |
|-----------------|------------------|------------------|-----------|------------|
| Kebele 1        | 2140             | 130              | 86        | 44         |
| Kebele 2        | 3080             | 160              | 100       | 80         |
| Kebele 3        | 1003             | 103              | 48        | 35         |
| Total sampled households | 234              | 159              |           |            |
The non-parametric local polynomial smoothing regression result in a positive correlation between the amounts of sesame produced the dependent variable and the independent variable area under cultivation for sesame was observed. This positive relationship was shown throughout the whole farm sizes. As presented in (Figure 2 and 3), initially, it seems constant, but later it increases. Similarly, there was a positive correlation between sesame productivity and hectare under cultivation, but this was observed for small farm size farmers only up to four hectares beyond that they were negatively related for large farm size farmers. This relationship has been shown that farmers with lower landholding were more expected to adopt newly introduced inputs to improve their productivity. This was in agreement with the studies of AZUMAH and ZAKARIA (2019) indicated the inverse relationship between land productivity and hectares under cultivation in low-income countries.

A slightly similar relationship in land productivity was found between adopters and non-adopters of inorganic fertilizers in the district. The dependent variable was log sesame productivity and the independent variable was land under sesame cultivation. But, relatively, adopters had continuous

| Variables                                   | Total sample (n = 393) | Adopters (n = 234) | Non-Adopter (n = 159) | t-test  |
|---------------------------------------------|------------------------|--------------------|-----------------------|--------|
| Mean                                        | Mean                   | Mean               | Mean                  |        |
| Land productivity (log), outcome variable   | 2.569(0.999)           | 2.592(0.947)       | 2.535(1.072)          | 0.579  |
| Explanatory variables                       |                        |                    |                       |        |
| Age of farmers                              | 39.353(10.456)         | 44.589(7.956)      | 31.647(8.806)         | 0.000  |
| Sesame farm                                 | 7.081(4.670)           | 6.844(15.177)      | 7.430(13.929)         | 0.697  |
| Household size of farmers                   | 3.839(1.527)           | 3.995(1.480)       | 3.610(1.570)          | 0.013  |
| Educational status of the household head    | 8.707(1.967)           | 8.346 (2.285)      | 9.144(1.637)          | 0.000  |
| Marital status of farmers                   | 0.928(0.257)           | 0.923(0.267)       | 0.937(0.243)          | 0.596  |
| farming experience of farmers               | 9.865(7.355)           | 10.070(6.822)      | 9.562(8.089)          | 0.502  |
| Access to off-farm working                  | 0.470(0.499)           | 0.495(0.501)       | 0.433(0.497)          | 0.697  |
| Practice of crop rotation                   | (0.491(0.500)         | 0.529(0.500)       | 0.433(0.497)          | 0.062  |
| Economically active household members       | 3.216(1.378)           | 3.380(1.341)       | 2.974(1.400)          | 0.004  |
| Total land for farming of farmers           | 9.601(15.961)          | 3.995(1.480)       | 9.665(15.143)         | 0.947  |
| Practice of land fallow                     | (0.432(0.496)         | 0.452(0.498)       | 0.402(0.491)          | 0.322  |
| Land ownership                              | 0.595(0.491)           | 0.628(0.484)       | 0.547(0.499)          | 0.108  |
| Access to extension services                | 0.636(0.481)           | 0.679(0.467)       | 0.572(0.496)          | 0.030  |
| Gender                                      | 0.659(0.474)           | 0.645(0.479)       | 0.679(0.468)          | 0.487  |
| Proportion of male adults in households      | 1.796(1.007)           | 1.871(1.010)       | 1.685(0.994)          | 0.071  |

Notes: Mean and standard deviations are in parentheses.
higher land productivity compared to non-adopters. The positive relationship between land productivity and adopters of inorganic fertilizer has been shown over the whole farm size. However, the pattern for non-adopter was not similar it changes with the size of the landholding. This accomplished relationship might be due to the other variables that were not controlled by the non-parametric local polynomial regression which influenced land productivity.

