

# A Microlevel Analysis of the Adoption and Efficiency of Modern Farm Inputs Use in Rural Areas of Kano State, Nigeria

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**Abstract** This study conducted a dual microanalysis of modern agricultural inputs use behaviour in rural areas of Kano State, Nigeria. Probit regression model was estimated to analyse the factors that influence modern inputs adoption. On the other hand, OLS, Poisson and instrumental variable regression models were used to estimate the efficiency of modern inputs adoption and consumption at farm level. The estimated OLS model indicates that additional use of 1 bag of fertiliser, increases the level of productivity by about 5.4%. Similarly, the estimated Poisson model indicates that an additional 1 bag of fertiliser use on a farm increases the productivity per hectare by about 4.5%. Meanwhile, the estimated 2SLS model shows that a 1% increase in the amount of fertiliser use increases the level of output productivity by about 0.34%. Furthermore, the method adopted by farmers on how to use modern agricultural inputs has a significant influence on the level of output production. Modern method of fertiliser application improves the level of output production. Government can use this medium to improve the rate of input use by rural farmers via agricultural schemes that will introduce the farmers to and maintain the modern techniques of farming. Additionally, farmers need to be exposed to skills and training on some off-farm jobs to raise their income to be able to afford the recommended amount of fertiliser. Lastly, the adoption of policies that will encourage the rate of farmers' contact with extension agents will improve the manner of fertiliser utilisation which in turn increases the level of efficiency.

**Keywords** Fertiliser · Adoption · Efficiency · Productivity · Rural · Skills · Training

## Introduction

Shortage of food in sub-Saharan Africa can be eliminated by enhancing agricultural productivity via the adoption of modern agricultural production technology, one of which is inorganic fertiliser. Inorganic fertiliser when added to the soil gives nutrients to the soil that are absorbed by plants leading to yield improvement which in turn gives farmers some amount of profits [35, 38]. In this way, modern fertilisers play a vital role in the growth of agricultural productivity [28]. For instance, in the developing world of Latin America and Asia, over the last two decades, inorganic fertilisers are responsible for about 50–75% rise in farm productivity [22, 33]. In the same vein, Ma et al. [19] reported that increase in the use of modern fertiliser has prompted around 40–60% rise in the worldwide agricultural yield. However, the situation is different for rural sub-

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Saharan Africa in which the rate of fertiliser use by rural farmers is far below the recommended level [8, 21]. Available data have shown that sub-Saharan Africa has the lowest rate of fertiliser use compared to other regions of the developing world. For instance, Sheahan and Jayne [34] reported that the rate of fertiliser use in other developing countries in 2008 was averagely 94 kg/ha, while that of sub-Saharan Africa in the same period was only 13 kg/ha. Figure 1 exhibits the per hectare rates of fertiliser application in sub-Saharan Africa in general and that of Nigeria in particular over the last decade.

Figure 1 compares the average kilogram of fertiliser per hectare used in Nigeria and sub-Saharan Africa to that of the world average of fertiliser consumption over the last decade. Figure 1 exhibits that the average rate of fertiliser application in Nigeria was lower than the sub-Saharan African average rate of fertiliser application, which is also far below the world average rate of fertiliser use. The highest rate of fertiliser application in Nigeria over the last decade was attained in year 2006. In this year, only about 10 kg/ha was applied. On the other hand, during the same period (i.e. the last decade), the lowest application rate was attained in the year 2007, by which the fertiliser application rate was just 4.21 kg/ha. In the case of sub-Saharan Africa, over the same period, the highest average rate of fertiliser application was in the year 2005. In this year, the average rate of fertiliser application per hectare for the region was 29.10 kg/ha. On the other hand, the lowest rate of fertiliser application in the region of sub-Saharan Africa over the last decade was in the year 2010, whereby the fertiliser application rate stood at 19.46 kg/ha. However, different situation was obtainable regarding the world average rate of fertiliser use. Figure 1 indicates that over the last decade, the lowest world average rate of fertiliser use was in the year 2009, by which the application rate stood at 170.95 kg/ha. On the other hand, over the same period (i.e. last decade), the highest average rate of fertiliser application globally was in the year 2006; when the application rate stood at 299.02 kg/ha. Many reasons were given for such low rate of fertiliser use in sub-Saharan Africa. These

