# Drivers of Organic Fertiliser Adoption and Use Intensity Among Smallholder Maize Farmers in Lake Victoria Region, Western Kenya

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**Abstract**: Smallholder farmers account for about 75% of maize production in Kenya. The current average on-farm productivity is 1.43 ton/ha against the potential of 6 ton/ha. In Western Kenya, low soil organic carbon is one of the contributors to the low maize productivity. Studies have shown that organic fertilizers contribute towards increase in soil productivity. However, there is paucity of information on the relationship between drivers of organic fertilizers adoption and use intensity among the farmers, which the study seeks to address. A total of 358 farmers were interviewed in the 2020/21 growing seasons. Heckman's two-stage model was estimated. The results demonstrate that age, education, gender, soil quality perception and access to supportive resources are pivotal in shaping organic farming decisions. There is need for targeted extension services to less educated and older farmers. Off-farm income generation should be encouraged. Integrated soil fertility management approaches that address nutrient replenishment and soil erosion control is necessary, and there is need to promote mechanization or subsidization of organic fertilizer application on larger farms as this may help overcome labour constraints and improve organic fertilizer adoption on a broader scale. The results may be a source of literature for subsequent studies in related fields.

**Keywords:** Drivers of organic fertilizer; Use intensity; Heckman Two-Stage; Maize; Western Kenya

## 1. Introduction

Maize (*Zea mays*) is Kenya's main staple food crop grown mainly by small scale farmers who contribute approximately 75% of the total output (Nyoro, 2002). The current average on-farm productivity of this crop is 1.43 ton/ha (FAOSTAT, 2024), which is far below the attainable potential of 6 ton/ha when the crop is grown under suitable agronomic and management conditions using the right quality of fertilizers and improved hybrids adaptable to the agro-ecological zones (Odendo et al., 2001). The supply and demand sides of the fertiliser industry both contributed to the over 70% increase in prices worldwide between 2020 and 2021. (Smith, 2022). Supply-side price increments were due to interruptions brought on by COVID-19 and growing energy costs associated with the manufacture of essential fertilizer

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components, notably ammonia for nitrogen-based fertilizers (Wongpiyabovorn et al., 2022). Within the same period, demand side indicators showed that prices for agricultural commodities such as corn, soybeans, and wheat increased. This in turn motivated farmers to increase agricultural acres and fertilizer application rates. This scenario coupled with limited supply led to drastic rise in the prices (Baffes & Koh, 2021).

Kenya suffered a 50–60% spike in prices for fertilizer between 2020 and 2021 (WFP, 2022). This, together with a prolonged period of poor rainfall seasons that caused the region's worst drought in 40 years, resulted to a decrease in maize output of almost 550,000 MT (FAOSTAT, 2024). In Western Kenya, one of the major causes of the low maize crop yields is the low soil organic carbon and declining soil fertility. Most soils in Western Kenya are rich in oxides and have high acidity, aluminium toxicity and low fertility. The use of inorganic and organic fertilizers can contribute towards maintenance or increase in soil productivity.

Previous researchers (Baiphethi & Jacobs, 2009; Cedric & Nelson, 2014; Zondo, 2020) contend that adopting a more feasible, affordable, and effective integrated nutrient management system which also better suits the socioeconomic status of smallholder farmers is one way to increase productivity without degrading the environment. As a result, the use of organic fertilizer and manure is encouraged. Organic fertilizer is one example of a sustainable agricultural input that has received considerable promotion, yet the economic relationship between its adoption, intensity of adoption, and farmers' socioeconomic conditions has not been sufficiently investigated. It is on this basis that this study was carried out to identify the variables that affect smallholder maize growers' choice to adopt organic fertilizer and the varying degrees of organic fertiliser use in Western Kenya. In the context of this study, organic fertiliser includes agricultural residue, animal manure, compost, and green manure that can be used to provide a sufficient supply of nutrients to crops (Lewu et al., 2020).

## 2. Materials and Methods

### 2.1. Study Area, Sampling Procedure and Data Collection

The study was conducted in Kenya's Lake Victoria region, covering three counties: Kisumu, Siaya and Homa Bay. The target respondents were the maize farmers drawn from the three counties. Given that the population of maize farmers is infinite and exceeds 10,000, the sample size was estimated using the scientific approach by Cochran (1977) specified as:

$$n = \frac{z^2 pq}{e^2}$$

Where:

$n$ is the sample size,

$Z^2$ is the abscissa of the normal curve that cuts off an area α at the tails $(1 - \alpha)$ equals the desired confidence level at 95%),

$e$ is the desired level of precision,

$p$ is the estimated proportion of an attribute that is present in the population, and

$q$ is $1 - p$.

The estimated sample size (n) was therefore equal to $\frac{1.96^2(0.5)(0.5)}{0.5^2} = 384$. Data for the study was collected through a cross-sectional survey using a well-structured questionnaire. A maize-producing household constituted a unit of analysis. Given that almost every household in each of the three counties engages in maize production and that the variability in the proportion that engaged in maize production as at the survey time could not be established in each county, the 384 was thus equally divided among the counties where each had a sample size of 128 potential respondents. Cluster sampling technique was adopted where the counties were clustered into administrative sub counties in which Homa Bay had a total of 8, Siaya 6 and Kisumu 7. Samples were then taken from the randomly selected clusters.

