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Research Article

Utilization of Organic Fertilizer in Ghana: Implications for Crop Performance and Commercialization

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Organic fertilizer commercialization may present a great opportunity to help deal with the issue of solid waste management and help improve the declining soil problems in many developing countries. Ghana's solid waste is predominantly organic, which is suitable for organic fertilizer production. This paper seeks to establish relationship between organic fertilizer usage and crop farm performance and assess its commercialization potential. The study employed a farmer-survey and key informant interviews to generate data from 300 farmers randomly selected across three regions in Ghana. The computed organic fertilizer use rate is 42% among farmers surveyed, and organic fertilizer is primarily used in vegetable and maize production. The estimated current demand for organic fertilizer is about 0.7 million t/annum with a potential to rise to about 2.7 million t/annum in the long term. This will however require sensitization on its importance, availability, and affordability. The study has established a strong relationship between organic fertilizer adoption and farm performance increasing yield by 57%, income by 53%, and gross margins by 63%. There is obviously a cost reduction when organic fertilizer is adopted. Organic fertilizer adoption was found to be mainly related to farmer base organization membership status, access to extension services, access to organic fertilizer, and transport cost. Organic fertilizer commercialization has the potential to make Ghana a net exporter of fertilizer and create sustainable jobs for the youth. We recommend the use of organic fertilizer by farmers and highly recommend the commercial production of organic fertilizer.

1. Introduction

Organic fertilizer commercialization may present a great opportunity to help deal with the issue of solid waste management and help to improve the declining soil problems in many developing countries. Organic fertilizer production has a great potential to deal with the poor organic waste management challenge [1]. In Ghana, the large amount of organic waste generated provides an opportunity to produce organic fertilizer [2–4]. There are numerous benefits associated with organic fertilizer production such as decrease in odour nuisance from dump sites and availability of dump sites for alternative agricultural uses, and the organic fertilizer produced is used for crop production. Conversion of organic and municipal waste to compost also provides human and environmental health protection and opportunities for employment [5].

There are a couple of challenges associated with organic fertilizer use, which include high labour cost, slow effect of organic fertilizer, bad odour, limited sources of organic material, high cost of transportation, weeds invasion, perception of soil fertility, and soil erosion [6, 7]. The application of organic fertilizer could be associated with potential hazards to soil and humans caused by trace metals [8]. Age, marital status, education, labour availability, farming experience, farm size, and number of livestock were positively associated with the utilization of organic fertilizer while single marital status, cost of laborer, household income, medium soil fertility, fertile soil, and home to farm distance were negatively associated with the utilization of organic fertilizer [9].

There are different kinds of organic fertilizers based on its source material such as plant-based materials, animal manure, and organic agricultural byproducts [10, 11]. The nutrient content of organic fertilizers is highly variable depending on the source materials and how easily biodegradable those materials are. On a per weight basis, organic fertilizers are low in nitrogen and phosphorus content compared to chemical fertilizers [12]. The macronutrients (N, P, and K) composition of organic fertilizers is well documented. The data on the secondary macronutrients including calcium (Ca), magnesium (Mg), sulfur (S), and sodium (Na) are often not available. Their content of micronutrients essential for plant growth is also very small. Their essential micronutrients content include boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) [13]. Many scientists are of the view that organic fertilizer should be used to replace some amount of chemical fertilizers in crop production [14–17]. Organic fertilizer production is a function of the availability of livestock and poultry manure, crop straws, sludge, grass carbon, and so on (organic material). Commercial organic fertilizer production will not be feasible when there is no reliable supply of organic material [18].

Solid waste management in urban areas is a major challenge in many developing countries [19]. There is a lack of access to proper and routine waste collection in urban areas of many developing countries, and the proper disposal of solid waste is a major concern [20, 21]. Improper disposal of solid waste results in the emission of greenhouse gases as noted by Gautam and Agrawal [22]. Poor waste management challenge is worsened by population growth, poverty, and increased urbanization rates [23]. Global estimates show that in 2020, the world was estimated to generate 2.24 billion tonnes of solid waste. With rapid population growth and urbanization, annual waste generation is expected to increase by 73% from 2020 levels to 3.88 billion tonnes in 2050. Aside the environmental benefits, effective solid waste management will also play a major role in preventing some urban health concerns, particularly in sub-Saharan Africa (SSA) [23, 24].

The daily solid waste generated in Ghana is estimated to be about 12,700–135,500 tons of which only about 10% is collected and disposed of with a daily generation of between 0.2 and 0.8 kg per capita [5, 25]. This situation is attributed to poor planning, rapid population growth, lack of sufficient budget, lack of adequate public awareness, and inefficient waste transport system [5, 21, 26, 27]. There has been a lot of effort by the government of Ghana to empower district, municipal, and metropolitan assemblies to regulate waste management in Ghana [21, 26]. It is estimated that the major cities in Ghana generate about 2000 tons of mixed municipal waste per day, of which 80% is collected [28]. The waste composition of Ghana is predominantly organic (61%), followed by plastics (14%), inert paper (3%), metals (3%), and glass (1%) [5]. The poor management of municipal waste and dump sites results in considerable emissions of greenhouse gases (methane (CH_4) and carbon dioxide (CO_2)). Productive lands are lost because of these dump sites. This trend indicates that if alternative uses are not identified for organic waste, its associated health and environmental negative impacts can only get worse. The increasing growth in the organic waste is a good sign of the sustainability of organic fertilizer production when adoption of organic fertilizer is high.

The adoption of organic fertilizers is constrained by the lack of stability and integrity in land tenure [29]. Easy access to technology, education, and extension has great influence on technology adoption [30]. A reduction in the offensive smell of organic fertilizer and its availability will increase its adoption [31]. Deliberate government policies to encourage and facilitate the marketing of organic waste-based fertilizers will help increase its adoption [32–34]. Membership of farmer-based organizations was also observed to positively influence the adoption of organic fertilizer while household income negatively influenced organic fertilizer adoption [35]. Encouraging entrepreneurs to invest in organic fertilizer processing plants would also improve the availability of organic fertilizer for smallholder farmers [35–37] and found that household size, livestock number, extension contacts, access to information media, and membership to farmer groups significantly influenced the decision to adopt organic fertilizer.

