Multivariate Regression Analysis of Inorganic Fertilizers use Intensity among Small Scale Cereal Crop Farmers in Ogbomoso ADP Zone of Oyo State, Nigeria

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ABSTRACT

The intensification of crop cultivation on the available agricultural lands makes the land prone to degradation and suggests the need for applying recommended rate of inorganic fertilizers to amend soil fertility. In view of this, the study focused on inorganic fertilizers use intensity (FUI) among small scale cereal crop farmers in Ogbomoso ADP zone of Oyo State, Nigeria. A four-stage sampling procedure was designed to select one hundred and seventy-five (175) respondents proportionally and primary data were collected using structured questionnaire with the aid of survey enumerators. Frequency percentage, FUI index and multivariate multiple regression were employed as analytical tools. Based on the results, the intensity/extent of NPK versus urea fertilizers applied by the cereal producing farmers were 3.3731kgha^{-1} and 0.8109 kgha^{-1} respectively on the average. As analyzed by the multivariate stepwise regression, the significant determinants of extent/intensity of NPK and urea fertilizers used are household size (count), farm size (ha) and cereal crops produced (kg). The finding further identified these: expensive price of inorganic fertilizers, ineffectiveness of inorganic fertilizers, poor record keeping of inorganic fertilizers used, no knowledge of inorganic fertilizers application as well as lack of access to subsidized inorganic fertilizers as challenges combating the cereal farmers in applying chemical fertilizers. It concludes that household size as a socio-economic factor, farm size and total cereal crops production have economic implications on intensity of NPK and urea fertilizers used to maintain soil fertility. It is therefore, necessary to give due emphasis to the indicated determinants and challenges in order to assist cereal producing farmers in Nigeria. Also, the efforts to enhance sustainable cereal production should focus on the farmers' use intensity of inorganic fertilizers as against the present economic policy and agro-ecological condition.

Keywords: Inorganic Fertilizer, Use Intensity, Small Scale, Cereal Farmers, Multivariate Regression.

INTRODUCTION

Cereal crops production, all over the world has surpassed long-term levels with substantial intensification and expansion in cultivation areas. Among the dominant cereal crops maize, guinea-corn, rice, millet and sorghum cultivated in the agro-ecological zones of Nigeria on yearly basis; maize and guinea-corn frontier among others, while cereal crops, such as rice and maize constitute a significant portion of the world's food supply and play a vital role in meeting the nutritional needs of a growing global population.

Yet, the high rate of food shortage remains a persistent challenge and unresolved in this country. The problem as perceived, is due to soil depletion versus land encroachments coupled with the climate change impact on

agriculture. For example, in Kenya like Nigeria soil fertility decline and climate change are the main limitations facing rain-dependent smallholder farmers in western Kenya (Musafiri, et al, 2023).

Soil fertility depletion according to Mekonnen, (2020) is one of the major constraints fostering cereal crop yields reduction. In consequence, inorganic fertilizers are continually in use by the cereal farmers across the world's agricultural regions in order to prevent loss of soil nutrients and enhance crop productivity (Baruwa 2016).

Substantively, there is recognition that increased use of inorganic fertilizers has been responsible for an important share of world-wide agricultural productivity growth. For instance in Nigeria, Olatunji and Akanbi, (2022) espoused that over 70% of the total population of arable farmers depend on inorganic fertilizers to maintain soil nutrients.

Understanding this fact about fertilizers, their significance in addressing food security challenges, particularly in regions with impoverished soils, cannot be overstated (Stewart and Roberts, 2012). In practice, crops (like cereal) receive essential minerals either through the application of organic manure or inorganic fertilizers. The application of fertilizers stands as a highly effective approach for meeting the nutritional needs of crops and replenishing depleted nutrients. Fertilizers, whether derived from natural sources or synthetically produced, are substances that, when administered to the soil, provide one or more vital nutrients necessary for plant growth and enhanced yields (Barker, 2019). Essentially, inorganic fertilizers, due to their rapid nutrient release, can provide quick boosts in crop yields.