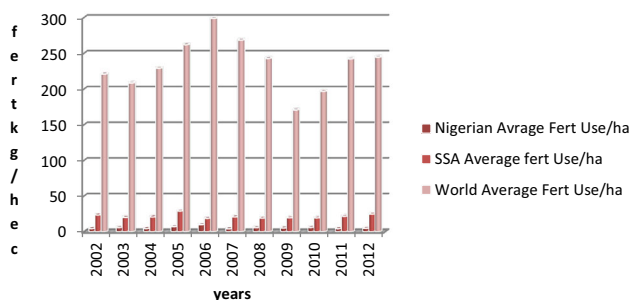
are high cost of fertiliser, lack of access to credit, seasonal variation of productivity, volatility in agricultural output price and lack of increase in the income of the farmers. Other reasons are poor contact with extension agents, poor information on modern agricultural technology and high distance from remote areas to fertiliser places [11, 16, 22, 31].

The main aim of this paper is to analyse fertiliser adoption and use intensity in rural areas of Kano State, Nigeria. This paper contributes to the existing literature by extending the work of Danlami et al. [9] in which their study is limited to analysing only the intensity of fertiliser consumption. Secondly, unlike most of the related previous studies that are macro in their approach, this study follows a microapproach to analysis. Furthermore, some of the previous studies [8, 37] in the relevant area are only limited to theoretical review. This study concentrates on a particular rural area in Kano State, Nigeria, as recommended by other studies [8, 33]. These studies emphasised the need for more studies to analyse fertiliser use intensity, each study to concentrate on a particular region or community. The major aim is improving agricultural productivity, food security, eliminating rural poverty and hunger that are among the major problems of rural sub-Saharan African countries.

## Conceptual Framework

Fertiliser use and consumption has been one of the major concern of some previous studies [2, 4, 5, 7, 15, 18–20, 23, 24, 30, 34–36, 38]. Assat et al. [5] used seemingly unrelated regression to analyse determinants of fertiliser use. The results indicated that output price, fertiliser price, age of the farmer, and income have positive significant impact on fertiliser application. On the other hand, education of farmers, size of household, and field size have a negative impact on fertiliser use. Similarly, Saweda and Tasie [30] found that the distance from the fertiliser place, price of maize, and the price of fertiliser have positive impacts on fertiliser adoption. Both of these two studies have the same conclusion that the increase in fertiliser price has a positive impact on the use of fertiliser. On the contrary, Wakeyo and Gardebroek [38] found that as the price of fertiliser rises, farmers tend to use less fertiliser. In addition, the higher the distance from the fertiliser places, the lesser the use of fertiliser by farmers. However, farmers tend to adopt more fertilisers when their total land holdings increase. In addition, level of education of the farmer and the capital possession encourage the use of more fertiliser by farmers.

In the same vein, Marino et al. [20] proved that biophysical factors like fertiliser deficiency, submergence-prone area and drought-prone area decrease the extent of



**Fig. 1** Average kg of fertiliser use per hectare for Nigeria/SS Africa/World (2002–2012)

fertiliser use as each of these factors rises. However, resources such as machinery ownership and non-rice income have the tendency of encouraging fertiliser use as they increase. In addition, a study conducted by Kormawa et al. [18] revealed that factors such as seed and pesticide costs, number of extension visit yearly, the degree of market orientation, membership in an association of farmers and credit unions encourage farmers to adopt fertilisers. Moreover, Ma et al. [19] found that the occurrence of the disaster like diseases, insects, and pests has a negative association with efficient use of fertiliser. The efficiency of fertiliser use tends to decrease in the event of frequent occurrence of the disaster. Additionally, Take-shima and Nkonya [36] held the view that rise in factors such as average rainfall in the farming area, distance from the source of fertiliser, and the farmer being having attended education at a primary level only, discourage the adoption of fertiliser. Naseem and Kelly [23] found that availability of road infrastructure, the quantity of yearly rainfall, the per head number of household members that are undergoing studies and the portion of farmland devoted to wheat and cotton production encourage the adoption and use of fertiliser in farm production. Akpan et al. [2] asserted that the higher the farmer's level of education, the higher the amount of fertilise uses. Similarly, contact with extension agents and the output yield encourage the intensity of fertiliser application. On the other hand, the distance from the fertiliser market was found to exact negative impact on the intensity of using fertiliser. Moreover, some studies [3, 4, 34, 35] found that fertiliser use at farm level increases when there exist increase in factors such as adoption of modern high yielding seeds, portion of irrigated area within the cultivated crops and rain onset delay. Idris and Ahmad [16] estimated the elasticities of fertiliser consumption in Myanmar and Lesotho. The estimates showed that in Myanmar, only income elasticity of fertiliser demand was significant which was elastic and positive in nature. One per cent (1%) increase in the farmer's income attracts three per cent (3%) increase in fertiliser use.