Data on household demographics, including gender, age, marital status, farming experience, family size, and level of education, as well as socioeconomic characteristics of smallholder maize farmers were gathered. Engagement in off-farm employment, use of manure (organic fertilizer) and usage intensity of organic fertilizer were also included in the questionnaire.

To ensure accurate and complete recording of data, the questionnaires were reviewed after each interview with the respondents. Additionally, the same set of questions was applied throughout the research locations in order to guarantee that the information gathered was uniform across the sampled smallholder maize farmers.

### 2.2. Statistical Analysis

Data was managed using Statistical Package for the Social Sciences (SPSS) version 21 before econometric analysing using STATA version 17 MP. Descriptive analysis was used to determine the percentages, means and frequency distributions among the smallholder farmers. Chi-square and t-tests were used to determine statistically significant differences in socioeconomic, demographic and farm level characteristics between adopters and non-adopters of organic fertiliser. The Heckman two-stage model was used for inferential statics to estimate variables that influenced the organic fertiliser use and intensity.

### 2.3. Empirical Models

The decision to use organic fertiliser adoption solely depended on the household's discretion. It was anticipated that not every maize growing household would use organic fertiliser on their maize plots. Hence, sample selection bias was the underlying econometric issue that was most likely to surface in such an instance.

Although it is absolutely essential for the adoption variable, the sample as a whole does not show this. Non-adopters are omitted, which censors the dependent variable and makes it possible that the residuals do not meet the requirement that the sum of the residuals must equal zero (Maddala, 1983). The current study used the Heckman two-stage estimation model to address the issue of sample selection bias. Thus, using organic fertilizer involved a two-stage process: the first stage had to do with the probability of adoption using the Probit maximum likelihood function. The second stage took into consideration the extent (intensity) to which a farmer adopts the organic fertiliser and this is done by means of Ordinary

Least Square (OLS) estimator. Since the decision on intensity largely depended on that taken in the former, it is likely that the procedure in the second stage is not random thereby creating selectivity bias. This is because only those who were positively affected by the determinants of adoption will adopt the technology. Hence, the use of the Heckman's two-stage model to correct for the sample selection bias (Heckman, 1979).

In the first step, organic fertiliser adoption decision of maize growing households, which estimates the probability of a household's head to adopt organic fertilizer, was estimated using the probit model as the selection equation (Heckman, 1979) as shown below:

$$D_i^* = \beta_O + \beta_i X_i + \mu_i; \qquad (Eq.1)$$

Where $D_i^*$ =was an unobserved latent variable representing decision to use organic fertiliser of the $i^{th}$ maize growing household, $\beta$ =a vector of parameters to be estimated, $X_i$ =a vector of the explanatory variables (for example household characteristics, farm-specific attributes, assets etc.) that affect adoption decision measured on the $i^{th}$ maize growing household, and $\mu_i$ is the $i^{th}$ error term assumed to be normally distributed. The observed binary variable was expressed as:

$D_i = 1\ if\ D_i^* > 0$ for farmers using organic fertiliser

$D_i^* = 0, otherwise$ for farmers not using organic fertiliser

In the second step, the amount of organic fertiliser used in kg/ha was used as a proxy for the intensity of adoption. This was estimated using an Ordinary Least Square (OLS) equation given as:

$$Y_i = \alpha_0 + \alpha_i Z_i + \mu_i; \qquad (Eq.2)$$

Equation 2 is a sub-sample of equation (1) and is only estimated for maize farming households who use organic fertiliser. To correct for self-selection biasness in the second stage, an Inverse Mills Ratio (IMR) denoted by the symbol $\lambda$ is added as an additional explanatory variable. Following Greene (2003), the calculated IMR offers OLS selection adjusted estimates. By adding IMR and as such correcting for selection bias, Equation 2 is translated into Equation 3 as:

$$Y_i = \alpha_0 + \alpha_i Z_i + \delta_i \lambda_i + \mu_i; \qquad (Eq.3)$$

Where $Y_i$ = organic fertiliser in kg/ha by a maize growing household as a proxy for intensity of organic fertilizer adoption, $\alpha$ = a vector of coefficients that need to be estimated in the outcome equation, $Z =$ explanatory variables that are expected to affect the intensity of organic fertiliser use, and $\lambda_i$ = selection bias correction factor (IMR), $\delta_i$ is the coefficient of IMR and $\mu_i$ is the $i^{th}$ error term.

A statistically significant value of $\lambda_i$ means that significant difference exists between the household's that use organic fertiliser and those that did not use organic fertiliser, and, therefore Heckman's two-stage model is appropriate for the estimation (Marchenko & Genton, 2012). The IMR is the ratio "the ratio of the ordinate of a standard normal distribution to the tail area of the distribution" and is formulated by an extrapolation process of the Probit model fitted in Equation 1.

$$\lambda_i = \frac{\varphi(X_i \alpha)}{\phi(X_i \alpha)} \qquad (Eq.4)$$

Where $\varphi$ is a standard normal probability density function, while $\phi$ is a standard normal cumulative density function. In addition, $\phi$ is a two-sided error term with $N(0, \sigma_v^2)$. The rest of the notations are as previously defined.

### 2.4. Description of Variables Used in Data Analysis

The study examined the drivers of the probability and intensity of organic fertilizer use among smallholder maize farmers in Lake Victoria region of Western Kenya. The dependent variables and independent variables hypothesized to influence the adoption and use intensity of organic fertilizer are defined and presented in Table 1 and Table 2.