3.2. Effect of inorganic fertilizer on Sesame productivity: Propensity score matching result

The result indicated that factors affecting the adoption of inorganic fertilizer were assessed by adopting the probit PSM regression model. Furthermore, the different estimates of matching algorithms were also employed (Table 3). The nearest neighbor matching algorithm estimation of the mean treatment on the adopters of inorganic fertilizer (ATT) revealed that on average, adopters of inorganic fertilizer would have produced 0.12 quintals per hectare higher than had they did not adopt the inorganic fertilizer. Likewise, the other matching algorithm estimation such as radius, stratification, and kernel implied that adopters of inorganic fertilizer would have produced 0.13 quintals per hectare higher compared to had they did not adopt inorganic fertilizer. This
Table 3. Estimates of matching algorithm

| Matching algorithm | No. of Treat | No. of Control | ATT | t-test |
|--------------------|--------------|----------------|-----|--------|
| Stratification     | 234          | 144            | 0.136 | 0.990 |
| Nearest neighbor   | 234          | 58             | 0.120 | 0.430 |
| Radius             | 234          | 159            | 0.122 | 0.775 |
| Kernel             | 234          | 159            | 0.134 | 0.892 |

Notes: ATT estimates were obtained after implementing propensity score matching.

Table 4. Propensity score matching estimate of inorganic fertilizer adoption (probit model)

| Variables                        | Sesame productivity (log) | Coefficient | Std.error | P value |
|----------------------------------|---------------------------|-------------|-----------|---------|
| Years of farming experience      |                           | −0.058      | 0.012     | 0.000*** |
| Age                              |                           | 0.117       | 0.010     | 0.000*** |
| Educational status               |                           | 0.022       | 0.043     | 0.606   |
| Access to off-farm activity (1 = yes) |                       | 0.470       | 0.168     | 0.005*  |
| Access to extension service (1 = yes) |                       | 0.430       | 0.164     | 0.009*** |
| Total farm size                  |                           | −0.001      | 0.005     | 0.844   |
| Marital status (1 = married)     |                           | −0.581      | 0.315     | 0.065 ** |
| Gender (1 = male)                |                           | −0.173      | 0.172     | 0.312   |

*, **, *** significant at less than 10%, 5%, or 1% respectively.

finding agrees with different studies that the adoption of inorganic fertilizer has a significant positive impact on land productivity in general which conducted in Ethiopia, Kenya, Nigeria, Zambia, and Tanzania (Khonje et al., 2015; Mason & SMALE, 2013; SIMTOWE et al., 2012; TAMBO & WUNSCHER, 2016; TURA et al., 2010) respectively.

The propensity score model result implies that the adoption of inorganic fertilizer was affected by years of farming experience, access to off-farm income, perception of soil fertility, access to extension service, and age of the respondents (Table 4). The result indicated that year of farming experience was negatively correlated with the adoption or use of inorganic fertilizer (Table 4). This implied that individual farmer with higher experience in Sesame farming operation is less likely to apply inorganic fertilizer. This might be due to: first, the farmer with good farming experience had various indigenous accumulated knowledge or skills that increase land productivity. Secondly, the cost of inorganic fertilizer is another challenge especially for the poor farmers and they choose their past farming experience at no cost. The age of respondents in sesame productivity was significant and positively affected the adoption of inorganic fertilizer (Table 4). The marital status of the farmers was negatively associated with the adoption of inorganic fertilizer. Individual farmers who married were less likely to adopt inorganic fertilizer compared to the single farmers. Access to off-farm income was significantly and positively associated with the adoption of inorganic fertilizer. Thus, the result suggested that income diversification plays a vigorous role for inorganic fertilizer adoption. Visiting the farmer extension center is also significantly and positively related to the adoption of inorganic fertilizer. Hence, the frequent extension center visit contributed to gathering information and knowledge concerning the importance of inorganic fertilizer.
Table 5. Endogenous switching regression estimate of log productivity for adopters and non-adopters