Generally, fertilizer adoption for crop production in Ghana is low due to the low-income levels of farmers and high cost of fertilizer. Very few studies have investigated this subject in Ghana, mainly looking at the relationship between fertilizer adoption and crop yield [38–42]. Other studies have focused on the determinants of fertilizer (especially chemical fertilizer) adoption [43–45]. This study expands the scope to examine the impact on farm income, gross margins, and its commercialization potential in Ghana.

Maize (*Zea mays* L.) is one of the most important cereals in SSA, and it is a staple food for over 600 million people in the region [46]. Maize is the most important cereal crop grown in Ghana and occupies over one million hectares of farmland, constituting 50–60% of Ghana's cereal production. Maize is grown in almost every part of the country [47]. Maize is the number one crop in terms of area planted and accounts for 50–60% of total cereal production and represents the second largest commodity crop in the country after cocoa [48]. Maize is the most common staple crop in Ghana and contributes significantly to consumer diets [49]. Based on the most recent domestic production data, the shortfall between domestic production and domestic consumption has increased more than 267,000 metric tons coupled with considerable unfulfilled demand for processed maize use and for the growing animal feed sector within

Ghana. It is also a high nutrient-dependent crop, hence the reason it was chosen as the crop for this study.

Fertilizer evaluations are typically done by analyzing changes in crop yield and soil quality. In this study, we hypothesized that organic fertilizers could improve crop yield, farm income, and farm profit when used. This study is, therefore, aimed at examining the adoption and impact of organic fertilizer (OF) on maize crop performance in Ghana and its commercialization potential. The specific objectives are to assess the adoption of organic fertilizer and identify the factors that will stimulate its adoption, to evaluate the impact of organic fertilizer adoption on maize farm performance (crop yield, farm income, and gross margins), and to assess the commercialization potential of organic fertilizer in Ghana by computing the current and potential future demand.

2. Materials and Methods

2.1. The Study Area. Northern Ghana (Northern, Upper East, and Upper West regions) occupies a total land area of 97,666 km^2 with an estimated population of 6.38 million [50]. The three regions share borders with the Republic of Togo to the east, Ivory Coast to the west, and Burkina Faso to the north. Within the country, northern Ghana is bordered by Volta Region to the southeast and Brong-Ahafo Region to the southwest. Northern Ghana lies between longitude 8°46′01.88″N and 10°58′34″N and latitude 2°45′45.40″W and 0°32′59.95″E. The three regions fall within the Guinea and Sudan Savannah agroecological zones and are characterized by a unimodal rainfall pattern, which begins in April/May and ends in October/November. Recorded annual rainfall ranges between 900 mm and 1200 mm. The vegetation is a typical Guinea savannah type, characterized by drought resistant grasses and trees. About 90 percent of households in the area are engaged in crop production, cultivating crops such as maize, rice, sorghum, soybeans, cowpea, cassava, yam, cotton, and vegetables. They also keep livestock such as poultry, small ruminants, cattle, and pigs. Agricultural production is, therefore, the main activity in the northern sector of Ghana and is practiced mainly on a seasonal and subsistence level. The production is largely rainfed, hence highly risky and increasingly subject to threats from climate change.

2.2. Sample Size Estimation and Stratification. Raosoft, a sample size calculator, was applied to the farmer population in the three regions to estimate the sample size for the survey. The estimation was done using a 95% Confidence Level and a 5% Margin of Error and the assumption of not knowing the population size. The sample size calculated was adjusted for a 10% nonresponse rate [51]. The sum of all regional samples constituted the total sample.

A multistage stratified sampling technique was applied to sample smallholder farmers in all three regions of Northern Ghana to participate in the study. The three regions were purposively selected based on the rapid decline in the soil health of these regions due to continuous cropping and the high agriculture activity in the regions. Three districts from each region were randomly sampled from a list of five (5) purposively selected districts based on crop production and geographical spread. Five communities were randomly selected from these selected districts. A total of three hundred (300) farmers were sampled from the fifteen communities for the study.

2.3. Data Types and Sources. The study employed both qualitative and quantitative data in this study. Primary data were the main data source for this study collected from farmers, input dealers, organic fertilizer (compost) producers, extension officers, and scientists. As a result, the study employed different data gathering tools, which included a survey questionnaires and focus group discussion checklist for primary and secondary actors of the study. Ten focus group discussion sessions were conducted, which covered the three regions. This was aimed at augmenting the administration of the survey questionnaire and serve as a means of triangulation to ensure the accuracy of interpretation and depth of discussion. Key informant's interviews were also conducted, engaging in a conversation with key stakeholders in the district such as crop officers, scientists, compost producers, and officials from the Ministry of Food and Agriculture (MoFA). The focus group discussions were carried out with purposively selected farmer groups currently involved in farming.

Semistructured questionnaires were administered to 300 randomly sampled farmers to collect data for the analysis of farm production, farm income and profit status, farm and farm household characteristics, as well as on the access, use, quality, cost, income, perceptions, challenges, recommended interventions, and willingness to adopt organic fertilizer. The questionnaires were administered through face-to-face interviews with the sampled farmers after their consent was sought.

2.4. Impact Estimation of Organic Fertilizer Adoption on Crop Performance. Where experimental data are unavailable, information on the counterfactual situation would normally be provided, and as such the problem of causal inference can easily be resolved [52–54]. However, when the data available are only from a cross-sectional survey as in this current study, where there are no data on the counterfactual situation, it becomes very difficult to measure impact. As argued by Dehejia and Wahba [55] and Hernandez-Sanjaime et al. [56], an effective way of measuring impact is to resort to an investigation of the direct effect of the program by analyzing the differences in outcomes (welfare) among the participants.

The simplest approach to determine the impact of participation on farm and welfare outcomes would be to include in the welfare equation, a dummy variable (one to represent the farm households that participated and then zero otherwise using ordinary least squares (OLS)). This approach, however, might yield biased estimates because it assumes that participation is exogenously determined while it may be potentially endogenous. The decision to participate or not is voluntary and maybe based on individual self-selection. Farmers who participated may have systematically different characteristics from the farmers who did not participate, and they may have decided to participate based on the expected benefits. Unobservable characteristics of farmers and their farms may affect both the participation decision and welfare measures (yield, farm income, and gross margin), resulting in inconsistent/biased estimates of the effect of participation on farm outcomes. For instance, if only the most skilled or motivated farmers choose to participate and we fail to control for skills, then an upward bias estimation will occur. The solution is to explicitly account for such an endogeneity problem using simultaneous equation models [56, 57].