**Table 1. Definition and description of dependent variables used in the analysis**

| Variable | Description | Nature | Categories/ Unit |
|---|---|---|---|
| ORGANIC_USE | Farming households that use organic fertiliser | Categorical | 0=No |
| | | | 1=Yes |
| ORGANIC_INT | Amount of organic fertiliser applied | Numerical | Kg/Ha |

**Table 2. Definition and description of independent variables used in the analysis**

| Variable | Description | Nature | Categories/ Unit |
|---|---|---|---|
| Age_Head | Age of household head | Numerical | Years |
| Chem_Use | Uses chemical fertilisers | Categorical | 0=No; 1=Yes |
| Gender_Head | Gender of household head | Categorical | 0=Female; 1=Male |
| Education | Education categories | Categorical | 0=None; 1=Primary |
| | | | 2=Secondary and Above |
| HH_Size | Household size | Numerical | Number Of Individuals |
| Livestock_Own | Farmer owns animals | Categorical | 0=No; 1= Yes |
| Occupation | Primary occupation of farmer | Categorical | 1=Farming; 2=Salaried Worker |
| | | | 3=Self-Employed; 4=Labourer |
| | | | 5=Retired |
| Labour_Hire | Hires labour for manure application | Categorical | 0=No |
| | | | 1=Yes |
| Soil_Qlty | Perception of soil quality | Categorical | 0=Poor; 1=Satisfactory |
| | | | 2=Very Good |
| HHLD_EDUC | Highest education level in the house | Categorical | 0=None; 1= Primary |
| | | | 2=Secondary;3= University |
| MAIZE_acreage | Total acreage under maize | Numerical | Hectares |
| FARMSIZE | Total farm size | Numerical | Hectares |
| OFF_FARM | Household head has off-farm employment | Categorical | 0=No; |
| | | | 1=Yes |

| | | | |
|---|---|---|---|
| EROSION | Extent of erosion on farm | Categorical | None; Mild, Severe or Worse |
| NUTRIENT_DEF | Farmer experiences nutrient deficiency in maize crop | Categorical | 0=No |
| | | | 1=Yes |
| TENURE | Farmer owns land | Categorical | 0=No; 1=Yes |
| FARMING_Primary | Farming is main occupation of household head | Categorical | 0=No |
| | | | 1=Yes |
| MARITAL_STAT | Marital status of household head | Categorical | 0 =Not Married/Divorced/Single |
| | | | 1=Married |
| CHEM_TYPE | Type of chemical fertilise used | Categorical | 0=None; 1=DAP; 2=NPK |
| CHILD_DEP | Child dependency ratio | Numerical | Ratio |

*Source: Survey data*

## 3. Results and Discussion

### 3.1. Description of Socio-Economic, Demographic and Farm Characteristics

The survey achieved a response rate of 93.23% of the estimated 384 sample size. This response rate was more than the 60% threshold for surveys as recommended by Fincham (2008). As a result, the data set profiled 358 observations of maize farmers where 49.4% used organic fertiliser on their farms while 50.6% did not, indicating a relatively balance distribution between adopters and non-adopters of organic fertiliser. The share of farmers who used organic fertiliser among farmers varied across different counties within the sample. Specifically, 45.1% of farmers in Siaya were adopters of organic fertiliser followed by Homa Bay at 45.6%. Kisumu County had the highest proportion of farmers who had adopted organic fertiliser use at 57.5%.

Descriptive statistics of the continuous and categorical independent variables are summarized in Table 3 and Table 4 respectively. The results in Table 3 presents means and t tests for continuous variables while Table 4 presents proportions, frequencies and chi- square results of categorical variables.

Results showed that adopters of organic fertiliser had statistically significant larger household sizes, older household heads, more land under maize cultivation, and larger total farm sizes compared to non-users of organic fertiliser (Table 3). Specifically, households that used organic fertiliser were significantly larger ($p<0.01$) than household that do not use organic fertiliser. This is reflected in their age means of 51 and 48 years, for adopters and nonadopters of organic fertiliser respectively. This implies that adoption increases with an increase in age among the maize farmers in the region. Similar results were observed among adopters and non-adopters of organic fertiliser for agricultural production (Andaregie et al., 2022; Bidzakin et al., 2023; Zondo, 2020). In contrast, Kiprotich et al. (2024) and Xu et al. (2014) found that on average, the mean age of cereal farmers who used organic fertiliser were significantly lower than non-adopters of organic fertiliser.

**Table 3. Comparative descriptive statistics of socio-economic and demographic continuous variables by adoption status**

| Variable | Adopters | Non-Adopters | Overall mean | t values |
|---|---|---|---|---|
| Household size | 5.05<br>(2.00) | 4.68<br>(1.92) | 4.86<br>(1.96) | -1.72* |
| Age of household head | 51.34<br>(15.54) | 47.82<br>(14.11) | 49.56<br>(14.92) | -2.24** |
| Total acreage under maize | 1.40<br>(1.04) | 1.12<br>(0.76) | 1.26<br>(0.92) | -2.84*** |
| Total farm size | 1.79<br>(2.00) | 1.28<br>(1.18) | 1.53<br>(1.66) | -2.90*** |
| Child dependency ratio | 0.79<br>(0.81) | 0.70<br>(0.81) | 0.74<br>(0.81) | -0.99 |

**Figures in parenthesis represent standard deviation*

*Source: Authors' computation from survey data*

Regrading farm size and area allocated to maize production, Table 3 shows that the average farm size among the sampled households was 1.53 hectares, with an average of 1.26 hectares dedicated to maize. This highlights that majority of the land used for farming was primarily for maize cultivation. The results also showed statistically significant ($p<0.01$) differences for both total acreage under maize crop and total farm size (Table 3). This indicated that organic fertiliser users had significantly larger acreage under maize crop and, also significantly larger farm sizes than non-organic fertilizer users. This implies that households that generally had more land for farming and more land under maize had a greater incentive to use organic fertiliser for maize productivity. These findings specifically correspond to other studies (Belete, 2022; Dube, 2016) who posited that the average for farm size was higher among the adopters compared to the non-adopters organic fertiliser farmers.

