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Factors influencing smallholder maize farmers' fertilizer use under the fertilizer subsidy programme in the northern region of Ghana

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Abstract
This study assess the factors influencing smallholder maize farmers' fertilizer use under the fertilizer subsidy programme in the Northern Region of Ghana. The study employed a descriptive cross-sectional survey design, with a sample of 400 smallholder maize farmers in the Northern Region interviewed using a questionnaire to collect the needed data for the study. Descriptive statistics and a multinomial logistic regression model was employed to assess the drivers of farmers' decisions to apply low (less than 50 kg/acre), medium (about 100 kg/acre), high (more than 150 kg/acre), or no fertilizer at all were used to analyze the data. The results indicate that proximity to subsidized fertilizer distributors, access to credit, use of improved maize varieties, access to extension services, and availability of labor had significant positive effects on farmers' fertilizer application rates. Conversely, pest and insect attacks were found to deter farmers from applying optimal quantities of fertilizer. The study revealed that the current application rate of fertilizer among smallholder maize farmers is an average of 80 Kg of NPK and an average of 40 Kg of ammonia. While a majority of farmers apply fertilizer, the actual quantities used often deviate from the recommended rates, with some over-applying and others under-applying. The study recommends improving access to subsidized fertilizers, enhancing credit availability, promoting improved maize varieties, strengthening extension services, implementing integrated pest management strategies, and encouraging soil testing and site-specific nutrient management. By addressing these key factors, policymakers and development practitioners can work towards enhancing the efficiency and sustainability of fertilizer use among smallholder maize farmers in the region.

Keywords: Usage, smallholder farmer, and fertilizer subsidy programme

1. Introduction

Maize is a major staple crop used in Northern Ghana throughout the year among households. Maize is also part of the crops supported by the fertilizer subsidy programme in Ghana (Ministry of Food and Agriculture (MoFA), 2018). Maize is in high demand for both domestic and industrial purposes in Ghana (Andam *et al*., 2017) [5]. The high demand for maize in Ghana for both domestic and industrial purposes has led to a government-targeted policy in increasing the productivity of maize through the provision of improved technologies and subsidy policy (Houssou, Kolavalli & Silver, 2016) [16]. It is suggested that supporting farmers with subsidized fertilizers can result in a massive increase in maize yields and ultimately bring improvement in the livelihood of farmers (Ricker-Gilbert, Jayne & Chirwa, 2011) [35]. Successive agricultural policies and programmes in Ghana have provided farmers with agricultural input subsidies to help maximize their farming potential. The fertilizer subsidy programme is to ensure the availability of subsidized fertilizers as well as guarantee affordable fertilizer prices in the market (Nyanda, 2022) [28]. This is because fertilizer in the open market is very expensive which often leads to a low application rate among smallholder farmers in Ghana (MoFA, 2012). The fertilizer subsidy programme was seen as key in addressing the high cost of fertilizer and low application rate from the existing rate of 8kg to an average of 20 kg per hectare by farmers (Ragasa & Chapoto, 2017; Rivaie *et al*., 2021) [34, 36]. Improved farmers' access to and use of subsidized fertilizer is expected to increase the fertilizer application rate among farmers. Applying the recommended rate of fertilizer will allow the vegetative growth to begin quickly and provide nutritional needs during the active growth of the maize plant.

Maize has a high nutrient demand for nitrogen (N), phosphorus (P) and potassium (K), in general. N is the most often restricting yield among these main nutrients. It specifies the number of leaves produced by the plants and the number of seeds per cob, thereby deciding the capacity for yield (Adu *et al*., 2014) [2]. The volume of mineral fertilizer to be added differs with the soil's P and K quality, its humidity level, and the variety's maturity time (Adu *et al*., 2014) [2]. The optimum fertilizer quality for maize, therefore, depends on the variety of seeds, past plant experience, embraced cultural practices and total field fertility. Application levels of compound fertilizer per hectare in Ghana typically average around 90 kg N. P_2O_5 60 kg and K_2O 60 kg (Tetteh *et al*., 2017) [42]. Nonetheless, it is recommended that fertilizer N levels up to 120 kg/ha be used on deteriorated soils (Tetteh *et al*., 2017) [42]. However, it is generally, perceived that maize farmers in northern Ghana do not apply the required quantity of fertilizer on their farms. With, the fertilizer subsidy programme is expected to address this challenge of low application rates among maize. Hence, this study, therefore, seeks to assess the factors influencing smallholder maize farmers' fertilizer use under the fertilizer subsidy programme in the Northern Region of Ghana.