Therefore, based on the above findings, the existing empirical studies on fertiliser use indicate that there exist inconsistencies as per the findings and conclusions of these studies. The reason is that fertiliser demand schedule varies from one region to another due to differences in socio-economic, cultural, geographical, environmental, climatic, and soil fertility situations. Additionally, differences in terms of farming systems and the nature of crops produce can cause variations in results and findings from different areas. For this reason, taking a new area as a case study for analysing farmers' fertiliser use is a contribution to the existing literature.

The conceptual framework of fertiliser use and the consequent effects of fertiliser adoption and use intensity, economically and socially, as well as on the general welfare of the whole society is illustrated in Fig. 2.

## Materials and Methods

### The Model

#### *Theoretical Framework*

The model of household production theory can serve as the basic framework for explaining farmers' fertiliser utilisation process to improve production of output. The argument of this theory is that households buy commodities from the market which serve as inputs that are used in the processes of production. These commodities are used to produce the "products" which appear in the utility function of households. In this specific case, a household combines fertiliser and other capital equipment to create a given level of agricultural output. The main target is to attain highest possible level of efficiency via the optimum utilisation of available inputs. Therefore, assuming the utility function of the household is stated as:

$$U = f(Q(F, TR), X; D, G)$$

where  $Q$  represents the Agricultural productivity,  $F$  is fertiliser,  $TR$  is the capital stock comprising tractor, seed and pesticide,  $X$  is a purchased composite numeraire commodity that directly yields utility,  $D$  is demographic characteristics and  $G$  geographic characteristics that influence the households' preferences.

In this framework, the decision of the farmer is perceived as a double-stage optimisation problem [13]. In the first stage, the farmer acts as a firm. The objective is to minimise the cost of producing a pre-determined output level  $Q$ . In the second stage of the optimisation problem, the farmer tries to maximise utility.