While there are a good number of methods for impact evaluation, the most common in the literature are the Differences in Differences approach (DiD), Propensity Score Matching (PSM) by Rosenbaum and Rubin [58], Endogenous Switching Regression (ESR), and the Instrumental Variables (IV) approach. If pre-and postproject panel data generated through well-designed experimental approaches are available, DiD has clear advantages over all others as it is potent in removing biases introduced through both observable and unobservable factors. However, such data are often not available to researchers as in this case, and hence nonexperimental approaches are used to statistically measure impact [52, 53, 59, 60]. Among such approaches, the instrumental variables approach is hailed for its strength in minimizing biases due to both observable and unobservable factors, but finding an appropriate instrument always remains a great challenge. As the data available for this study are only a one-shot household survey, the endogenous treatment effect regression model (ETERM) is employed. Three indicators are used to measure farm performance in this study, which include crop yield, farm income, and gross margins.

2.5. Endogenous Treatment Effect Model (ETEM). The endogenous treatment effect model is a linear model that allows for the correlation between unobservable factors affecting the treatment equation and those affecting the outcome measures. The idea is to model the treatment effect on the outcome measure as in [12, 61]. This model has also been used in the medical field such as in the study of the effect of medical advice on individual alcohol consumption [62] and in investigating the impact of smoking on body weight [59]. It was also used to assess the effect of the number of visits to a health facility on the health status of an individual [63]. This model assumes a joint normal distribution between the errors of the treatment equation and the outcome equation.

It is perceived that organic fertilizer (OF) offers several potential advantages over inorganic fertilizer (IOF). To measure the effect of organic fertilizer on maize production, we must control for differences between farmers who choose to adopt and those who do not. For example, most organic fertilizer adopters maybe more educated or have less managerial or technical capability of maize production that could be correlated with yield, income, and gross margins. Unfortunately, many factors that correlate with both adoption and farm outcomes (yield, farm income, and gross margin) are unobservable. When this arises, simple regression of farm outcomes on the exogenous factors and organic fertilizer adoption will result in biased parameter estimates. This problem is what is referred to as self-selection (self-selection bias arises in any situation in which individuals select themselves into a group, causing a biased sample with nonprobability sampling) problem. In this case, the endogenous treatment model is used to assess the determinants of organic fertilizer adoption and its impact on yield, income, and gross margin of maize production and their determinants jointly. This model is chosen because of its ability to overcome the potential self-selection problem and hence give us unbiased estimates.

2.6. Specification of Endogenous Treatment Effect Model (ETEM). Estimation of endogenous treatment effects is a common feature in empirical studies in economics. When the treatment can be categorized by a dichotomous indicator function, its effects are typically estimated via instrumental variables or variants of the control function approach motivated by Heckman [59, 61, 64–66], The endogenous treatment effect model allows for a correlation between unobservable factors affecting OF adoption and those affecting the farm outcomes (yield, farm income, and gross margin). As in the study by Bidzakin et al. [61] and Green [12], we employ the endogenous treatment effect model specification to assess the impact of organic fertilizer adoption on yield and gross margin and determine the factors influencing organic fertilizer adoption and farm outcomes. This model assumes a joint normal distribution between the errors of the treatment equation (organic fertilizer adoption) and the outcome equation (yield, farm income, and gross margin). We specify the outcome model as follows:

$$Y_i = \beta X_i + \delta U_{\mathrm{iOF}} + \epsilon_i, \quad (1)$$

where the effect of organic fertilizer adoption is the net utility derived from using organic fertilizer (U_{iOF}) on farm outcomes (yield, farm income, and gross margins) expressed as (Y_i). The impact of organic fertilizer adoption on farm outcomes is not captured by δ because these households were not randomly assigned to adoption or otherwise but were personal decisions of the participants to adopt or not (case of self-selection) and the unobserved variables that may correlate with both the treatment variable and the outcome variable (case of endogeneity (the problem of endogeneity occurs when the independent variable is correlated with the error term in a regression model)) may both occur. Hence, neglecting the self-selection and potential endogeneity of organic fertilizer adoption will produce wrong estimates of the treatment model and will overestimate the effect of organic fertilizer adoption (U_{iOF}) on household farm outcomes, hence the use of the ETEM.

Farmers who adopted organic fertilizer (treatment) maybe influenced by farm, household, and community characteristics, and this is modelled using the random utility approach where utility (U) is determined by a set of farm, household, and community variables (G), which also influence farmers' ability and willingness to adopt organic fertilizer. The farmer is assumed to maximize utility when

$$\text{Max}\, U = f(G). \tag{2}$$

We hypothesize that a maize farmer i will adopt organic fertilizer at a particular time (t) if the expected utility derived from adopting (U_{itOF}) is greater than the expected utility of not adopting (U_{itNOF}) ($U_{\text{itOF}} > U_{itNOF}$). The latent utility can also change over time. The net utility derived by the farmer is represented by the latent variable:

$$U_{it}^{*} = U_{\text{itOF}} > U_{\text{itNOF}}, \tag{3}$$

where U^{*} represents the benefits of adoption of organic fertilizer as opposed to not adopting. While U^{*} itself is unobserved, we can determine the farmer choice as his or her revealed preference. The probability that the farmer (i) adopts organic fertilizer can be denoted by Pr ($i = 1$). If the farmer does not adopt, U^{*} takes a value of 0. If we assume a linear relationship, U^{*} can be written as follows:

$$U_{\text{iOF}}^{*} = \alpha_i G_i + u_i, \tag{4}$$

where α_i is a vector of coefficients to be estimated and u_i is a vector of random disturbance of the unobserved factors affecting the adoption decision. The variables included in G include farm, household, and community level socioeconomic characteristics where U_{iOF}^{*} represent utility of adopting organic fertilizer, X_i and G_i are covariates that are unrelated to the error terms ϵ_i and u_i, and β and α are the parameter estimates for the outcome and treatment equations, respectively. The assumption is that, ϵ_i and u_i are jointly normally distributed with mean vector zero and variance covariance matrix Σ given as follows:

$$\begin{pmatrix} \beta_{\text{i}} \\ \alpha_{\text{i}} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & \rho\sigma_1 \\ \rho\sigma_1 & 1 \end{pmatrix}\right], \tag{5}$$

where N denotes the normal distribution.