2. Methodology

The Northern Region is one of the sixteen regions of Ghana. It is located in the north of the country and it was the largest of the sixteen regions, covering an area of 70,384 square kilometres or 31 per cent of Ghana's area. Until December 2018 when the Savannah and North East Regions were created out of it (Ghana Statistical Services (GSS), 2014). The Northern Region has a generally dry climate, with only one rainy season that runs from May to October. Annual rainfall fluctuates between 750 and 1050 mm with a mean temperature of 35 °C (GSS, 2014). More than 75% of the economically active population in the region is employed in the agricultural sector (MoFA, 2018). The main economic activity taking place in the region is agriculture. Crops like yam, maize, millet, guinea corn, rice, groundnuts, beans, soya beans and cowpea, are widely grown in the region.

Research design, sampling techniques, data collection and analysis

To address the study objective, the study employed only quantitative research approach for collecting, verifying and analyzing data to give in-depth information about the factors influencing smallholder maize farmers' fertilizer use under the fertilizer subsidy programme. Furthermore, the study adopted a descriptive study design in guiding data collection.

Based on the Ministry of Food and Agriculture (2018), the total population of maize farmers in the northern region is 123,626. Through the application of Cochran's (1977) [9] sample size determination formula a sample size of 400 smallholder maize farmers was found appropriate for the study. Five (5) districts were randomly selected using a simple random sampling method. The sample districts are Tolon District, Kumbungu District, Yendi Municipal, Savelugu Municipal and Mion District. This is because maize farming is widely cultivated across all districts in the region (GSS, 2014) [11]. From each sample district, four (4) communities were randomly sampled. The selection is to ensure that the researcher acquires the needed information about the concepts under study through a survey. From each sample community, random sampling was used to select twenty (20) smallholder maize farmers. Data were collected using questionnaire administration to 400 smallholder maize farmers.

Analysis of the effects of fertilizer subsidy programme on smallholder maize farmers' usage of fertilizer

Analysis of how the fertilizer subsidy programme has affected smallholder maize farmers' usage of fertilizer was achieved using frequency, percentage and multinomial logistic regression model. A multinomial logistic regression model was to examine the factors influencing farmers' level of fertilizer use on their farms. According to Tetteh *et al*. (2017) [42], the recommended rate of fertilizer per acre of maize 100kg of compound fertilizer (NPK) and 50 kg of sulphate of ammonia for Northern Ghana. Here, a smallholder maize farmer who uses less than 50kg of either compound fertilizer (NPK) or sulphate of ammonia is considered a low user, about 100kg of either compound fertilizer (NPK) or sulphate of ammonia is considered a medium user and 100kg of compound fertilizer (NPK) and 50 kg of sulphate of ammonia are considered as high users. However, a smallholder maize farmer who does not apply fertilizer on his/her farm at all is considered a non-user.

Multinomial logistic model

A multinomial logistic regression model is to empirically establish the drivers of smallholder maize level of use of fertilizer subsidy programme. Multinomial logistic regression models assume that the error terms are independently and identically distributed (Plass *et al*., 2015) [33]. In the context of this study, an unordered multinomial logistic model is useful because it can take care of categorical dependent variables (thus, the nominal categories of dependent variables have multiple choices). The multinomial logistic regression model was used in this study to assess the factors that influence smallholder maize farmer level of use of fertilizer in FSP.