Cereal farmers' fertilizer choices are often driven by economic, environmental, agronomic as well as some socio-economic factors in the sense that, the arbitrary cost of fertilizers is adding to the variable costs of producing cereal crops which in turn affect the returns. Also, sequel to the possibility of having environmental degradation, resulting from misuse or overuse of chemical fertilizers, many farms have often been cautioned on their usage with resultant declining in the application rate. Another thing is that, mainly for crop suitability, soil composition always determines when the land needs fertilizers application to conserve soil fertility and the socio-economic characteristics of the farmers like age, family size, educational background, experience/skill, farm size and others play important roles in rationing financial resource that is, between home upkeep and purchase of farm inputs as well as physical handling of inorganic fertilizers adoption.

Moreover, the adoption of inorganic fertilizers is often linked to modernization and mechanization in agriculture, because effective application of fertilizers is easily practiced on the mechanized farms. This justification outlines the reasons for investigating the intensity of inorganic fertilizers use among cereal crop farmers with the aim of addressing undesirable application of the chemical fertilizers such as NPK and urea to mention but a few. In addition, analysing the intensity of fertilizer use can aid in fine-tuning fertilizer recommendations to maximize crop yields while minimizing input costs.

Overall, inorganic fertilizers represent a pivotal technology for augmenting crop yields most importantly cereal crops. However, their usage often falls below recommended levels, with a substantial number of farmers abstaining from their use altogether.

Nevertheless, the available evidence underscores that fertilizer application has remained at low levels in many parts of Nigeria, as noted by Olayide et al, (2010), and it remains lower than what is observed in other developing regions at moment, particularly in Nigeria as a consequence of fuel of subsidy removal. Since February 2022, the price of fertilizer has more than doubled in Nigeria and other countries. In Nigeria alone, Africa's most populous country, nearly 90 million people roughly two-fifths of the nation suffer from "insufficient food consumption," according to data from the World Bank, 2024. Currently, the inability to afford fertilizer technology makes it harder for rural families to overcome such challenges. This present situation of Nigerian's farmers requires serious research works on this aspect in order to sustain cereal producing farmers and all sundry.

In view of this, the study estimated the key influencers of inorganic fertilizers use intensity among small scale cereal crop farmers in Ogbomoso ADP zone of Oyo state, Nigeria by assessing the different types of inorganic

fertilizers available to cereal farmers, computing the extent/intensity of inorganic fertilizers use by small scale cereal crop farmers and examining the factors influencing fertilizer use intensity among the cereal crop farmers and investigating the constraints faced by the farmers in the use of inorganic fertilizer in the study area.

In conjunction, the study also raised one typical hypothesis which presumes that there is no relationship between the existing socio-economic factors and intensity of inorganic fertilizers use by the cereal producing farmers. This section of the text is followed by the research design and data analysis.

MATERIALS AND METHODS

Study Area

This study was conducted in Ogbomoso Agricultural Development Programme (ADP) zone located in Oyo State of Nigeria from January, 2023 to April, 2024. The area is geographically situated between latitudes 7°15'N and 7°30'N and longitudes 3°30'E and 3°45'E and fell within the tropical zone of Nigeria, with a climate characterized by distinct wet and dry seasons. The Yoruba language is extensively spoken as the local dialect of the people with English being the official speaking language.

The people of Ogbomoso ADP zone are known for their warm hospitality and a strong sense of togetherness/belonging. Economically, they are primarily relied on agriculture as its mainstay. The fertile plains and favorable climate conditions support the cultivation of crops such as maize, yam, cassava, and cocoa. The Ogbomoso ADP zone also has a vibrant agricultural sector with crops such as cereal, tuber, pepper, plantain, cocoa, and kolanut grown in the area. Trade also blossoms in the zone with the area hosting several markets which provide platforms for the exchange of a variety of goods and services.

Sampling Procedure and Data Collection

The population of the study comprised all small scale cereal farmers in Ogbomoso ADP zone of Oyo state, Nigeria and the study was based on a cross-sectional survey design. Multistage sampling technique was used to select respondents coupled with proportional sample size determination approach developed by Yamane (1967). First, Ogbomoso ADP zone was randomly sampled out of four ADP zones in Oyo State. Secondly, as the most rural parts of the zone, 3 LGAs (namely Oriire, Surulere and Ogo-oluwa) out of the 5 LGAs were randomly selected based on the predominance of cereal crops production. In the third stage, the cereal producing farmers were purposively selected from the list of registered food crop farmers provided by the ADP extension workers in the zone. Lastly, from the total number of the registered small scale cereal farmers (population frame) we determined the sample size following the method described by Yamane (1967) sampling approach.