The model can be estimated using the two-step approach or the maximum likelihood approach. This is, therefore, modelled simultaneously as the organic fertilizer adoption decision model (treatment) as in equation (4) and the outcome model as in equation (1). Consistent estimates of the impact of organic fertilizer adoption on yield, income, and gross margin are obtained by accounting for self-selection bias and for the endogeneity of participation. The determinants of organic fertilizer adoption decision and those of the farm outcomes are jointly determined. The maximum likelihood approach is used to analyse the model using STATA software.

2.7. Estimating the Current and Potential Future Demand for Organic Fertilizers. Using the survey data and secondary data obtained from the Ministry of Food and Agriculture (MoFA), both the short-term and long-term demand of organic fertilizer in the three regions where soil fertility is a major problem was computed using farmer population data and survey data. The farmer population data for each region were obtained from the regional department of agriculture for all three regions. The active farmer prevalence rate was also obtained from the regions. This represents the number of farmers who cultivate in a production season. Moreover, organic fertilizer adoption and potential adoption rates were estimated as well as mean acreage under organic fertilizer production, using the survey and secondary data. The average quantity of organic fertilizer used by these adopters was also estimated. Current demand (short-term) and potential future demand (long term) were estimated as follows for each region:

$$A_{OF} = \frac{T_{OF}}{T_S}, \tag{6}$$

where A_{OF} represents Organic Fertilizer Adoption Rate. This is the ratio of the total number of farmers surveyed who are using organic fertilizer (T_{OF}) relative to the total number of farmers surveyed (T_s), which represent the pace at which organic fertilizer is acquired and used by the public.

$$A_{\text{OFP}} = \frac{T_{\text{OFW}}}{T_S}, \tag{7}$$

where (A_{OFP}) is the Organic fertilizer potential adoption rate. This represents the ratio of the total number of farmers who are willing to adopt organic fertilizer (T_{OFW}) relative to the total number of farmers surveyed (T_s).

$$T_{AF} = P_{RF} * \text{Pr}_{AF}, \tag{8}$$

where (T_{AF}) represents the total number of active farmers in the region. This is computed as the product of the total regional farmer population (P_{RF}) and active farmer prevalence rate for the region (Pr_{AF}). Pr_{AF} is computed as the proportion of farmers in a region who are likely to farm in the year.

$$DD_C = T_{AF} * A_{OF} * M_{FA} * M_{\text{QOF}}, \tag{9}$$

where DD_C is the computed current demand for organic fertilizer, which is the product of the total number of active farmers (T_{AF}), organic fertilizer adoption rate (A_{OF}), mean acreage under organic fertilizer (M_{FA}), and mean quantity of organic fertilizer used per acre (M_{QOF}).

$$DD_F = T_{AF} * PA_{OF} * M_{\text{FFA}} * M_{FQ}, \tag{10}$$

where DDF is the computed future demand, which is a product of the total number of active farmers (T_{AF}), organic fertilizer potential adoption rate (PA_{OF}), projected future mean acreage under organic fertilizer (M_{FFA}), and projected mean quantity of organic fertilizer to be used (M_{FQ}).

These equations were used to guide in computing the current demand for organic fertilizers and the potential future demand for organic fertilizer.

3. Results and Discussion

3.1. Characteristics of Farmers and Their Maize Farms. Based on the farmers sampled, 39% of them are using organic fertilizer in their crop production with 75% them being males and 25% females. Nonadopters were made up of 89% males and 11% females. About 49% and 35% of the adopters and nonadopters, respectively, had formal education, which could mean education has a positive influence on organic fertilizer adoption. The highest level of education obtained by the farmers is the senior high level, representing about 14% and 10% of adopters and nonadopters, respectively (see Table 1). The majority of farmers interviewed are illiterates, and this may have a negative impact on organic fertilizer adoption as education tends to have positive influence on technology adoption [67–69]. On the contrary, Uematsu and Mishra [70] indicated that formal education can be a barrier to technology adoption, especially when small scale farmers have higher tendency to work off-farm. This may not apply in this case as most of our farmers may not have the skill requirement for off-farm employment as they are mostly illiterates. Even those who may have the skills may not be able to find jobs as there is a very high unemployment rate in the country.

The study found that the average organic fertilizer adopter is three years older than nonadopters. This is reflected in their age means of 46 and 43 years, respectively, for adopters and nonadopters of organic fertilizer (see Table 2). Adopters and nonadopters had a mean year of farming experience of 22 and 21 years, respectively, with an average of 15 and 14 household members, respectively. Organic fertilizer adopters recorded an average total household worth of $437, and nonadopters recorded an average total household worth of $404 (see Table 2). This implies that age and years of farming experience may have a positive influence on organic fertilizer adoption. Organic fertilizer adoption may also have a positive impact on the income of farm households. Age and farming experience may also have positive impact on organic fertilizer adoption, as shown in Table 2.

The mean maize farm size for adopters and nonadopters is 1.12 and 1.24 ha, respectively, with mean yield of 2.2 t/ha and 1.3 t/ha, respectively. The mean total production cost of maize was estimated as $70 for adopters and $85 for nonadopters, respectively (Table 3). The total farm revenues of adopters and nonadopters are $222 and $167, respectively. As expected, adopters recorded a higher gross margin of $152 compared to $82 for nonadopters. The farm sizes of adopters are smaller than those of their nonadopter counterparts. The smaller farm sizes maybe the reason for the higher yields of adopters than nonadopters, which could be as a result of effective and efficient farm management. The total cost of production of adopters was lower than that of nonadopters, just as their cost of input. This could be because of their relatively smaller farm sizes, and this could have a positive impact on farm profitability.

3.2. The Adoption of Organic Fertilizer and Factors That Will Stimulate Its Adoption

3.2.1. Organic Fertilizer Usage in Crop Production. The study revealed that the reason for nonadoption of organic fertilizer by most farmers was as a result of the nonavailability (scarcity) of organic fertilizer (compost) in their communities, as supported by the work of Waithaka et al. [71], where they established the fact that access to input market could influence organic fertilizer adoption positively. Abebe and Debebe [72] found that the availability of composting material could increase organic fertilizer adoption in their organic fertilizer study in Ethiopia. Reference [73] showed that access to extension services had a positive effect on technology adoption. This is followed by high transportation costs and lack of knowledge of organic fertilizer importance, which is collaborated by the work of [74]. It was also revealed that about 90% of organic fertilizer adopters applied animal droppings on their farms, whereas compost and farmyard manure applications were about 5% each. About 95% of organic fertilizer adopters obtained their animal droppings from their own animal's pens, only 5% indicated they bought it. This buttresses the point that availability is a major factor in influencing the adoption of organic fertilizer. Almost all farmers who adopted organic fertilizer had animals at home and hence had access to the animal dropping, which allowed them to apply it on their farms. To increase organic fertilizer adoption as the results indicates, more education must be done on the importance of organic fertilizer in crop production, and it must be made readily available through capacity building of farmers on the production of organic fertilizer and encourage investors to go into commercial production of organic fertilizer. Increased access to transport will have positive impact on the adoption of organic fertilizers as it is bulky and hence very expensive to transport. Transport subsidy for organic fertilizer transportation will be a useful policy option.