Smallholder maize farmers' level of use of fertilizer subsidy programme is based on the farmers' economic status (Decision categories). These consists of the decision categories for multinomial logit model having combinations denoted as j=0 if a smallholder maize farmer uses less than 50 kg fertilizer per acre P_1 (Low users), j=1 if a smallholder maize farmer uses about 100 kg fertilizer per acre P_2 (Medium users), j=2 if a smallholder maize farmer uses more than 150 kg fertilizer per acre P_2 (High users), j=3 if a smallholder maize farmer does not use fertilizer at all on his/her far P_3 (Non- users).

Drawing from the discrete choice theory of utility maximization (McFadden, 1976) [21], smallholder maize farmer level of use of fertilizer subsidy programme is based on the option that maximizes utility subject to the inherent cost (Financial or non-financial) which is determined by perceived attribute of the fertilizer, institutional and socioeconomic characteristics of the smallholder maize farmer.

Hence, following the work of Greene (2003) [13], an unordered multinomial logistic regression model for the choices of the varieties subjected to the model was specified as follows:

$$Pr(Y=1)=\frac{e\beta_j^{'}x_i}{\sum e\beta_k^{'}x_i}, j=0,1,2,3 \quad (1)$$

The estimated equation (1) leads to a set of possibility for j^{th} smallholder maize farmer level of use of fertilizer subsidy programme (*i*), in this case, fertilizer subsidy programme is P_0 (Low users), P_1 (Medium users), P_2 (High users), P_3 (Non-users). Vector X_i describes fertilizer perceived attributes, institutional and individual socio-demographic and economic characteristics. $ß^j$ describes the vector coefficients of *Xi* associated with the j^{th} fertilizer subsidy programme (Greene, 2003) [13].

$$Pr(y=0)=\frac{1}{1+e\sum e^{\beta_k^{'}x_i}} \quad (2)$$

Normalization is achieved by setting *ß0*= 0 as presented in equation 1. Thus, obtain a vector $ß^j$ for each possibility except for the one which is a normalized alternative (A reference or base outcome). The estimated coefficients of the model can, therefore, be interpreted as the effect of the vector x_i on the possibility of fertilizer subsidy programme *j* relative to the level of use of fertilizer subsidy programme which is a base outcome (Reference category). In this case, the reference/base outcome was subsidized fertilizer.

The effect of a unit changes in any of the X explanatory variables on the probability that the i^{th} smallholder maize farmer will use subsidy fertilizer is given by the marginal effect statistic (Greene, 2003) [13], which is derived as follows:

$$\Delta P_j/\Delta X_i = P_j\left[P_j-\sum_{k-1}^{m} Pk\beta k\right] \quad (3)$$

Table 1: Description, Measurement and hypothesized sign in the multiple regression model

Variables	Descriptions	Apriori
Dependent Variable		
Level of fertilizer subsidy usage	0=Low users 1= Medium users 2= High users 3= Non- users	+
Smallholder Farmer Socio-demographic and Economic characteristics		
Age	Years	+
Sex	1=male 0=female	+/-
Educational level	1=formal 0=no formal	+
Household size (HS)	Number of people in a household	+
Marital status	1=married 0= not married	+/-
Household head (HH)	1= yes 0= no	+
Farm Level Characteristics		
Farm size	Acres	+
Access to labour	1= yes 0= no	+
Improve seeds used (ISU)	1= yes 0= no	+
Experience in farming	No. of years in farming	+
FBO membership	1= yes 0= no	+
Off –farm income	1= yes 0= no	+
Institutional Level Characteristics		
Late delivery of subsidized fertilizer	1= yes 0= no	-
Access to credit (AC)	1= yes 0= no	+
Access extension service	1= yes 0= no	+
Early delivery of subsidized fertilizer	1= yes 0= no	+
Access to fertilizer market	1= yes 0= no	+
Distance to a source of fertilizer	Kilometre per hour	+/-
Subsidy amount	Amount absorbed per Kg	+/-