$n = N/(1+N (e)^2)$ ………………………..(1)

N = assumed population size = 450, and e = degree of desired precision (0.05).

$n = 405/ (1+450 (0.05)^2) = 212$ cereal crop farmers

Research questionnaire designed was administered to 212 respondents to collect data. Due to incomplete responses, 37 questionnaires were rejected leaving 175 which was finally used for this study.

Data Analysis and Model Specification

All variables of interest (both the regressors and regresands) captured for the analysis were summarized and described with descriptive statistics such as mean, standard deviation, frequency percentage. Specifically for example, the quantities of inorganic fertilizers applied on cereals and their extent/intensity of use, as well as the constraints encountered by the most small scale cereal farmers were reported by frequency percentage, standard deviation and mean as a measure of central tendency. Also, fertilizers use intensities were computed

based on the quantity of fertilizer used (kg) per land area in hectare (ha) while the index of NPK and urea fertilizers were jointly fitted into a multivariate regression. This regression analysis simultaneously predicted all the key determinants of inorganic fertilizers (NPK and urea) use intensities in cereal crops farming.

Fertilizer use intensity index

Fertilizer use intensity (FUI) as defined by Fufu and Hassan, (2006); Maiangwa, (2007); Olatunji and Akanbi, (2022) was described as follows:

$$\text{Fertilizer Use Intensity} = \frac{\text{Quantity of Fertilizer Used (Kg)}}{\text{Area of Land (Ha)}} \dots\dots\dots\dots\dots\dots 1$$

Multivariate regression analysis

This model was used to analyze the factors that affect fertilizer use intensity among the small scale cereal farmers. It is expressed as:

$$Y_i = \beta_0 + \beta_i X_i + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2$$

$$Y_1, Y_2, = \beta_0 + \beta_i X_i + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3$$

Where Y_i= individual farmer's inorganic fertilizers use intensities, X_i=Vector of explanatory variables, β_i =Vector of unknown coefficients, μ_i = independently distributed error term, i = number of observations = 1, 2, 3…. n.

$$Y_1, Y_2, = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_{5+} \beta_6 X_{6+\dots} \beta_8 X_8 + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots 4$$

Y_i = Fertilizer use intensity in kg/ha each of NPK and Urea respectively, X_1 = Household size (person), X_2= Farm size (hectares), X_3= Extension service (ha), X_4= Quantity of maize produced (tons), X_5= Quantity of maize produced (tons), X_6= Manure use (applied=1, otherwise=0), X_7= Land conflict (yes = 1, no = 0), and X_8= Continuous cultivation (yes = 1, no = 0).

Generally, it has to be mentioned that the inclusion of these variables into model specification has been based on literature reviews from past studies (Baruwa, 2016; Aman et al, 2022).

RESULTS AND DISCUSSION

Measurement and Description of the Variables Included in the Study

The descriptive analysis of the variables included in the study was expressed in the summary statistics Table 1 provided below. It shows that the average age of farmers was 49.67years, education was 11.04 years with maximum of 25years, and household size approximately was 6 person per family with minimum and maximum household size of 1 to 12 people (Table 1). It is tandem with the result gotten by Olatunji and Akanbi, (2022). Farm experience was vast enough at the average of 26.13years, and the least experience of 4years and highest of 55years in cereal farming. The average farm size cultivated was 2.48ha per individual farmers which further showed the prevailing scale of operation among the cereal farmers, while the minimum and maximum land in hectares farmed were 1ha and 8ha respectively.

This result affirmed the previous work done by Baruwa, (2016) wherein the mean farm size was 2.54 hectares of land which falls within the range of land holding of small scale farmers and they use low level of fertilizer. The intensity indicates the average amount of fertilizers applied per hectare of land. Plot nourished with NPK covered the average size of 2.23ha, but the quantity of NPK fertilizer used was 7.24kg making the intensity of NPK applied to be 3.3708kgha^{-1}. Plot nourished with urea was 1.124ha and the quantity of urea used was 1.577kg, with this the intensity of urea applied was 0.8109 kgha^{-1} (Table 1). Specifically, the average maize produced was 35142.8kgha^{-1} and the average guniea-corn produced was 3661.7kgha^{-1}.