| Variables                         | Log of productivity (adopters) | Log of productivity (non-adopters) |
|-----------------------------------|--------------------------------|-----------------------------------|
|                                  | Coefficient | Std.error | P value | Coefficient | Std.error | P value |
| Year of farming experience        | -0.001       | 0.004     | 0.712   | -0.009       | 0.005     | 0.064*  |
| Total land area                   | 0.007        | 0.002     | 0.002** | 0.018        | 0.003     | 0.000***|
| Economic active members           | -0.061       | 0.054     | 0.257   | -0.018       | 0.068     | 0.793   |
| Educational status                | -0.006       | 0.013     | 0.595   | -0.041       | 0.022     | 0.071*  |
| Household size                    | 0.123        | 0.042     | 0.004** | 0.052        | 0.057     | 0.360   |
| Land ownership (1 = owned)        | 0.517        | 0.085     | 0.000***| 0.603        | 0.119     | 0.000***|
| Sesame area cultivated            | 0.459        | 0.061     | 0.000***| 0.353        | 0.080     | 0.000***|
| Male adults in households         | -0.003       | 0.041     | 0.940   | 0.000        | 0.058     | 0.989   |
| Crop rotation practice (1 = yes)  | -0.029       | 0.084     | 0.729   | 0.091        | 0.116     | 0.430   |
| Access to extension (1 = yes)     | -0.025       | 0.060     | 0.672   | -0.017       | 0.072     | 0.812   |
| Practice of land fallow (1 = yes) | 0.331        | 0.095     | 0.001***| 0.378        | 0.124     | 0.002** |
| Access to off-farm activity (1 = yes) | 0.297    | 0.096     | 0.002** | 0.151        | 0.127     | 0.234   |
| rho_1, rho_0                       | 0.118        |           | 0.317   |             |           |        |
| Wald chi2                         | 817.810      |           |         |             |           |        |
| Log likelihood                    | -375.427     |           |         |             |           |        |
| LR test of Indep. eqns: chi2      | 3.460        |           |         |             |           |        |
| Number of observations            | 393          |           |         |             |           |        |

Notes: estimated by Full Information Maximum Likelihood

*significant at the 10% level, ** significant at the 5% level, ***significant at the 1% level

Table 6. Conditional expectation of sesame productivity, treatment, and heterogeneity effects

| Subsamples                        | Adoption Decision | Treatment effect |
|-----------------------------------|-------------------|------------------|
|                                   | To adopt          | Not to adopt     |
| Farm households that adopt        | 2.592 (0.855)     | 2.442 (0.943)    | ATT = 0.150** |
| Farm household that did not adopt | 2.796 (0.904)     | 2.535 (0.982)    | ATU = 0.261** |
| Heterogeneity effect              | -0.204**          | -0.093**         | -0.111*        |

Note: ** p < 0.05, * p < 0.1: 2.592 and 2.535 represents actual Sesame productivity, 2.796 and 2.442 represents counterfactual Sesame productivity. The value in parentheses depicts standard errors.

adoption for improving Sesame productivity. This result is consistent with the finding of (MARTEY et al., 2019).

3.3. Effects of inorganic fertilizer on sesame productivity: Endogenous switching regression result

The full information maximum likelihood estimation model was employed for further analysis of the model that provides full information regarding adopters and non-adopters of inorganic fertilizer which is estimated altogether (Table 5). The full information maximum likelihood and endogenous switching regression model also contain the result of selection equations and two different results for both adopter and non-adoptive of inorganic fertilizers estimated simultaneously. The selection model indicated the factors that determine the decision for the adoption of fertilizers. The result of endogenous switching regression implied that total land available for cultivation, household size of the farmers, land ownership, area under sesame cultivation, the periodic practice
of land fallowing, and access to off-farm activity were significantly determined sesame productivity among adopters.

Both of those variables were positively and significantly influenced the productivity of Sesame for the adopters of inorganic fertilizer in the district. Those who had large cultivated land, more household size, owned farmland, cultivating a large amount of farm for Sesame, applied of land fallow, access to an off-farm activity, or diversifying sources of income are more willing to adopt inorganic fertilizer to improve sesame productivity. The result indicated that farmers who practice fallowing had higher sesame productivity compared to those who practice continuous cropping. But fallowing by itself was not guaranteed for increasing sesame productivity. The land tenure system also plays a key role in adopting agricultural inputs. Those who had their land are enthusiastic to accept the new technology compared to contract or sharecropper farmers. Since possessing land reduces the cost of inputs. Therefore, increased the application of inorganic fertilizer leads to more productive land. The positive effect of land fallowing on land productivity is consistent with the finding of (MATSUMOTO & YAMANO, 2011). Also, access to off-farm income had a positive and significant impact on inorganic fertilizer adoption. This implies that households who had access to off-farm income had a higher likelihood of inorganic fertilizer adoption. Hence, off-farm activities deliver additional income for households that might be contributed to buy agricultural inputs. Nowadays, in Ethiopia, households are expected to cover the total cost of inorganic fertilizer and better-quality sesame seeds. This result agrees with the finding of (Shaibu et al, 2019) conducted in Ethiopia. It was also found that total farmland available for cultivation had a statistically significant impact on inorganic fertilizer. This outcome indicated that households with large farm size had a greater chance of adopting inorganic fertilizer. This finding is consistent with Oghereunuemu and Abdul-Hameed (2019) studied in Ghana.