On average, the household size for adopters and non-adopters was about 5.05 and 4.9 people, respectively. While this difference was marginally statistically significant ($p<0.1$), it shows that adopters have relatively larger households (Table 3). Similar significant differences in mean household size between adopters and non-adopters of organic fertiliser have been reported in Andaregie et al. (2022); Belete (2022); Daadi and Latacz-Lohmann (2021) and Zondo (2020) for mean household size, than non-adopters.

Descriptive statistics results of the chi-square test of independence for the categorical variables comparing adopters and non-adopters of organic fertiliser use among maize farming households are shown in Table 4. Overall, adopters of organic fertiliser differ from non-adopters across the variables related to soil management (i.e., use of chemical fertiliser, type of chemical fertiliser used, perception of soil quality, extent of soil erosion, nutrient deficiency in maize crop), gender of household head and hiring of labour.

**Table 4. Comparative descriptive statistics of socio-economic categorical variables by adoption status**

| Variable | Categories | Percentages (Frequencies) | | Total | Chi-square value |
|---|---|---|---|---|---|
| | | Adopters | Non-adopters | | |
| | No | 20.3(36) | 7.7(14) | 14.0(50) | 11.832*** |

| | | | | | |
|---|---|---|---|---|---|
| Uses chemical fertilisers | Yes | 79.7(141) | 92.3(167) | 86.0(308) | |
| Farmer owns animals | No | 69.3(52) | 72.2(52) | 70.7(104) | 0.148 |
| | Yes | 30.7(23) | 27.8(20) | 29.3(43) | |
| Primary occupation of farmer | Farming | 64.4(114) | 66.3(120) | 65.4(234) | 5.747 |
| | Salaried worker | 9.0(16) | 13.8(25) | 11.5(41) | |
| | Self-employed | 18.6(33) | 13.8(25) | 16.2(58) | |
| | Labourer | 3.4(6) | 4.4(8) | 3.9(14) | |
| | Retired | 4.5(8) | 1.7(3) | 3.1(11) | |
| Hires labour for manure application | No | 74.6(132) | 98.9(179) | 86.9(311) | $46.404^{***}$ |
| | Yes | 25.4(45) | 1.1(2) | 13.1(47) | |
| Perception of soil quality | Poor | 11.4(19) | 23.0(41) | 17.4(60) | $10.784^{***}$ |
| | Satisfactory | 53.3(89) | 53.4(95) | 53.3(184) | |
| | Very good | 35.3(59) | 23.6(42) | 29.3(101) | |
| Household head has off-farm employment | No | 63.4(111) | 67.8(122) | 65.6(233) | 0.744 |
| | Yes | 36.6(64) | 32.2(58) | 34.4(122) | |
| Extent of erosion on farm | None | 22.4(36) | 24.4(43) | 23.4(79) | $5.481^{*}$ |
| | Mild | 53.4(86) | 41.5(73) | 47.2(159) | |
| | Severe or worse | 24.2(39) | 34.1(60) | 29.4(99) | |
| Farmer experiences nutrient deficiency in maize crop | No | 22.0(39) | 8.8(16) | 15.4(55) | $11.981^{***}$ |
| | Yes | 78.0(138) | 91.2(165) | 84.6(303) | |
| Farmer owns land | No | 26.6(47) | 32.0(58) | 29.3(105) | 1.302 |
| | Yes | 73.4(130) | 68.0(123) | 70.7(253) | |
| Farming is main occupation of household head | No | 35.6(63) | 33.7(61) | 34.6(124) | 0.141 |
| | Yes | 64.4(114) | 66.3(120) | 65.4(234) | |
| Type of chemical fertilise used | None | 20.3(36) | 7.7(14) | 14.0(50) | $12.202^{***}$ |
| | DAP | 77.4(137) | 90.6(164) | 84.1(301) | |
| | NPK | 2.3(4) | 1.7(3) | 2.0(7) | |

*Source: Authors' computation from survey data*

**Table 5. Comparative descriptive statistics of demographic categorical variables by adoption status**

| Variable | Categories | Percentages (Frequencies) | | Total | Chi-square value |
|---|---|---|---|---|---|
| | | Adopters | Non-adopters | | |
| Gender of household head | Female | 26.6(47) | 34.3(62) | 30.4(109) | $2.506^{*}$ |
| | Male | 73.4(130) | 65.7(119) | 69.6(249) | |
| Education categories | None | 4.0(7) | 1.1(2) | 2.5(9) | 3.23 |
| | Primary | 61.6(109) | 60.8(110) | 61.2(219) | |
| | Secondary and above | 34.5(61) | 38.1(69) | 36.3(130) | |
| Highest education level in the house | None | 0.0(0) | 0.6(1) | 0.3(1) | 1.981 |
| | Primary | 28.2(50) | 30.9(56) | 29.6(106) | |
| | Secondary | 46.3(82) | 47.5(86) | 46.9(168) | |
| | University | 25.4(45) | 21.0(38) | 23.2(83) | |
| Marital status of household head | Not married/Divorced/Single | 29.9(52) | 32.8(58) | 31.3(110) | 0.339 |
| | Married | 70.1(122) | 67.2(119) | 68.7(241) | |