Table 1: Summary statistics of the variables included in the study (n=175)

Variables	Measurement	Mean	Std dev.	Mini.	Maxi
Age range	Age in years	49.6743	10.81358	26	72
Year of education	Actual years in school	11.04	6.128284	0	25
Household size	Number of people	5.86286	2.211138	1	12
Farm experience	Years in farming	26.1257	11.87464	4	55
Farm size	Hectares of land farmed	2.484	1.977394	1	8
NPKF ertili~area	Plot nourished with NPK (ha)	2.23028	1.745321	0	7
NPKF ertili~qty	NPK fertilizer (kg)	7.24571	6.771065	0	30
Intensity~NPK	Intensity of NPK $kgha^{-1}$	3.37098	2.672957	0	17.5
NPK Costpe~g	Amount of NPK (₦)	23077.1	8212.063	0	32000
Urea Areaof~r	Plot nourished with urea (ha)	1.124	1.485716	0	5
Urea Quanti~s	Urea fertilizer (kg)	1.57714	2.595541	0	10
Intensityu~a	Intensity of urea ($kgha^{-1}$)	0.81095	1.10627	0	10
Urea Costpe~g	Amount of urea (₦)	14948.6	10153.57	0	26000
Maize Quant~d	Maize output ($kgha^{-1}$)	35142.8	32.74838	4	110000
Guineacorn~u	Guinea-corn output ($kgha^{-1}$)	3661.7	6.915871	0	25000

Source: Field survey analysis, 2023

Descriptive analysis of socio-economic characteristics

The descriptive statistics shown in Table 2 indicated that 82.86% of the sampled cereal farmers were male, which implies that male farmers dominate crop farming, and supported by Olatunji and Akanbi, (2022) with the fact that farming involves more energy-demanding activities. Meanwhile, both married and farmers whose main occupation was farming were 86.86% and 65.71% respectively. Around 40.57% of them acquired land through rented, while 30.86% and 21.14% of the farmers access land through inheritance and purchased modes respectively. Additionally, extension agents are responsible for the dissemination of information on farming procedure, 73.14% received extension visits and training on fertilizer use, while a vast population (87.43%) of the farmers work on insecure land as shown in Table 2. It was also observed that most of them (77.71%) intensively and continually cultivate their croplands, which serves as evidence for regular application of fertilizers among farmers as equally pointed out by Baruwa, (2016) wherein 85.71% proportion of farmers also enriched the soil fertility with organic manure. From the summary statistics, significant rate (68.57%) of the farmers participate in their association. In the associations, there is always a chance of getting links and networks that will assist farmers in sourcing farm inputs and other incentives.

Table 2: Distribution of socio-economic characteristics of respondents (n=175)

Socio-economic characteristics	Frequency	Percentage
Sex		
Male	145	82.86
Female	30	17.14
Marital level		

Married	152	86.86
Non married	23	14.14
Main occupation		
Farming	115	65.71
Non farming	60	34.29
Mode of land acquisition		
Inheritance	54	30.86
Purchased	37	21.14
Leased	11	6.29
Rented	71	40.57
Gift	2	1.14
Extension services		
Yes	128	73.14
No	47	26.86
Land insecurity		
Yes	153	87.43
No	22	12.57
Practice continuous cultivation		
Yes	136	77.71
No	39	22.29
Apply organic manure		
Yes	150	85.71
No	25	14.29
Member of farmers association		
Yes	120	68.57
No	55	31.43

Source: Field survey, 2023

Determinants of Inorganic Fertilizer Use Intensity based on Multivariate Regression