3.2.2. Effect of Organic Fertilizer Application on Maize Production Factors. The *t*-test results in Table 4 show that the mean difference in maize farm size of nonadopters and adopters of organic fertilizer is about 0.2 acres, which is not statistically significant. The mean difference in the amount farmers is willing to pay for organic fertilizer per acre, yield, and gross margins for nonadopters compared to adopters which are $7.7, 32.9 kg/acre, and $75, respectively, which are all statistically significant at 1% level of significance. The mean difference between nonadopters and adopters farm income is $59, which is statistically significant at 1% level of significance. Cost of maize production of nonadopters is far more than that of the adopters with a mean difference of $16, which is significant at 1% level of significance. With respect to access to extension services, adopters had more access to extension services than nonadopters, as shown in Table 4. Increased access to extension services could have positive influence on the adoption of organic fertilizer.

Table 1: Characteristics of adopters and nonadopters.

Variables	Response	Nonadopters (%)	Adopters (%)	Total (%)
Sex of farmer	Female	11.0	25.5	18.3
	Male	89.0	74.5	81.7
Formal education status of farmers	No formal education	65.2	50.5	57.9
	Formal education	34.8	49.5	42.1
Highest level of education by farmers	JSS	12.0	19.4	15.7
	None	65.2	50.5	57.9
	Primary	12.5	15.7	14.1
	SHS	10.3	14.4	12.3

Source: survey 2020.

Table 2: Characteristics of farm household and farmers sampled.

Variables	Nonorganic fertilizer adopters				Organic fertilizer adopters			
	Mean	Min	Max	STD	Mean	Min	Max	STD
Age of farmers	43	21.0	70.0	10.9	46	26.0	72.0	11.8
Farming experience in (yrs)	21	3.0	51.0	11.8	22	5.0	48.0	11.2
Household size	14	5.0	34.0	6.0	15	5.0	36.0	7.0
Total household worth ($)	404	44	4241	644	437	40	2486	492

Source: survey 2020.

Table 3: Factors of production of maize farmers.

Variables	Nonorganic fertilizer adopters				Organic fertilizer adopters			
	Mean	Min	Max	STD	Mean	Min	Max	STD
Farm size (ha)	1.24	0.24	5.6	0.76	1.12	0.4	6.4	0.92
Yield (t/ha)	1.30	0.30	14.29	1.58	2.18	0.25	6.70	1.47
Total cost of chemical fertilizer ($)	73.1	0.0	688.0	113.3	46.7	0.0	340.0	54.0
Total cost of organic fertilizer ($)	0.0	0.0	0.0	0.0	15.2	0.0	100.0	17.9
Total cost of other inputs ($)	11.9	0.0	50.7	12.4	8.5	0.0	28.0	7.1
Total production cost ($)	85.1	0.0	688.0	116.8	70.3	21.1	360.0	56.0
Amount ($) farmers are willing to pay for OF	24.8	4.0	72.0	15.3	17.6	6.7	45.3	9.5
Total revenue ($) production	166.6	32.0	1813.3	234.0	222.0	54.4	725.8	154.3
Gross margins ($)	81.6	−528.0	1792.0	268.4	151.7	−118.1	642.4	156.5

Source: survey 2020.

3.2.3. Farmers Fertilizer Preference. The majority of farmers interviewed preferred organic fertilizer to mineral fertilizer with the reasons being that organic fertilizers improve the soil capacity to hold nutrients for longer period, it is less expensive, it improves the soil structure, and it increases crop yield. 64% of organic fertilizer adopters indicated their preference for organic fertilizer. The majority of nonadopters (48%) indicated that they preferred organic fertilizer to mineral fertilizer although they were currently not using it. About 93% of the farmers interviewed indicated that organic fertilizer is very scarce in their communities, and about 52% of them indicated that organic fertilizer was more affordable than mineral fertilizer if available. See Table 5. With these perceptions, if organic fertilizer is available, the majority of farmers are likely to use it; hence, more effort should be put into the production of organic fertilizer to increase its availability and access.

3.2.4. Factors Stimulating Organic Fertilizer Adoption. The adoption of organic fertilizer is mainly influenced by their farmer-based organization (FBO) membership status, consistent with the findings of [35] where they found membership to farmer-based organizations positively influenced the decision to adopt organic fertilizer in their work on Analyzing the Determinants of Adoption of Organic Fertilizer by Smallholder Farmers in Shashamane District, Ethiopia. There were similar findings in the work of [75] in their rice work in Nigeria. Access to extension services also had a positive influence on organic fertilizer adoption, which is consistent with the findings of Abebe and Debebe [72], where they established that access to extension services could increase organic fertilizer adoption in their organic fertilizer study in Ethiopia. Ali et al. [43] also found a positive relationship in their fertilizer adoption work in Ghana. Ajewole [30] study of organic fertilizer adoption in Nigeria also established a positive relationship. Age of the farmer also have positive impact on OF adoption consistent with the findings of Kariyasa and Dewi [74] in their study of factors affecting adoption of integrated crop management farmer field school in swampy areas. Fertilizer subsidies and farm size play positive roles in influencing 'farmers' decision to adopt organic fertilizers. Reference [76] in a study of

Table 4: Effect of organic fertilizer on maize production factors.

Variables	Organic fertilizer adopters	Nonorganic fertilizer adopters	Mean difference	t-statistic
	Mean	Mean		
Maize farm size in acres	2.84	3.05	−0.21	−1.0313
Chemical fertilizer used in kg/ha	241.03	259.02	−18.0***	−87.7
Access to extension services	2.3	1.2	1.1***	5.3
Amount farmers are willing to pay for organic fertilizer per acre	18.8	26.6	−7.7***	−37.8
Yield per acres	509.2	476.3	32.9***	1.6
Total farm income $	237.9	178.5	59.3***	285.7
Total cost of production $	75.4	91.1	−15.8***	−76.9
Gross margins $	162.5	87.4	75.1***	371.4

***significant at 1% level of significance; **significant at 5% significance level; *significant at 10% significance level.