3. Results and Discussion

3.1 Average quantity of fertilizer maize farmers applied per acre

The findings in Table 2, indicate that from 2017 to 2019, maize farmers in the study area applied a maximum of 100 kg of NPK fertilizer and 50 kg of ammonia fertilizer per acre. These application rates aligns with the general guidelines for optimal maize production, which emphasize the critical role of nitrogen (N), phosphorus (P), and potassium (K) in achieving high yields. Similar to a study conducted by Adu *et al*. (2014) [2], this research underscores the importance of these nutrients, particularly nitrogen, in determining the yield potential of maize. As Adu *et al.* (2014) [2] highlight that the recommended application rates of chemical fertilizer per hectare in Ghana average around 90 kg N, 60 kg P2O5, and 60 kg K_2O. However, in practice, the actual quantity of fertilizer applied by farmers can vary based on soil nutrient content. For instance, soils with significant degradation may require up to 120 kg/ha of nitrogen to meet the crop's nutritional demands (Adu *et al*., 2014) [2]. These study's findings are consistent with this recommendation, as the observed maximum fertilizer application rates fall within the suggested range for nitrogen, albeit slightly lower for phosphorus and potassium. Though, Adu *et al*. (2014) [2], revealed a critical gap in the adoption of soil testing practices. Despite the recommendation for farmers to conduct soil tests before fertilizer application to tailor nutrient management strategies (Adu *et al*., 2014) [2], this study suggests that many farmers may not be following this crucial step. This oversight could lead to suboptimal fertilizer use, either through over-

application or under-application, thereby affecting crop yields and economic efficiency.
Comparatively, other studies have reported varying levels of adherence to recommended agronomic practices among maize farmers. For instance, a study by Sheahan *et al.* (2013) [38], found that while some farmers strictly follow the recommended fertilizer application rates, others either apply less due to financial constraints or more in an attempt to maximize yields, sometimes leading to negative environmental impacts. This study corroborates these findings, as the fertilizer application rates observed indicate a range of practices rather than a uniform adherence to guidelines. Additionally, the predominant use of NPK and ammonia fertilizers in the study area is consistent with the trends reported by Omari *et al.* (2017) [31], who noted that these types of fertilizers are widely preferred by maize farmers due to their effectiveness in meeting the crop's nutritional needs. However, Omari *et al.* (2017) [31] also pointed out that the lack of access to affordable and timely soil testing services remains a significant barrier to the precise application of these fertilizers, a challenge echoed in our study

Table 2: Quantity of Fertilizer Farmers Apply per acre in seasons

Types of Fertilizer	Min	Max	Mean
NPK used for 2017	0 Kg	100 Kg	89.5 Kg
NPK used for 2018	0 Kg	100 Kg	88.5 Kg
NPK used for 2019	0 Kg	100 Kg	92.5 Kg
Ammonia used for 2017	0 Kg	50 Kg	42 Kg
Ammonia used for 2018	0 Kg	50 Kg	41 Kg
Ammonia used for 2019	0 Kg	50 Kg	41.5 Kg

Source: Field Survey Data, 2020

However, on average, maize farmers applied 89.5 Kg, 88.5 Kg and 92.5 Kg of NPK respectively from 2017 to 2019 (Table 2). The average application rate of NPK fertilizer is below the recommended rate of 100 Kg of NPK fertilizer per acre. However, the results are encouraging as the marginal difference is about 12.0 Kg of NPK fertilizer. In the application of ammonia, maize farmers in the study area apply a maximum of 50 kg of ammonia fertilizer on an acre of maize farm. An average of 42 Kg, 41 Kg and 41.5 Kg respectively were applied from 2017 to 2019 on an acre of maize farm. The results suggest that farmers are leaving up to expectations in their fertilizer use. The success in fertilizer application rate can be linked to the timely delivery and availability of subsidized fertilizer under the Planting for Food and Jobs Programme. Furthermore, since the physical distance that farmers travel to obtain the subsidized fertilizer is an important determinant of the accessibility of fertilizer by a farmer (Ogada, Mwabu & Muchai, 2014) [29], the introduction of the Planting for Food and Jobs Programme has completely reduced the physical distance challenge, where farmers now have easy access to fertilizer at a subsidized rate.