The result of multivariate regression model presented in Table 3 below gave the number of observations, number of parameters, root mean square estimation (RMSE), R-square, F-ratio, and P-value obtained from the analysis. It was observed that each of the two univariate models is empirically significant at P = 0.000. The standard R-square showed that all the predictor variables jointly explained 38.19% and 18.62% of variances in the outcome variables (NPK and Urea) respectively. The major econometric findings revealed that household size, farm size, quantity of maize and guinea-corn produced were statistically significant at 5% for household size and 1% for farm size, quantity of maize and guinea-corn produced respectively Table 3 as in NPK model. Household size is indirectly related to the NPK fertilizer use intensity, it implied that as the household size increases, the NPK fertilizer use intensity decreases. It is agreed with a priori expectation, as the farm household heads' spending on household upkeep can shrink resource needed to purchase farm inputs inclusive fertilizers. Olatunji and Akanbi (2022) found that cereal-farmers with high household size will definitely influence fertilizer use intensity negatively, simply because cereal-crop farmers with high household size will

devote more resources in caring for the family which will cause reduction in fertilizer purchase and when this happened it will lead to low fertilizer usage.

Also, farm size is statistically significant at 1% level with negative coefficient indicating that as the farm size increases the intensity of inorganic fertilizers use decreases all things being equal. This signifies that farmland expansion can diminish intensity of inorganic fertilizers use in the region and the result is reasonable, because the new farm site opened in the process of expanding farm size may be fertile due to organic fertilizers present on the land thus, preventing farmers from adding much inorganic fertilizers to it. It contradicts to the findings by Amanze, et al, (2010); Baruwa, (2016) where the farm size was significant and positively influenced the use of inorganic fertilizers among smallholder farmers. In a similar research conducted by Aman et al, (2022) using double hurdle regression, it was found that sex, family size and land size were positively affected the extent (intensity) of inorganic fertilizer use whereas age and distance of household from nearest market determine use intensity negatively.

However, the total output of maize and guinea-corn produced had positive coefficients and both were statistically significant at 1% level, it signified that the improved output of cereal crops results from increased inorganic fertilizer use intensity ceteris paribus. This result is expected and agreed with a priori expectation.

Similarly, in the case of urea fertilizer used intensity, the regression showed that the household size and total output of maize and guinea-corn produced were significantly determined urea fertilizer used intensity among cereal farmers. Specifically, household size is negatively significant at 10% level indicating that the increase in household size, causes a significant decreases in the urea fertilizer used intensity ceteris paribus. This finding is similar to the result gotten in the case of NPK fertilizer and household size discussed in the above (Table 3). In addition, the nexus between the total output of maize and guinea-corn produced and urea fertilizer used intensity is as explained in the model of NPK fertilizer used intensity. However, farm size is not significant with urea fertilizer used intensity in the study area. All other explanatory variables such as extension access, land conflict/insecurity, use of manure and continuous cultivation were not significant for both models.

Table 3: Determinants of Inorganic Fertilizer Use Intensity using Multivariate Regression Model

Equations	Obs.	Parms	RMSE	R-sq.	F-val.	P-val.
Intensity of NPK(kg)	175	9	2.1515	0.3819	12.819	0.0000
Intensity of Urea(kg)	175	9	1.0217	0.1862	4.7479	0.0000
Explanatory vars.	**NPK Coeff**	**Std.dev**	**t-value**	**Urea Coeff**	**Std.dev**	**t-value**
Household size	-0.24273	0.08466	-2.87**	-0.06501	0.04020	-1.65*
Farm size	-0.33696	0.10849	-3.11***	-0.00531	0.05152	-0.10
Extension access	-0.07356	0.37318	-0.20	-0.23994	0.17722	-1.35
Maize produced	0.03425	0.00588	5.83***	0.00485	0.00279	1.74*
Guinea-corn produce	0.12680	0.02452	5.17***	0.05374	0.01164	4.61***
Manure use	-0.26680	0.47069	-0.57	-0.11523	0.22352	-0.52
Land insecurity	-0.06666	0.08729	-0.76	-0.03036	0.04145	-0.73
Continuous cultivatn	0.282954	0.39889	0.71	0.18746	0.18943	0.99
Constant term	4.78090	0.67987	7.03	1.23336	0.32286	3.82

Source: Data analysis, 2023. Statistical significance levels: 1% (***), 5% (**) and 10% (*)

Constraints to Inorganic Fertilizer Use Intensity among Cereal Crop Farmers

This finding showcased the paramount constraints challenging the use of inorganic fertilizers among the cereal producing farmers in the study area. As shown in Table 4 below, the expensive price of inorganic fertilizers has been the main limitation experienced by almost (94.29%) all of the sampled farmers. At moment, fertilizer price is alarmingly increasing and do not offer farmers much incentive to its use in Nigeria because of naira devaluation.