Table 5: Farmer fertilizer preferences.

Variables	Response	Nonorganic fertilizer adopters	Organic fertilizer adopters	Total
Choice of fertilizer	Both	11.8	15.3	10.5
	Chemical fertilizer	40.3	20.2	30.0
	Organic fertilizer	47.9	64.5	59.5
Reason for choice of organic fertilizer	It improves the soil structure	6.2	9.2	6.8
	It is less expensive	10.8	6.6	6.7
	Its nutrient lasts longer in the soil	73.0	66.2	70.9
	Gives higher yield	10.0	18.0	15.6
Organic fertilizer availability	No	91.4	95.0	93.0
	Yes	8.6	5.0	7.0
Organic fertilizer affordability	No	64.7	25.2	48.0
	Yes	35.3	74.8	52.0

Source: survey 2020.

chemical and organic fertilizers by apple growers in China conducted in 2016 found that fertilizer subsidies influenced organic fertilizer adoption.

3.3. The Impact of Organic Fertilizer Adoption on Maize Farm Performance

3.3.1. The Impact of Organic Fertilizer on Maize Yield. Results of the endogenous treatment effect model, which was used to analyse the impact of organic fertilizer adoption on yield, are presented in Table 6. The results of the determinants of organic fertilizer adoption are presented in the 4th and 5th columns of Table 6, while impacts on the yield of maize are presented in the 2nd and 3rd columns of Table 6.

From the results, the Wald test is statistically significant (1%) indicating the goodness of fit of our endogenous treatment effect model justifying the use of the endogenous treatment model. The likelihood ratio test of independence of organic fertilizer adoption and yield (outcome) equations indicates that the null hypothesis of no correlation between usage (adoption) and yield should be rejected at the 1% level of significance. The results have established a strong positive relationship between organic fertilizer usage and crop yield. Maize yields of farmers who used organic fertilizer are higher than those who did not apply organic fertilizer on their maize farms. Reference [77] indicated there is generally a positive relationship between compost and crop yield from several literature reviewed. Reference [78] established that yield is significantly enhanced by the contribution of manure in their evaluation of poultry manure on maize yield, which is in line with the findings of this study. For the sake of sustainability, the authors in [79] argue, despite the positive impact of organic fertilizer on yield, it is advisable to integrate with inorganic fertilizer, which was the case with most of the adopters in this study.

The estimated average treatment effect on the treated (ATET) of organic fertilizer adoption in maize production is estimated to be 1,143 kg (1.14 t) of yield, which is about 57% increase in yield when compared to nonadopters. Thus, the impact of organic fertilizer adoption on maize yield is about 57% yield increase. This implies that all things been equal, farmers using organic fertilizer will obtain higher yields than those not using organic fertilizer, which is consistent with

Table 6: Estimates of the endogenous treatment effect model of the impact of OF on yield.

Variables	Yield		OF	
	Coef.	Std. err.	Coef.	Std. err.
Farm size	−38.43	26.72		
Worth	0.00	0.01	0.00	0.00
Chemical fertilizer	−0.29	0.25		
Organic fertilizer	−0.22	0.22		
Age			0.01*	0.01
Extension serv.			0.04*	0.06
FBO-M			0.509***	0.22
OF affordability			0.10	0.22
1.OF (ATET)	1142.987***	171.54		
Constant	360.843***	130.81	−0.79	0.40
/athrho	−1.30***	0.239		
/lnsigma	6.47***	0.098		
rho	−0.863	0.06		
Sigma	646.93	63.17		
Lambda	−558.01	86.49		
Log likelihood	−820.28			
Wald test χ^2 (19)	55.48***			
LR test of independent equations χ^2 (1) 8.7***				

***Significant at 1% level of significance; **significant at 5% significance level; *significant at 10% significance level.

Amfo and Baba [38] in their vegetable work in Ghana, where they established that organic and inorganic fertilizers improve farm productivity; Martey [40] also showed a positive effect of organic fertilizer on productivity and income in his study of Welfare effect of organic fertilizer use in Ghana.

Boateng [80] who worked on adoption, technical efficiency, and welfare effects of organic vegetable production in the northern region of Ghana also established a positive relationship between organic fertilizer use and yield increase. The estimated correlation between the treatment assignment and the outcome error term is −0.86. This shows that the unobservable yield increase also tends to occur with the unobservable influences of organic fertilizer usage (self-selection). This implies that if self-selection was not controlled, the estimates will have been overstated (biased), resulting in wrong estimates and hence poor conclusions. The negative sign indicates a positive bias, suggesting that farmers with above average yield have a higher propensity of adopting organic fertilizer. As demonstrated by this study, organic fertilizer is very good in maize production and has the potential to increase maize yields up to about 57% when used.

This, however, may not have the same impact when used in other crops, and hence the study recommends future research involving other crops. The study also did not specify the type of organic fertilizer used and the quantities were very varied, and hence it will be useful to dive deeper to consider specific type of organic fertilizers and the specific quantities used to assess their impact on farm performance to guide making specific recommendations regarding fertilizer rates for promotion.

3.3.2. The Impact of Organic Fertilizer on Maize Farm Income. One of the major contributions of this study is to go beyond the impact on yield to include income and profitability, which is often not studied. The results of the endogenous treatment effect model on the impact of organic fertilizer on income are presented in Table 7. The results of adoption equation representing the decision to adopt and the factors influencing the organic fertilizer adoption decision are given in the 4th and 5th columns of Table 7 while the impact on farm income is presented in the 2nd and 3rd columns of Table 7.