3.2 Quantity of Fertilizer Application per Acre

In the northern part of Ghana, soil degradation and low nutrient content are prevalent issues, as highlighted by Mensah (2015) [22]. To mitigate these challenges, research scientists have recommended that farmers should apply an average of around 90 kg N, 60 kg P2O5, and 60 kg K_2O of chemical fertilizer per hectare (Adu *et al.*, 2014) [2]. This recommendation aims to enhance soil fertility and improve crop yields. However, the results presented in Table 3 of this study indicate a divergence from these recommendations. In 2017, out of 400 maize farmers interviewed, 73.8% of the respondents applied 150 kg of fertilizer, consisting of 100 kg of NPK and 50 kg of ammonia (see Table 3). This application rate exceeds the recommended amounts, particularly in terms of nitrogen, which could have implications for soil health and environmental sustainability. Furthermore, 18.5% of the respondents applied 100 kg of fertilizer, consisting of 50 kg of NPK and 50 kg of ammonia, which is below the recommended rate. This suggests variability in fertilizer application practices among farmers, potentially due to factors such as financial constraints, access to fertilizers, and knowledge of proper application rates. Only 6.5% of the respondents applied 50 kg of NPK fertilizer, and a mere 1.3% did not apply any fertilizer to their maize farms. These findings contrast with the recommendations by Adu *et al.* (2014) [2], indicating that a significant proportion of farmers are either over-applying or under-applying fertilizers, which could affect maize production and soil nutrient balance. In comparison to similar studies, it is evident that fertilizer application rates and practices vary significantly among farmers in different regions. For instance, a study by Houssou *et al.* (2019) [15], found that in the central region of Ghana, farmers were more likely to adhere to recommended fertilizer application rates due to better access to agricultural extension services and input subsidies.

Table 3: Quantity Fertilizer Application per Acre for 2017

Quantity	Frequency	Per cent
Low usage (50 Kg)	26	6.5
Medium usage (100Kg)	74	18.5
High usage (150 Kg)	295	73.8
No usage (0 Kg)	5	1.3

Source: Field Survey Data, 2020

A similar trend was observed in the 2018 farming season, where the majority, 72.3% of the respondents, applied 150 Kg of fertilizer, consisting of 100 Kg of NPK and 50 Kg of Ammonia (See Table 4). This high percentage of respondents using a balanced mix of fertilizers aligns with findings from previous studies that emphasize the importance of a balanced nutrient application for optimal crop yield. For instance, Sitienei *et al.* (2017) [39], reported that the combination of NPK and ammonia significantly improved maize yield and soil fertility in smallholder farms. Furthermore, nearly 18.5% of the respondents in the 2018 season applied 100 Kg of fertilizer, which consisted of 50 Kg of NPK and 50 Kg of Ammonia. This practice, though less prevalent, indicates a preference for a moderate nutrient application, which was also noted in the research by Vanlauwe *et al.* (2015) [45], who found that moderate fertilization practices were often adopted by farmers with limited resources or smaller farm sizes. Additionally, 6.5% of the respondents applied only 50 Kg of NPK fertilizer, demonstrating a minimalist approach that might be influenced by economic constraints or local agricultural practices. This is consistent with findings by Ryan *et al.* (2012), which highlighted that economic factors often dictate the quantity and type of fertilizers used by farmers. Finally, 2.8% of the respondents did not apply any fertilizer to their maize farms, a trend that mirrors the findings of Adnan *et al.* (2018) [1], who identified that a small fraction of farmers refrain from using fertilizers due to either financial limitations or a reliance on organic farming practices

Table 4: Quantity Fertilizer Application per Acre for 2018

Quantity	Frequency	Per cent
Low usage (50 Kg)	26	6.5
Medium usage (100Kg)	74	18.5
High usage (150 Kg)	289	72.3
No usage (0 Kg)	11	2.8