Poor record keeping of inorganic fertilizers used also dominates the problems faced by the farmers, this study identified that 87.43% of them rely on their memories in the case of documentation of farm activities including the fertilizers application. Inorganic fertilizers has to do with timely application of accurate quantity at a recommended rate per area of land. The methods of application also differ from one fertilizer to another. Surely, adequate record keeping of all operations carried out is vital to the success of farm production. This challenge can be greatly solved if farmers- extension link is strong in the rural areas.

Parallel to the above scenario, the weaknesses of agricultural extension workers is showing side effects on the ability of many farm households to implement recommended agricultural technologies. Evidently, in this finding, significant number (84.57%) lack adequate knowledge of inorganic fertilizers application, which is also responsible for low cereal productivity as it's causing deterrent to the use of inorganic fertilizers in the study area.

Furthermore, in Nigeria fertilizers subsidy programs have not been successful ones. In the sense that, the farmers who supposed to collect fertilizers will not even share out it, because it's often hoard by some other people that are not targeted for the incentive according to the government. In this review, it was discovered that 73.14% of cereal farmers lack access to inorganic fertilizers subsidy. It suggests sanctioned policy formulation for the set of people that in care of agricultural resources management to ensure true delivery of farm materials and incentives to the needy.

Ineffectiveness of inorganic fertilizers is another serious constraint to majority (64.0%) of the cereal farmers, due to the poor exposure on the use of fertilizers, farmers that applied fertilizers may not see the expected result from the crop yields, as compare with others that did not apply, thence they ponder more on this effect and it consequently hinders farmers' ability to procure fertilizers for crop production in the study area.

Table 4: Constraints to Inorganic Fertilizers Use Intensity among Cereal Crop Farmers

Constraints to inorganic fertilizers use	Frequency	Percentage	Rank scores
Expensive price of inorganic fertilizers	165	94.29	1st
Ineffectiveness of inorganic fertilizers	112	64.00	5th
Poor record keeping of inorganic fertilizers use	153	87.43	2nd
No adequate knowledge of inorganic fertilizers use	148	84.57	3rd
Lack of access to subsidized inorganic fertilizers	128	73.14	4th

Source: Field survey, 2023.

CONCLUSION

The study provided comprehensive insights into the determinants of inorganic fertilizers use intensity among cereal crop farmers and identified the main challenges constraining the usage of inorganic fertilizers. The findings indicated the major determinants of extent/intensity of NPK and urea fertilizers used as household size, farm size and total cereal crops produced. It further identified the challenges like expensive price of inorganic fertilizers, ineffectiveness of inorganic fertilizers, poor record keeping of inorganic fertilizers used, no knowledge of inorganic fertilizers application as well as lack of access to subsidized inorganic fertilizers as affected the cereal farmers. It concludes that household size, farm size and total cereal crops production have

economic implications on intensity of NPK and urea fertilizers used to maintain soil fertility. It is therefore, necessary to give due emphasis to the indicated determinants and challenges in order to assist cereal producing farmers in Nigeria. Also, the efforts to enhance sustainable cereal production should focus on the farmers' use intensity of inorganic fertilizers as against the present economic policy and agro-ecological condition.

Since the study had identified farm size as a major factor causing setback to use of inorganic fertilizer used which in turn reduces crop production. It is recommended that federal government should expedite action in enforcing the Land Use Act of 1978 and more liberal in making land available for agricultural production and the land tenure system can be reviewed in favour of agricultural production.

Furthermore, the weaknesses of agricultural extension workers is showing side effects on the ability of many farm households to implement recommended agricultural technologies including inorganic fertilizers use, it was observed that most of the farmers were poor in terms of record keeping, knowledge of inorganic fertilizers application and access to subsidized inorganic fertilizers. It is recommended that the agricultural extension should change their attitudes towards farmers and ready to assist them through educational aids.

Conflict of Interest

Authors declare no conflict of interests.

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