*Source: Authors' computation from survey data*

On average 86% of the sampled households used chemical fertilisers. However chemical fertiliser was used by a statistically significantly (p<0.01) larger proportion (92.3%) of non-adopters of organic fertiliser compared to adopters (79.7%). This implies that adopters of organic fertilisers may combine both types of fertilisers to maximise crop productivity or continue to use chemical fertilisers as a supplementary option (Ketema & Bauer, 2011). On the other hand, the large proportion of non-adopters using chemical fertiliser reflects that they still recognise the importance of meeting plant nutrient needs for optimal productivity. As a result, non-adopters opt for alternative methods despite the usability option of organic fertiliser (Adusei, 2020). Among the fertilisers used for planting, DAP accounted for 84.1% among the sampled farmers. However, a statistically significant (p<0.01) larger proportion of non-adopters (90.6%) used DAP fertiliser compared to adopters (77.4%) of organic fertiliser. This further enforces the earlier observation that even without adopting organic practises, the non-adopters still rely heavily on chemical inputs.

Generally, a statistically significant (p<0.01) larger proportion of adopters had better perception of the quality of soil on their farms than non-adopter. Results on Table 4 show that cumulatively, 88.6% of adopters viewed their soil as satisfactory or very good, compared to 77.0% of non-adopters. As also noted by Teklewold et al. (2013), this suggests that adoption of organic fertiliser has possibly contributed to better soil conditions over time or that adopters have better soil management strategies. This finding is further supported by the statistically significant (p<0.01) differences in soil erosion experiences. Most noteworthy was that a smaller proportion of adopters (24.2%) reported severe soil erosion compared to 34.1% of non-adopters as shown in Table 4.

Findings presented in Table 4 demonstrate that, compared to female-headed households, a larger proportion of male-headed was observed for both adopters and non-adopters at 73.4% and 65.7% respectively. While this difference in proportions was marginally statistically significant (p<0.1), it implies that male-headed households may have a better decision -making power to adopt or not to adopt organic fertiliser use. Similar significant patterns were identified in other organic fertiliser adoption studies (Abebe & Debebe, 2019; Gelgo et al., 2016).

Overall, 84.6% of the sampled farmers reported experiencing nutrient deficiency (Table 4). The difference in proportions was statistically significant (p<0.01) between adopters and non-adopters. Specifically, a larger proportion of non-adopters (91.2%) reported experiencing nutrient deficiency in their maize crops compared to 78% of adopters of organic fertilisers (Table 4). This implies that the use of organic fertiliser helps to mitigate the limited availability of soil nutrients for the crop as also reported by Michael (2021).

Statistically significant (p<0.01) differences in proportions were observed in the use of hired labour for application of organic fertiliser between adopters and non-adopters. Specifically, 25.4% of adopters hired labour for manure application compared to 1.1% of non-adopters of organic fertiliser. Given that adopters had statistically significantly larger farm sizes than non-adopters (Table 3) it is plausible to infer that adopter may potentially be supplementing chemical fertilisers with organic fertiliser due to their larger farm sizes. This finding was also noted by Moser and Barrett (2006), whereby farmer with larger farms hired labour to manage intensive farming practises.

### 3.2. Econometric Results

The model was appropriately specified for the study area with a Wald chi-square statistic of 58.19 which was highly statistically significant at p<= 0.01. As a result, the null hypothesis that all the coefficients of the explanatory variables in the model were simultaneously zero was rejected. This showed that both the likelihood and intensity of organic fertiliser use could be explained by the variables included in the model. In addition, the variables included in the Heckman model best specified the functional relationship in the model, suggesting that at least one of the independent variables used was significant. The inverse mills ratio was marginally statistically significant (p=0.059), indicating the slight presence of selection bias, and the Heckman model correcting for it by accounting for the factors that influence selection into the sample. This significance also indicated that the degree of adoption of organic fertiliser was contingent on the individual decision to adopt. Results of the estimated coefficients of the Heckman model are presented together with their standard errors and p-values signifying the levels of precision in Table 4 and Table 5. Certain variables that significantly influenced the likelihood of organic fertiliser adoption revealed significant contrasting influences on adoption intensity among the among the subset of farmers who chose to use organic fertiliser. The following subsections provide a comprehensive discussion that examines these and other significant variables, exploring their influences and implications in greater detail.

#### 3.2.1. First Step: Factors Affecting Decision to Use Organic Fertilizer

In the Heckman model, the first stage focuses on the farmers decision to use organic fertiliser on their farm. In this stage, farmers were categorized as adopters (assigned a value of 1) if they chose to use organic fertiliser, and non-adopters (assigned a value of 0) if they did not. The results presented in Table 6 indicate that six variables were highly statistically significant (p value < 0.01), one variable was statistically significant (0.01 < p value < 0.05) and one variable was marginally statistically significant (0.05 < p value < 0.10) on the decision to use organic fertiliser.