Similarly, years of farming experience, total land available for cultivation, educational level of the farmers, the area under sesame cultivation, land ownership, and land fallow practices were also had significantly influenced among non-adopters (Table 5). The result for non-adopter revealed that farming experience had a negative and significant impact on the adoption of inorganic fertilizer. Suggesting that having an only better experience on-farm operation had not secured sesame productivity without enhancing soil fertility through the adoption of inorganic fertilizers. Opposite to the previous studies, it was found that farmers who had long-time farming experience had a higher likelihood of adopting inorganic fertilizer compared to those who had short time farming experience. Likewise, the educational status of farmers had a negative and significant impact on the adoption of inorganic fertilizer. This indicates that households with less level of education had a high likelihood of adopting inorganic fertilizer. This result implies households who had higher literacy levels did not guarantee to improve sesame productivity. This finding is consistent with Shaibu et al. (2019).

The predictable Sesame productivity for the counterfactual and actual circumstance between households who adopted inorganic fertilizer package and those who did not are shown in (Table 6). The expected sesame productivity for the adopters of the inorganic fertilizer was 2.59 quintals per hectare. Similarly, the expected sesame productivity for the non-adopters of the fertilizer was 2.53 quintals per hectare. The coefficient of average treatment on the treated (ATT) had a positive sign. This implies that the adopters of inorganic fertilizer produce more sesame compared to the non-adopters of inorganic fertilizers. For the counterfactual situation (row 1), households who adopted the inorganic fertilizer would have harvested 2.44 quintals of sesame per hectares if they had not adopted. For the counterfactual circumstance (row 2) where households who did not adopt had decided to adopt, they would have harvested 2.79 quintals of sesame per hectare. The result indicates that the inorganic fertilizer adoption program increased sesame productivity. The transitional heterogeneity impact was negative, which implies that the impact of the inorganic fertilizer was higher for the households who adopted compared to those who had not to adopt the package. Inorganic fertilizer intervention plays a crucial role in low-income countries to enhance land
productivity. The findings (Asfaw et al., 2012; BAYU et al., 2006; MARTEY et al., 2019; TADESSE et al., 2013) from endogenous switching regression coefficient and the treatment effect on the treated indicated that there was a direct relationship between inorganic fertilizer adoption and land productivity.

4. Conclusion

Inorganic fertilizer adoption plays a crucial role in improving the livelihood of poor farmers by enhancing land productivity. To make easily accessible the inorganic fertilizer input for those agricultural input poor farmers in the district such kinds of major policy intervention packages was important. The total land area available for cultivation, household size, land ownership, farm area under cultivation for sesame, the practice of land fallowing, and access to off-farm activity are the most important factors which significantly affect sesame productivity using inorganic fertilizers. Correspondingly, years of farming experience, total landholdings by the farmers, educational status of farmers, land ownership, farm area under sesame cultivation, and practice of land fallowing are importantly influenced the log sesame productivity amongst the non-adopters of inorganic fertilizers. The study demonstrates that the adoption of inorganic fertilizer has a positive impact on sesame productivity. The result of the study also supports other scholar studied in different areas that provides weight the necessity to encourage farmers’ accessibility for agricultural inputs to boost sesame productivities. Due to the incapability of controlling the time-variant variable adopting the cross-sectional data for an impact assessment may be uncertain. This study also lacks in terms of incapability to assess the variability of inorganic fertilizer applications. This study indicates the future studies to focus their investigation regarding the amount of inorganic fertilizer use per hectare, the length of land fallow, and crop rotation practices as remedial of the impact of soil fertility enhancement mechanisms on sesame productivity. Regarding the agricultural policy of outlook, continuing access to agricultural input plays a crucial role in improving sesame productivity.

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