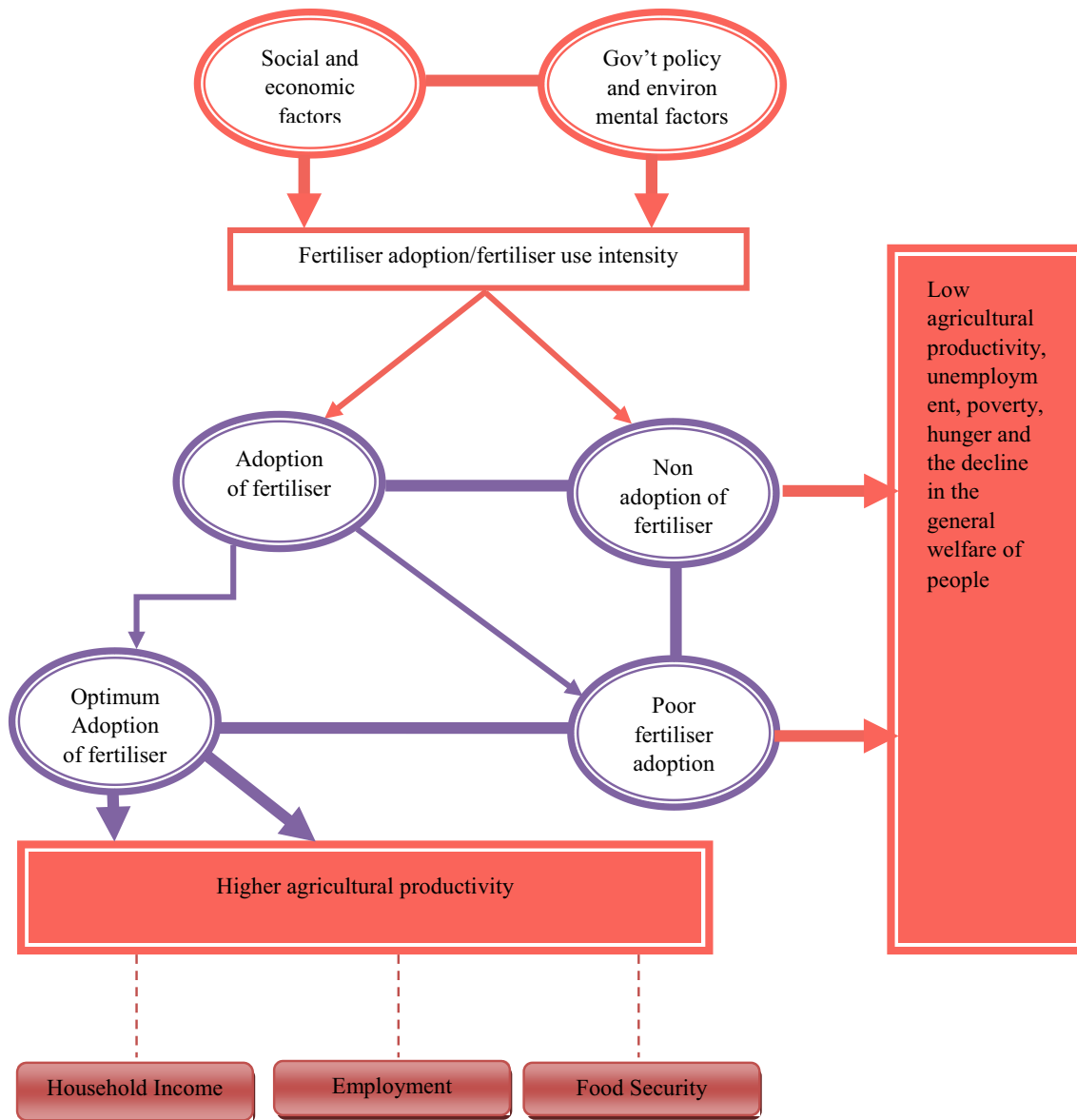
#### *Cost Minimisation of the Farmer*

In this situation, the farmer is perceived as a producer (a firm) that combines different inputs to produce a pre-determined level of agricultural output ( $Z$ ). The production function looks like:

$$Z = \delta(X_f, X_l, X_n) \quad (1)$$

where  $X_f$  = the quantity of fertiliser used,  $X_l$  = the quantity of labour,  $X_n$  = the quantity of other inputs used in the production process like seeds, pesticides.

In this case, given a targeted level of output to be produced by the farmer, the farmer acts as a cost minimiser by



**Fig. 2** Conceptual framework of fertiliser adoption and use intensity determinants and consequences

producing the targeted level of output with the least possible costs of production, this is attained usually by producing at a point where the marginal product equals the extra cost of using additional factor (i.e.  $\partial Z = \delta'(X)$ ). Given the following output function and the cost function as:

$$Z = \delta(X_f, X_l, X_n) \tag{2}$$

$$C = P_f X_f + P_l X_l + P_n X_n, \tag{3}$$

Therefore, the cost minimisation composite Lagrangian function looks like:

$$L = (C - P_f X_f - P_l X_l - P_n X_n = 0) + \lambda \delta(X_f, X_l, X_n) \tag{4}$$

By differencing this function with respect to fertiliser (as the focus of our analysis) holding other factors constant, we get

$$\frac{\partial L}{\partial X_f} = -P_f + \lambda \delta'(X) = 0 \tag{5}$$

Therefore,

$$\lambda \delta'(X) = P_f \tag{6}$$

Since the farmer is assumed to be using one type of fertiliser (compound fertiliser) by definition;

$\lambda = 1$ , Therefore, we have  $\delta'(X) = P_f$ ; this is the most efficient level of fertiliser use.

Here  $\delta'(X)$  = marginal agricultural product produced from using additional unit of fertiliser, and

$P_f$  = Cost of using the extra unit of the fertiliser

However, for the farmer using more than one type of fertiliser (say three) such as nitrogenous fertiliser, (denoted by  $X_f$ ) phosphate fertiliser (denoted by  $X_p$ ) and potassium fertiliser (denoted by  $X_t$ ). The output and the cost functions, in this case, are modified as:

$$Z = \delta(X_f, X_p, X_t, X_l, X_n) \tag{7}$$

$$C = P_f X_f + P_p X_p + P_t X_t + P_l X_l + P_n X_n, \tag{8}$$

where  $X_l, X_n$ , are as known before.