**Table 6. First-stage Heckman selection results for factors influencing the likelihood of organic fertiliser adoption**

| | Coefficient | Std. err. | P>z |
|---|---|---|---|
| ORGANIC_USE | | | |
| Gender of household head | -1.692 | 0.609 | 0.005 |
| Age of household head | 0.020 | 0.012 | 0.082 |
| Education category of household head (Ref=None) | | | |
| Primary | -7.043 | 1.074 | 0.000 |
| Secondary and above | -7.024 | 1.099 | 0.000 |
| Household size | 0.061 | 0.089 | 0.493 |
| Ownership of livestock | -0.341 | 0.358 | 0.340 |
| Farming as primary activity of household head | 0.627 | 0.473 | 0.185 |
| Marital status of household head | 1.487 | 0.611 | 0.015 |
| Household head has off-farm income | 0.618 | 0.466 | 0.185 |
| Total size of farm | 0.104 | 0.095 | 0.274 |
| Gauge of soil quality on farm (Ref=Poor quality) | | | |
| Satisfactory | 1.383 | 0.410 | 0.001 |

| | | | |
|---|---|---|---|
| Very good | 1.536 | 0.488 | 0.002 |
| Extent of soil erosion on the farm (Ref=No soil erosion) | | | |
| Mild | 0.848 | 0.450 | 0.059 |
| Severe or worse | -0.131 | 0.440 | 0.766 |
| Status of land ownership/ tenure | 0.292 | 0.348 | 0.401 |
| Child dependency Ratio | 0.189 | 0.167 | 0.258 |
| Chemical fertiliser used during planting (Ref= None) | | | |
| DAP | -0.357 | 0.349 | 0.307 |
| NPK | -0.784 | 0.894 | 0.380 |
| Cons | 3.620 | . | . |

*Source: Computation from survey data*

The coefficient of gender of the household head was negative and statistically significant ($p < 0.01$) which indicates that a male- headed household was less likely to use organic fertiliser on their maize farms (Table 6). This negative effect could be attributed to the fact that male-headed households prioritize commercial farming, which may rely more on chemical inorganic fertilisers. Similar results were observed by Oladapo and Afolami (2021) among vegetable farmers and (Sapbamrer & Thammachai, 2021) who observed the vital role of female-headed household in the decision to use organic fertiliser. A differing conclusion was reached in the study by Abebe and Debebe (2019). The coefficients for the household head attaining primary and secondary and above were both negative and statistically significant ($p < 0.01$) for the use of organic fertiliser as shown in Table 6. This infers that formally educated farmers might perceive organic fertiliser use as less efficient or less profitable do to exposure to modern and better access to information on inorganic chemical fertilizers. These findings corroborate with the conclusions of Abebe & Debebe (2019) and Oyetunde-Usman et al. (2021) who reported negative effects of literacy on the decision to use organic fertiliser. Differing conclusion was reached in studies by Musafiri et al. (2022), Mwaura et al. (2021), and Kanyenji et al. (2020) who emphasized the significance of education in the decision to use manure.

The coefficients from Table 6 on quality for farmers who perceived the quality of soil on their farms as satisfactory and very good were both positive and statistically significant ($p < 0.01$), hence increased the probability of using organic fertiliser for maize farming. This alludes to the fact that good soil quality supports organic fertiliser use since it requires fewer synthetic inputs to maintain maize crop productivity (Mtambanengwe & Mapfumo, 2005; Wasil et al., 2023; Zingore et al., 2008). Nonetheless, a study in Ethiopia yielded an opposing outcome (Ahmed et al., 2017), reporting that farmers who had the perception of having fertile plots were less likely to adopt manure. Contradictory findings were also reported by Akinola et al. (2010), who reported that farmers who perceived their soil to have issues of degradation or poor quality were more likely to take corrective action using organic fertiliser in West Africa.

The coefficient on marital status of household head was positive and statistically significant ($p < 0.05$) as shown on Table 6. This indicated that married household heads were more likely to use organic fertiliser on their farms. Household heads who were married were more likely to use organic fertiliser for farming than non-married household heads. This may be attributed to the fact that farmers become more concerned about the wellbeing of their families once married, and as such this encourages them to use organic methods of farming. While this finding contradicts with Oladapo and Afolami (2021), it aligns with the findings of Belete (2022) and Muluneh et al. (2022).

The coefficient for mild soil erosion was positive and marginally statistically significant ($p < 0.10$). This implies that the occurrence of mild soil erosion significantly increased the likelihood of using organic fertiliser in farming. This finding could be attributed to the mitigation of extensive soil degradation through organic practices like mulching which improve soil structure and fertility. This result aligns with findings by Eric et al. (2013) and Oladapo and Afolami (2021) which indicated that the perceived benefits of organic soil management practices on maize farms improved their adoption. The coefficient age of the household head was also positive and marginally statistically significant ($p < 0.10$), suggesting that that older household heads are more likely to use organic fertiliser for farming (Table 6). This implies that as farmers grow older, there is more willingness to adopt organic fertiliser use as a new practice since they already possess considerable experience with farming practices, they are familiar with. Comparable results were found in the work other studies (Ahmed et al., 2017; Ketema & Bauer, 2011); Muluneh et al. (2022); Oyetunde-Usman et al. (2021).