From the results, the Wald test was statistically significant (1%) indicating the goodness of fit of our endogenous treatment effect model justifying the use of the endogenous treatment model. The likelihood ratio test of independence of using organic fertilizer (adoption decision) and income (outcome) equations indicates that the null hypothesis of no correlation between usage and income can be rejected at the 1% level of significance. The implication is that there is a positive relationship between organic fertilizer use and farm income. Application of organic fertilizer will result in an increase in farm income. The estimated average treatment effect on the treated (ATET) of organic fertilizer adoption in maize production is $409.60 of income, which is about 53% increase in income. Thus, the impact of organic fertilizer on income is about 53% increase of farm income. This implies that farmers using organic fertilizer will obtain higher incomes than those who did not use organic fertilizer, which is consistent with the findings of Amfo and Ali [38], Martey [40], and Boateng [80]. The increase is as a result of increase in yield, as demonstrated in Table 6. Farm income is a function of the product of quantity produced and its unit price. The increase in farm income could also be as a result of high market premium associated with organic products. Reference [81] in their study of conservation agriculture establishes that organic production increases farm income and profitability.

The estimated correlation between the treatment assignment error and the outcome error is −0.90, which implies that the unobservable variables that increased income also tend to occur with the unobservable variables that influences OF adoption (self-selection). The negative sign indicates a positive bias, suggesting that farmers with above average income have a higher propensity of adopting organic fertilizer. Organic fertilizer did not only increase yields but also increased farm income up to about 53% when used. The adoption of organic fertilizer is perceived to result in increase in cost of production due to extra labour requirement and transport cost associated with the technology, as supported by the works of [36, 37]. However, the findings of [81] establish a negative relationship with the cost of production. Either an increase or a decrease in cost of production, it will have implications for farm profitability. This is what motivated this study to dive deeper to assess the impact of organic fertilizer on farm profitability (gross margins). The study has established a positive relationship between organic fertilizer adoption and farm revenue in maize production mainly due to increased yield in other places, where premium is place on organic products farm revenue could even go higher.

Table 7: Estimates of impact of the endogenous treatment effect model of the impact of OF on income.

Variables	Income		OF	
	Coef.	Std. err.	Coef.	Std. err.
Farm size	194.671	75.303***		
Worth	−0.001	0.043	0.000	0.000
Chemical fertilizer	−0.309	0.680		
Organic fertilizer	−0.286	0.583		
Age			0.013*	0.007
Extension serv.			0.009*	0.047
OF FBO			0.368**	0.195
OF affordability			0.134	0.202
1.OF (ATET)	409.601***	58.961		
Constant	−126.422	362.722	−0.906	0.368
/athrho	−1.507***	0.213		
/lnsigma	7.538***	0.090		
rho	−0.906	0.038		
sigma	1878.522	168.854		
lambda	−1702.565	204.570		
Log likelihood	−921.188			
Wald test χ^2 (5)	64.590***			
LR test of independent equations χ^2 (1) 18.22***				

***Significant at 1% level of significance; **significant at 5% significance level; *significant at 10% significance level.

3.3.3. The Impact of the Organic Fertilizer on Maize Farm Gross Margin. The results of the endogenous treatment effect model on the impact of organic fertilizer on the gross margins of maize farms are presented in Table 8. The results of adoption decision equation representing the determinants of adoption are given in the 4th and 5th columns, while the impact on farm gross margin is presented in the 2nd and 3rd columns of Table 8.

From Table 8, the Wald test is statistically significant at 1% level of significance indicating the goodness of fit of our endogenous treatment effect model justifying the use of the endogenous treatment effect model. The likelihood ratio test of independence of organic fertilizer adoption and gross margin equations indicates that the null hypothesis of no correlation between organic fertilizer usage and gross margin was rejected at the 1% level of significance. This implies that organic fertilizer adoption is positively

Table 8: Estimates of the endogenous treatment effect model of the impact of organic fertilizer on gross margin.

Variables	Gross margin		OF	
	Coef.	Std. err.	Coef.	Std. err.
Farm size	227.619	88.030		
Worth	0.008	0.045	0.000	0.000
Chemical fertilizer	−2.673	0.779		
Organic fertilizer	−0.697	0.675		
Age			0.009*	0.008
Extension serv.			0.003*	0.052
OF FBO			0.552**	0.217
OF affordability			0.342	0.232
1.OF (ATET)	431.134	168.533		
Constant	−248.777	411.673	−0.984	0.411
/athrho	−1.226***	0.210		
/lnsigma	7.582***	0.093		
rho	−0.842	0.061		
sigma	1963.300	183.442		
lambda	−1652.150	250.469		
Log likelihood	−932.162			
Wald test χ^2 (19)	51.77			
LR test of independent equations χ^2 (1)	12.5***			

***Significant at 1% level of significance; **significant at 5% significance level; *significant at 10% significance level.

correlated with gross margin. The estimated average treatment effect on the treated (ATET) of organic6466 fertilizer adoption in maize production is about $431 of gross margin, which is about 63% increase in gross margin. Thus, the impact of organic fertilizer usage on the gross margin is about 63% increase in gross margin.

Contrary to the perceived increase in the cost of production associated with organic fertilizer adoption, as supported by the works of [36, 37], the study establishes a decrease in the cost of production by adopters and also increase yield of adopters resulting in increase in profit. The impact of organic fertilizer adoption on profit is higher than its impact on yield and income. This is similar to our findings in Tables 4 and 6 that show that the cost of production is lower among adopters when compared to nonadopters and income is also higher among adopters when compared to nonadopters. This implies farmers using organic fertilizer will obtain higher gross margins than those not using organic fertilizer, as supported by [82] in their work on organic agriculture in the twenty-first century and [34] when they investigated the factors affecting the adoption of organic farming in Pakistan. The reasons for increase in profitability are the increase in revenue, and also the reduction in cost is due to the cheaper cost of organic fertilizer relative to inorganic fertilizers.

The estimated correlation between the treatment assignment error and the outcome errors is −0.84. This shows that the unobservable variables that increased gross margin also tend to occur with the unobservable variables that influence organic fertilizer usage indicating the presence of self-selection problem. The negative sign indicates a positive bias, suggesting that farmers with above average gross margin have a higher propensity of using organic fertilizer. The finding implies that not only does the use of organic fertilizer increase yield and farm income but also has the potential to increase gross margins by 63%. Farmers will earn more money from the use of organic fertilizer and will enhance their livelihoods.

Aside the environmental and health benefits associated with organic fertilizer production, the economic benefits of using organic fertilizer are so great and all farmers should be encouraged to adopt organic fertilizer in their maize production and probably in all their crop production activities.