The composite Lagrangian function looks like:

$$L = (C - P_f X - P_p X - P_t X_t - P_l X_l - P_n X_n = 0) + \lambda \delta(Z) \tag{9}$$

Differencing the above equation with respect to the various fertiliser inputs ( $X_f, X_p, X_t$ ) (the focus of our analysis) while holding other factors constants, we get

$$\frac{\partial L}{\partial X_f} = -P_f + \lambda \delta'(Z_f) = 0 \tag{10}$$

$$\frac{\partial L}{\partial X_p} = -P_p + \lambda \delta'(Z_p) = 0 \tag{11}$$

$$\frac{\partial L}{\partial X_t} = -P_t + \lambda \delta'(Z_t) = 0 \tag{12}$$

$$\lambda \delta'(Z_f) = P_f \tag{13}$$

$$\lambda \delta'(Z_p) = P_p \tag{14}$$

$$\lambda \delta'(Z_t) = P_t \tag{15}$$

By making  $\lambda$  the subject of the relation in each of Eqs. 13, 14 and 15, we arrive at

$$\lambda = \frac{P_f}{\delta'(Z_f)} = \frac{P_p}{\delta'(Z_p)} = \frac{P_t}{\delta'(Z_t)} \tag{16}$$

The above expression explains that the optimum level of fertiliser use by the farmer who uses more than one type of fertiliser. It is a point where the ratios of the additional cost spent on securing the extra unit of fertilisers to the marginal productivity of such an additional fertilisers are equals.

*Farmers' Profit Maximisation Point* Given the profit function of using fertiliser

$$\pi = TR - TC \tag{17}$$

$$TR = PZ \tag{18}$$

$$Z = \delta(X_f, X_l, X_n) \tag{19}$$

$$TR = P\delta(X_f, X_l, X_n) \tag{20}$$

The cost function is given as

$$C = P_f X_f + P_l X_l + P_n X_n, \tag{21}$$

Substituting both the revenue and the cost functions in the profit function, we obtained

$$\pi = P\delta(Z) - (P_f X_f + P_l X_l + P_n X_n) \tag{22}$$

$$\pi = P\delta(Z) - P_f X_f - P_l X_l - P_n X_n, \tag{23}$$

The main focus here is change in fertiliser use holding other factors constant in order to obtain the maximised profit from fertiliser alone

$$\frac{\partial \pi}{\partial X_f} = P\delta'(Z^*) - P_f = 0 \tag{24}$$

Equation (24) is the first-order condition for the maximised profit of the farmer.

Differencing Eq. (24),

$$\frac{\partial^2 \pi}{(\partial X_f)^2} = P\delta''(Z^*) \leq 0 \tag{25}$$

Equation (25) is the second-order condition for the maximised profit of the farmer.

Therefore, for the farmers to maximise their profit from the use of fertiliser, they have to meet either the first- or second-order conditions for profit maximisation.

### The Second Stage of Household Production Theory

In this stage, the farmer is viewed as a consumer, he tries to maximise satisfaction from consuming fertiliser measured by the yield obtained from using a given quantity of fertiliser purchased.

Taking back the farmer household utility function:

$$U = f(Q(F, TR), X; D, G) \tag{26}$$

All the items are as has been explained earlier. However, for the purpose of our analysis we are concerned with only fertiliser consumption, in this case, the modified version of the household utility function can be expressed as:

$$U = f(F_n) \tag{27}$$

Given the budget constraints as:

$$Y = PF_n \tag{28}$$

A farmer maximises satisfaction by using more and more fertiliser until the point where the benefits gain from using the additional fertiliser is exactly equal to the

additional cost of purchasing the extra unit of the fertiliser. Now let

$$L = f(F_n) + \lambda(Y - PF_n = 0) \quad (29)$$

$$\frac{\partial L}{\partial F} = f' - \lambda P = 0 \quad (30)$$

Since the farmer use single type of fertiliser by definition,  $\lambda = 1$ , therefore  $f' = P$ . This is the utility maximisation point for the farmer that uses one type of fertiliser. Any additional purchase of the same fertiliser implies loss of satisfaction, while any use of fertiliser below the above expressed point implies underutilisation of fertiliser.