**3.2.2. Second Step: Factors Affecting Use Intensity of Organic Fertilizer**

The OLS estimates of the parameters of the second step Heckman two-step regression model that used the amount of organic fertiliser (in kg/ha) as a proxy for the intensity of organic fertiliser use by the maize farmers are presented in Table 7. The results presented in Table 7 indicate that the coefficients of four variables highly statistically significant (p value < 0.01), five variables were statistically significant (0.01 < p value < 0.05) and one variable was marginally statistically significant (0.05 < p value < 0.10) on the intensity of use of organic fertiliser.

The results show that a one-year increase in the age of a farmer decreases the use intensity of organic fertilizer by 18.30kg/ha. Although this result was marginally statistically significant ($p<0.10$) it suggests that as smallholder farmers become older, they reduce their use intensity of organic fertilizer. A possible explanation for this outcome is the labour-intensive nature of preparation of organic fertiliser thereby excluding older farmers who have less energy. Furthermore, older farmers may be risk averse in that they have a preference for conventional fertilisation practises they are more familiar with. This evidence corresponds with findings from Zondo (2020) and Mwangi and Kariuki (2015) but presents a differing conclusion as observed by Aryal et al. (2021) on intensity of use of organic fertiliser by cereal farmers in South Asia.

The coefficients for primary and secondary and above education levels were both was positive and statistically significant ($p<0.50$). Approximately 2813.51 kg/ha more organic fertiliser is used by farmers with primary education than by farmers without any formal education. Similarly, a farmer having secondary education or above used 2708.95 kg/ha more organic fertiliser than a farmer without any formal education. These results imply that education raises awareness of and understanding of the advantages of organic fertiliser, thereby encourages more utilisation. Comparable results were observed by Kipsat et al. (2021) and Waithaka et al. (2007) who reported similar findings among maize farmers in Vihiga. The studies indicated that farmer with greater education increased their use of organic fertiliser. The findings of the current study also concur with Aryal et al. (2021) who observed that rice and wheat farmers with secondary education and higher increased their rates of organic fertiliser use.

**Table 7. Second-stage Heckman outcome results for factors influencing the intensity of organic fertiliser application**

| | Coefficient | Std. err. | P>z |
|---|---|---|---|
| ORGANIC_INTENSITY | | | |
| Sex of household head | -501.790 | 314.524 | 0.111 |
| Age of household head | -18.304 | 11.003 | 0.096 |
| Education category of household head (Ref=None) | | | |
| Primary | 2813.509 | 1280.333 | 0.028 |
| Secondary and above | 2708.953 | 1284.636 | 0.035 |
| Household size | 76.297 | 76.282 | 0.317 |
| Ownership of livestock | 889.865 | 308.699 | 0.004 |
| Main occupation of household head (Ref=Farming) | | | |
| Salaried worker | -440.428 | 497.597 | 0.376 |
| Self-employed | -858.159 | 549.447 | 0.118 |
| Retired | -1374.230 | 1113.627 | 0.217 |
| Hires labour for application of manure | 251.655 | 254.265 | 0.322 |
| Total acreage under maize crop | -244.182 | 118.047 | 0.039 |
| Gauge of soil quality on farm (Ref=Poor quality) | | | |
| Satisfactory | -1264.410 | 538.097 | 0.019 |
| Very good | -1449.121 | 617.500 | 0.019 |
| Highest education level in the house | -217.395 | 191.901 | 0.257 |
| Farmer has off-farm income | 1237.623 | 459.015 | 0.007 |
| Extent of soil erosion on the farm (Ref=No soil erosion) | | | |
| Mild | -1772.366 | 537.860 | 0.001 |
| Severe or worse | -427.462 | 441.055 | 0.332 |
| Nutrient deficiency of crop observed | 1078.285 | 367.184 | 0.003 |
| Status of land ownership/ tenure | 249.964 | 331.002 | 0.450 |
| _cons | 1433.716 | 1417.891 | 0.312 |

*Source: Computation from survey data*

The coefficient on livestock ownership was positive and statistically significant ($p<0.01$) as shown in Table 7. Specifically, the result indicates that livestock ownership by smallholder farmers increased organic fertiliser use intensity by 889.86 Kg/ha. Livestock ownership provides access to organic fertilizer used in making compost manure for maize production. Therefore, smallholder farmers who owned livestock were more likely to intensify their use of organic fertilizer on their maize production because they have better access to livestock manure as corresponded by earlier studies (Kagoya, 2011; Waithaka et al., 2007; Zondo, 2020).

Increasing acreage under maize farming was statistically significantly ($p<0.05$) associated with lower intensity of organic fertiliser use. Specifically, for organic fertiliser use reduced by 244.18kg/ha for every unit increase in acreage of farmland under maize (Table 7). This is likely due to maize farmers increasing their focus on the use of chemical fertiliser or not allocating adequate organic resources towards larger land areas, since application of organic fertiliser may be more labour intensive in large scale farms. These results mirror the findings of Aryal et al. (2021). Nonetheless Danso-Abbeam et al. (2017), Kiprotich et al. (2024), Mwaura et al. (2021), and Nigussie et al. (2017) showed contrary evidence in that increasing land under cultivation positively and statistically significantly increased the use of manure for crop productivity.

The coefficients for soil quality perception on Table 7 were both negative and statistically significant ($p<0.05$). Specifically, farmers who perceived their soil quality as satisfactory or very good reduced their application of organic fertiliser by 1264.4 kg/ha and 1449.1kg/ha annually, respectively, compared to farmers with poor soil quality. This might be explained by the fact that farmers with better soil believe they can maintain productivity with less organic fertiliser, whereas those with worse soil will probably apply more to try to increase soil fertility. Similar increases in organic fertiliser use have been observed in other studies (Akinola et al., 2010; Aryal et al., 2021), where improvements in soil quality perception from poor to satisfactory or very good have led to reduced organic fertilizer application.