Source: Field Survey Data, 2020

In the 2019 farming season, the majority of respondents (76.0%) applied 150 kg of fertilizer, consisting of 100 kg of NPK and 50 kg of Ammonia (see Table 4.5). This finding aligns with the study by Heffer and Prud'homme (2016) [14], which reported a similar trend where 70% of farmers applied a combination of NPK and Ammonia fertilizers to enhance crop yield. Similarly, Tewatia and Chanda (2017) [43] found that a significant portion of farmers preferred the combined application of NPK and Ammonia, indicating its effectiveness in improving soil fertility and crop productivity. Nearly 17.3% of the respondents in the current study applied 100 kg of fertilizer, consisting of 50 kg of NPK and 50 kg of Ammonia (see Table 4.5). This is somewhat consistent with the findings of Min *et al*. (2021) [23], where 20% of farmers used a lower total fertilizer application but maintained a balanced combination of NPK and Ammonia. This approach suggests a strategic use of fertilizers to optimize input costs while ensuring adequate nutrient supply to crops. Additionally, 6.3% of respondents applied only 50 kg of NPK fertilizer (see Table 4.5). This contrasts with the findings of Islam *et al*. (2022) [17], who reported a higher percentage (15%) of farmers exclusively using NPK fertilizer, possibly due to regional differences in soil nutrient requirements or availability of fertilizers. However, both studies highlight a subset of farmers focusing on NPK as a primary nutrient source, with only 0.5% of respondents in the current study did not apply any fertilizer on their maize farms. The lower percentage in the current study may indicate improved access to fertilizers or better financial support for farmers

Table 5: Quantity Fertilizer Application per Acre for 2019

Quantity	Frequency	Per cent
Low usage (50 Kg)	25	6.3
Medium usage (100Kg)	69	17.3
High usage (150 Kg)	304	76.0
No usage (0 Kg)	2	.5
Total	400	100.0

Source: Field Survey Data, 2020

3.3 Factors Influencing the Quantity of Fertilizer Use by Smallholder Farmers per Acre

This section presents results on the factors influencing the quantity of fertilizer used by smallholder farmers per acre. Table 6 present the results of the multinomial logit regression model on the predictors of smallholder maize farmers' application rate of chemical fertilizer per acre. The results of the multinomial logit regression show a log-likelihood value of -321.25909. This is significant at the 1% level of significance. This means that the explanatory variables or factors included in the model jointly explained the factors which influence the rate of fertilizer usage among farmers.

Table 6: Multinomial logistic regression of predictors influencing smallholder farmers' quantity of fertilizer per acre

Predicators	Coef.	Std. Err.	z	P>|z|
Low usage (50 Kg)				
Nearness to subsidised fertilizer distributor	4.529	1.391	3.26	0.001
Use of Improved Seeds	3.810	1.799	2.12	0.034
Access to Credit	5.968	1.752	3.41	0.001
Access to Labour	2.669	1.312	2.03	0.042
Pest/Insect Attacks	-6.156	1.891	-3.26	0.001
_cons	8.482	3.289	2.58	0.010
Medium usage (100Kg)				
Nearness to subsidised fertilizer distributor	4.529	41.391	3.26	0.001
Access to Extension Service	3.018	1.892	1.59	0.111
Use of Improved Seeds	3.810	1.799	2.12	0.034
Access to Credit	5.968	1.752	3.41	0.001
Access to Labour	2.669	1.312	2.03	0.042
Pest/Insect Attacks	-6.156	1.891	-3.26	0.001
_cons	-8.482	3.289	-2.58	0.010
High usage (150 Kg)				
Nearness to subsidised fertilizer distributor	3.803	1.416	2.68	0.007
Access to Extension Service	3.940	1.938	2.03	0.042
Use of Improved Seeds	4.462	1.825	2.45	0.014
Access to Credit	5.706	1.772	3.22	0.001
Access to Labour	2.919	1.335	2.19	0.029
Pest/Insect Attacks	-6.022	1.909	-3.15	0.002
_cons	9.771	3.336	2.93	0.003
Number of obs	400			
LR chi2(33)	416.22			
Prob > chi^2	0.000			
Pseudo R^2	0.6931			
Log-likelihood	-321.25909			

a. The reference category is No usage (0 Kg).
b. This parameter is set to zero because it is redundant.
Source: Field Survey Data, 2020

The Pseudo R^2 value of 0.6931 also indicates that all the explanatory variables included in the model were able to explain about 69.3% of the rate of fertilizer usage among maize farmers (Table 6).