3.4. The Commercialization Potential of Organic Fertilizer in Ghana

3.4.1. Computing the Current and Potential Future Demand of Organic Fertilizer. The third objective of this study is aimed at establishing if there is a chance for organic fertilizer production to be commercialized. Out of the organic fertilizer adopters sampled, the distribution of organic fertilizer used by the various crops shows that the majority of the organic fertilizer adopters used it in vegetable production (42%). This is followed by maize production (25%), and rice and millet scored about 9% and 10%, respectively (see Figure 1). This shows that the current organic fertilizer demand is driven primarily by vegetable and maize production. However, in terms of land area and total production, maize production is far much more than vegetable production. This is an indication that when adoption increases among maize farmers, organic fertilizer demand will increase significantly.

The current demand of organic fertilizer is estimated to be about 718 thousand metric tonnes (see Table 9). When this was valued at the 2020 organic fertilizer price of $6 per 50 kg, it yielded $108 million. This can make Ghana a net exporter of fertilizer when compared to the 2021 fertilizer import bill of $79 million. This can also create sustainable jobs for the youth contributing positively to the unemployment situation in the country (Table 9).

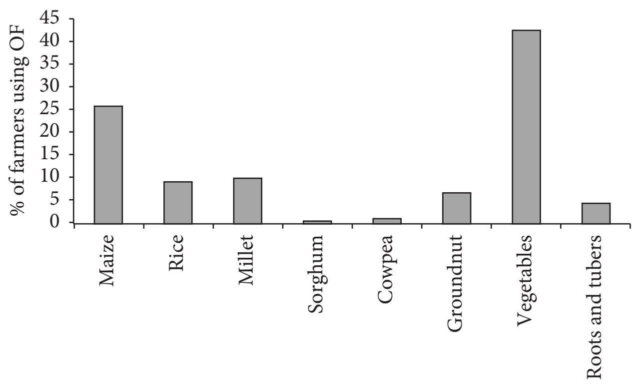

Figure 1: Organic fertilizer usage by crop.

Table 9: Estimated current demand of organic fertilizers.

Region	Farmer pop.	Active farmer pop.	OF adoption rate 39 (%)	No. of farmers	Mean ha using	Mean OF quantity/ha (kg)	Estimated demand (t)
NR	2450000	1715000	39	668850	1	625	418,031
UER	910000	728000	45	327600	0.9	750	216,216
UWR	630000	504000	42	211680	0.8	500	84,672
Total demand							718,919

Source: author computation.

Table 10: Estimated potential future demand of organic fertilizers.

Region	Farmer pop.	Active farmer pop.	OF adoption rate 39 (%)	No. of farmers	Projected future mean acreage under OF	Projected future mean OF quantity used/acre (kg)	Estimated demand (t)
NR	2450000	1715000	59	1011850	3.1	500	1,568,367
UER	910000	728000	61	444080	2.8	600	746,054
UWR	630000	504000	65	327600	2.5	400	327,600
Total demand							2,642,021

Source: author computation.

The potential future demand for organic fertilizer is estimated to be about 2.6 million metric tonnes (see Table 10). When this was valued using 2022 organic fertilizer price of $9 per 50 kg, it yielded about $475 million. This will contribute significantly to Ghana's agriculture development and to the national economy in general (see Table 10).

The major limiting factors to the adoption of organic fertilizers identified in the study include the nonunavailability of organic fertilizer, as collaborated by [83] in their work on farmers' perceptions of organic farming in India and Reference [84] in their work on perception in organic fertilizer in rice production in Cambodia. Lack of information regarding its ability to increase farm benefits also hinders its adoption, as supported by the findings of [85, 86] in their work in Nigeria on organic farming status. It is clearly demonstrated that the availability of the product and public education on its importance in crop production will play a great role in influencing farmers to adopt organic fertilizer and also expand their farm sizes under organic fertilizer as supported by [83]; hence, this will drive an increase in the demand of organic fertilizer. Interactions with fertilizer distributors and retailers expressed their willingness to distribute organic fertilizers to farmers if they are made available.

4. Conclusions and Recommendations

The study revealed that the reason for the low adoption of organic fertilizer by farmers is because of the nonavailability (scarcity) of organic fertilizer (compost). Availability of composting material and access to input market could influence organic fertilizer adoption positively. High transportation costs and lack of knowledge of organic fertilizer importance are limiting factors to the adoption of organic fertilizer. Educating farmers on the importance of organic fertilizer in crop production is very important in influencing the adoption of organic fertilizer. Increased access to transport will have a positive impact on the adoption of organic fertilizers as it is bulky and hence very expensive to transport. Transport subsidy for organic fertilizer transportation will be a useful policy option.

Farmers should also be encouraged to participate in farmer base organizations to help them in accessing knowledge and hence increase the adoption of organic fertilizer. The study has clearly revealed that farmers prefer organic fertilizer over chemical fertilizers. Organic fertilizer adopters used less chemical fertilizer with the lowest production cost and had better access to extension services. They also reported higher yields, farm income, and gross margins. Organic fertilizer adopters have smaller farm sizes compared to nonadopters. They, however, reported higher yields compared to nonadopters and incur lower production costs leading to larger gross margins.

The endogenous treatment effect model was employed to assess the impact of organic fertilizer on farm performance. The results show a significant impact of organic fertilizer adoption on farm yield, farm income, and gross margins. Organic fertilizer adoption increases yield by 57% and increases farm income by 53%, and farm gross margins increased by 63%. There is a cost reduction when organic fertilizer is adopted, and there is an increase in farm income resulting in an increase in farm profit. Promoting the use of organic fertilizer in maize production is highly recommended. Farmers should be sensitized on the potential gain they are likely to obtain when organic fertilizer is used. Subsidy on organic fertilizer should be considered as it will stimulate its adoption and increase yield, income, and profit significantly. This will also provide opportunity for job creation and reduce the import bill of the country.

Commercialization of organic fertilizer production will provide a great opportunity for the large organic waste generated in the country to be converted into organic fertilizer for crop production. This will reduce the negative environmental impacts, will reduce the cost of waste management, will improve soil health, will reduce the cost of crop production, will increase farm household income, and will generate about $475 million per annum. We recommend the government and other major stakeholders to support individuals andor entities who are interested in venturing in organic fertilizer production in Ghana. There is a great market potential for organic fertilizer in Ghana; thus, investments should be increased in this regard to promote the benefits of organic fertilizer, increase its production, and facilitate easy access by farmers. Commercialization of organic fertilizer production should be encouraged and capacity building on organic fertilizer production should be considered.

Data Availability

Data will be made available by the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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