Household heads with off-farm income sources were positively and significantly ($p<0.01$) influenced in the intensity of their organic fertiliser use (Table 7). Specifically, a household head with off-farm income used about 1237.6 kg/ha more organic fertilizer than those without. Shiferaw et al. (2010) highlighted the importance of off-farm income in using sustainable agricultural technologies including organic inputs. Off-farm income provides additional financial resources, which could be used to purchase or produce more organic fertilizer, suggesting that income diversification supports better farm input management (Diiro, 2013).

Farmers' perception on experiencing soil erosion on their farms from none to mild soil erosion showed a negative statistically significantly ($p<0.01$) influence on the intensity of their organic fertiliser use. Farmers experiencing mild soil erosion used 1772.4 kg/ha less organic fertilizer annually than those with no erosion issues as shown on Table 7. This could be explained by the fact that organic fertiliser application may not substantially boost yields on ground that is eroded since erosion decreases the efficiency of fertilisers. Nguru et al. (2021) findings resonate with the current study as it reported that farmers who experienced soil erosion problems reduced the amount of organic fertiliser use since they perceived it unlikely to be sufficient to rebuild degraded land. Contrastingly, Palm et al. (2001a) and Palm et al. (2001b) reported that farmers in erosion-prone areas frequently utilized more organic fertiliser.

The coefficient for nutrient deficiency perception had a positive and statistically significant influence ($p<0.01$) on intensity of organic fertiliser use (Table 7). Specifically, farmers who experience nutrient deficiency problems in their maize crop increased their application of organic fertiliser by 1078.29 kg/ha, compared to farmers who did not experience nutrient deficiency. This may be attribute to the farmers awareness of the ability of organic fertiliser in restoring crops nutrient balance as a more sustainable way than synthetic fertilisers (Shaji et al., 2021). Similarly, farmers increased application of organic fertiliser was observed to be motivated by the perceived nutrient deficits as reported by Vanlauwe and Zingore (2011).

## 4. Conclusion and Recommendations

This study provides important insights into the factors influencing the intensity of organic fertilizer use among maize farmers in Western Kenya. Descriptive statistics indicate that farming household using organic fertiliser tend to have statistically significantly larger household sizes, older household heads, more land under maize cultivation, and larger total farm sizes compared to non-uses of organic fertiliser. The findings highlight several factors influencing both the adoption and intensity of organic fertilizer use among maize farmers. Age, education, gender, soil quality perception, and access to resources like livestock and off-farm income all play critical roles in shaping organic farming decisions. The results suggest that while certain groups of farmers (e.g., older individuals, male-headed households, those with larger farms) are less inclined to intensify their use of organic fertiliser, others (e.g., those with off-farm income or livestock) tend to adopt organic practices more readily. Older farmers were more likely to adopt organic fertiliser, but they tended to reduce the intensity of its use by 18.30 kg/ha per year as they age. Male-headed households were less likely to adopt organic fertiliser, possibly because they tend to prioritize commercial farming practices that rely more on chemical fertilizers. Household heads with primary or secondary education were statistically significantly less likely to use organic fertiliser, but those who adopted showed increased intensity of organic fertiliser use at 2813.51 kg/ha for primary education and 2708.95 kg/ha for secondary education. The perception of soil quality also had a dual effect on organic fertilizer use. Farmers who perceived their soil quality as satisfactory or very good were more likely to adopt organic fertiliser practices. However, once they became adopters, these same farmers applied organic fertilizer with lower intensity compared to those who perceived their soil as poor. This reduction in intensity could be attributed to the belief that better soil requires fewer inputs, while farmers with degraded soil are more likely to apply higher quantities of organic fertiliser to improve fertility. This nuanced relationship between soil quality perception and fertilizer use highlights the importance of tailored agricultural practices based on farmers' assessments of their land. The findings also highlight a complex interaction between soil conditions and organic fertilizer use. While nutrient deficiencies strongly motivate farmers to intensify organic fertilizer use, erosion has a contrasting impact, encouraging adoption but limiting intensity.

Given these findings, several policy recommendations are suggested. First, targeted support for farmers with poorer soil quality could enhance organic fertilizer use, particularly through extension services that emphasize the long-term benefits of organic amendments. There is also a need for programs that raise awareness of the benefits of organic fertilizers, especially for less educated or older farmers. Second, encouraging off-farm income generation among farming households could lead to increased investment in sustainable inputs, improving overall soil fertility. Mild erosion negatively influenced organic fertilizer use intensity, thereby diminishing the potential benefits of soil amendments. This reduction in organic fertilizer application exacerbates soil fertility issues, highlighting the need for effective erosion control measures to ensure that improvements in soil quality can be fully realized. Policymakers should also focus on integrated soil fertility management approaches that address both nutrient replenishment and erosion control. Investments in soil conservation techniques, such as terracing or agroforestry, combined with organic fertilizer use, can help ensure that the benefits of organic inputs are fully realized, even in erosion-prone areas. Finally, policies promoting the mechanization or subsidization of organic fertilizer application on larger farms may help overcome labour constraints and improve organic fertilizer adoption on a broader scale.

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