Specifically, the results show that nearness to subsidised fertilizer distributors, access to credit and pest/insect attacks were all significant at 1% confidence level. Also, access to extension service, use of improved seeds and access to labour were all significant at 5% level.

Nearness to subsidised fertilizer distributor

Maize farmers' nearness to subsidised fertilizer distributors had a positive significant effect on farmers' decision to apply 50Kg, 100Kg and 150Kg of fertilizer on their farms at 1% significant level. Farmers who were located near subsidised fertilizer distribution had a higher probability of applying 50Kg, 100Kg and 150Kg of fertilizer on their farms by 4.529Kg and 3.803Kg respectively compared to farmers who were not located near subsidised fertilizer distribution sources if all things remain the same. Comparing this with similar studies, the findings are consistent with the conclusions of Ghimire *et al*. (2015) [12], who found that the proximity to agricultural input suppliers significantly influences the adoption and usage intensity of inputs among smallholder farmers. In their study, farmers closer to input suppliers were more likely to use the recommended amounts of fertilizer due to easier access and reduced transportation costs. Similarly, a study by Keyser *et al*. (2015) [18] in Africa highlighted that farmers' proximity to agro-dealers positively affects their use of improved seeds and fertilizers. The study pointed out that logistical challenges and transportation costs are significant barriers for rural farmers who are far from these dealers, which aligns with your findings that urban-located subsidized fertilizer retailers create accessibility issues for rural farmers. In contrast, other studies have shown mixed results. For instance, the research by Alabi and Adams (2015) [4] in Nigeria revealed that while proximity to fertilizer distributors is important, other factors such as access to credit, extension services, and overall farm income also play crucial roles in determining fertilizer usage. This suggests that while nearness to distributors is a significant factor, it is not the sole determinant of fertilizer application rates among farmers.

Use of Improved Varieties of maize Seeds

The use of improved varieties of maize seeds had a positive and significant effect on farmers' decision to apply 50Kg, 100 Kg, and 150 Kg of fertilizer on their farms at a 5% significance level. Farmers who used improved maize varieties had a higher probability of applying 50 Kg, 100 Kg, and 150 Kg of fertilizer on their farms by 3.810 Kg and 4.462 Kg, respectively, compared to farmers who did not use improved varieties of maize seeds if all things remained the same. Adoption of improved maize varieties requires the right quantity of fertilizer to achieve optimal yield. Hence, it was not surprising that improved maize varieties positively influenced smallholder maize farmers' use of fertilizer. Comparing these findings to other studies, similar positive effects of improved seed varieties on fertilizer use and yield have been documented. For instance, Akinbode and Bamire (2015) [3] found that the adoption of improved maize varieties significantly increased the likelihood of fertilizer use among smallholder farmers in Nigeria, leading to higher yields and increased farm productivity. This aligns with this study results, demonstrating the critical role of improved seed varieties in enhancing agricultural practices and outcomes. Contrastingly, Tahiru *et al*. (2015) [41], observed a different trend in southern Ghana where the use of improved maize varieties did not significantly impact fertilizer application rates. This discrepancy may be due to variations in local agricultural practices, soil fertility, or access to agricultural inputs, highlighting the importance of contextual factors in determining the effectiveness of improved seed varieties. Additionally, Thierfelder *et al*. (2015) [44], emphasized the importance of complementary agricultural practices, such as proper soil management and timely application of fertilizers, to fully realize the benefits of improved maize varieties. This suggests that while improved seed varieties can enhance fertilizer use and yield, a holistic approach incorporating multiple agricultural best practices is essential for achieving optimal results

Access to Credit

Access to credit significantly influences farmers' fertilizer application decisions, as evidenced by the findings showing that farmers with access to credit are more likely to apply larger quantities of fertilizer compared to those without access (see Table 6). For instance, farmers with credit access applied an average of 5.968 Kg more of fertilizer than those without credit, holding other factors constant. This aligns with previous research indicating that financial constraints hinder smallholder farmers' ability to afford fertilizers and other inputs, thereby limiting their crop yields (MoFA, 2018) [25]. Conversely, farmers lacking access to credit may face difficulties in affording necessary inputs like fertilizers, potentially leading to suboptimal application rates (Liverpool-Tasie & Takeshima, 2013) [19].

Access to Labour

Access to labour had a positive and significant effect on farmers' decision to apply 50 Kg, 100 Kg and 150 Kg of fertilizer on their farms at 5% significant level. Farmers who had access to labour had a higher probability of applying 50 Kg, 100 Kg and 150 Kg of fertilizer on their farms by 2.669 Kg and 2.919 Kg as compared to farmers who do not have access to labour if all things remain the same. This finding is in agreement with Nandi, inferred from the positively significant relationship between labour availability and adoption of Agricultural innovation and concluded that labour availability is a requirement for technology adoption which increases the yield of farmers. Because improved agricultural practices require lots of labour and hence household with a relatively high labour force uses the technologies on their farmlands more than those with a low labour force.

Pest/Insect Attacks

Pest/insect attacks had a negative significant effect on farmers' decision to apply 50Kg, 100Kg and 150Kg of fertilizer on their farms at 5% significant level. Farmers whose farms were affected by pest/insect attacks had a higher probability of applying 50Kg, 100Kg and 150Kg of fertilizer on their farms by 6.156Kg and 6.022Kg as compared to farmers whose farms were not affected by pest/insect attacks if all things remain the same. This indicates a direct correlation between pest pressures and agricultural input decisions among smallholder maize farmers. In contrast, other studies have highlighted similar deterrent effects of pest and insect invasions on farm profitability and investment in agricultural inputs (Wyckhuys *et al*., 2020) [46]. These findings underscore the widespread challenges posed by pests and insects in agricultural production, affecting both yield potential and economic outcomes for farmers (Bottrell & Schoenly, 2018; Snyder *et al*., 2020) [7, 40]. Thus, the reluctance among smallholder farmers to use fertilizers due to pest pressures appears to be a consistent theme across various agricultural crops (Chinseu *et al*., 2019) [8].

Access to Extension Service

Access to extension service had a positive and significant effect on farmers' decision to apply 150Kg of fertilizer on their farms at 5% significant level. Farmers who had access to extension service had a higher probability of applying 150Kg of fertilizer on their farms by 3.940Kg compared to farmers who do not have access to extension service if all things remain the same. Fertilizer application requires some level of knowledge and techniques, hence, smallholder farmers' exposure to extension officers would help in increasing farmers' knowledge on the timing of fertiliser application, application rate and observation of agronomic precautional measures. This finding aligns with previous studies that have also highlighted the pivotal role of extension services in improving agricultural practices (Argaw *et al*., 2023; Noah & Abidoye, 2019) [6, 27]. Farmers with access to extension services demonstrated a notably higher likelihood of applying the recommended fertilizer amount compared to those without such access (Martey *et al*., 2014) [20]. Furthermore, the study underscores the importance of extension services in enhancing farmers' knowledge and skills related to fertilizer application techniques, timing, and agronomic best practices. Similar studies have shown that increased exposure to extension officers correlates with improved agricultural productivity and adherence to recommended farming practices (Pan *et al*., 2018; Okoffo *et al*., 2016) [32, 30]. Thus, the positive influence of extension services on fertilizer usage among smallholder maize farmers is consistent with broader findings on the impact of extension programs in agricultural development (Gebrehiwot, 2015) [10].

Conclusion and Recommendation

The study concluded that proximity to subsidized fertilizer distributors, access to credit, use of improved maize varieties, access to extension services, and availability of labor all had significant positive effects on farmers' decisions to apply higher amounts of fertilizer per acre. Conversely, pest and insect attacks were found to deter farmers from applying optimal quantities of fertilizer. The study further concluded that while a majority of farmers apply fertilizer, the actual quantities used often deviate from the recommended rates, with some over-applying and others under-applying. This variability highlights the need for targeted interventions to promote judicious and efficient use of fertilizers among smallholder farmers. Also, government should improve access to subsidized fertilizer distribution points are strategically located and easily accessible to rural farmers can significantly increase fertilizer usage rates.

Conflict of interests

The authors have not declared any conflict of interest.

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