Let assume that the farmer uses more than one type of fertiliser, for example, three nitrogen, potassium and phosphate fertilisers denoted by  $W_1$ ,  $W_2$ , and  $W_3$ . For this farmer, the optimum level of satisfaction is a point where the ratios of the additional satisfaction gained from the use of extra units of such fertilisers to their prices are equal.

Given the utility and budget constraint functions as:

$$U = f(W_1 W_2 W_3) \quad (31)$$

$$Y \leq P_1 W_1 + P_2 W_2 + P_3 W_3 \quad (32)$$

The composite function will be:

$$L = f(W_1 W_2 W_3) + \lambda(Y - P_1 W_1 - P_2 W_2 - P_3 W_3 = 0) \quad (33)$$

The marginal utility with respect to each of the type of fertiliser is

$$\frac{\partial L}{\partial W_1} = f'_1 - \lambda P_1 = 0 \quad (34)$$

$$\frac{\partial L}{\partial W_2} = f'_2 - \lambda P_2 = 0 \quad (35)$$

$$\frac{\partial L}{\partial W_3} = f'_3 - \lambda P_3 = 0 \quad (36)$$

$$f'_1 = \lambda P_1$$

$$f'_2 = \lambda P_2$$

$$f'_3 = \lambda P_3$$

Therefore,

$$\lambda = \frac{f'_1}{P_1} = \frac{f'_2}{P_2} = \frac{f'_3}{P_3} \quad (37)$$

The above equation expressed the utility maximisation point for using more than one type of fertiliser together at a point of time, that the most efficient amount of fertiliser to use at a farm level for the farmer that uses at least three different types of fertiliser.

## Methodology

### Sample Size and Data Source for the Study

This study was based mainly on primary data. A structured questionnaire was used as an instrument for gathering of the primary data. The total sample size used in the study was determined based on Dillman [10].

## Annexure

The sample size of the study was determined based on the formula:

$$S = \frac{NP(1 - P)}{\left(\frac{B}{C}\right)^2 (N - 1) + P(1 - P)}$$

where  $S$  = required sample size,  $N$  = the population size = 7425 (i.e. the estimated total number of households in Tofa local government area, Nigeria),  $P$  = the population proportion expected to answer in a particular way (the most conservative proportion is 0.50),  $B$  = the degree of accuracy, expressed as a proportion (0.10),  $C$  = the  $Z$  statistic value based on the confidence level (in this case 1.96 is chosen for the 95% confidence level).

Therefore, the sample size can be determined as:

$$S = \frac{(7425 * 0.5)(1 - 0.5)}{(0.10/1.96)^2 (7425 - 1) + (0.5)(1 - 0.5)} = \frac{1856.25}{19.3252 + 0.25}$$

$$S = \frac{1856.25}{19.5752} = 95$$

Approximately a total number of 100 households were used as the samples for the study. The sample size mentioned above commensurate with the sample size recommended by social science researchers. For instance, according to Roscoe [29] and Sekaran [32], a sample size in a range of 30 to 500 is accepted for empirical studies. Secondly, they further suggested that in a multivariate research (such as regression analyses), a sample size that is as larger as 10 times the number of independent variables is preferable. Furthermore, Bartlett et al. [6] gave a rule of thumb for the accurate sample size of at least 5–10 times larger than the number of variables. These assertions by the above experts in social science research further validated the sample size chosen for this study. Additionally, this sample size can represent the population of the study, based on the fact that the study area is a small rural area containing homogenous farmers with less variability in their socio-demographic and economic characteristics. The sampling technique adopted is two-stage cluster area sampling. In the first stage, four districts were chosen using a random sampling technique from the list of the 15

districts in the local government area. In the second stage, 25 farmer households were systematically selected from each of the selected communities, making a total sample size of 100 households used for the study.

## Model Specification

### The Probit Model

In order to examine the factors that influence farmers' adoption of fertiliser, probit regression model was used to assess the impacts of such factors on the probability of fertiliser adoption. This is because on deciding to adopt fertiliser, a farmer is face with only two alternative choice categories, i.e. to adopt fertiliser or otherwise. Such a kind of situation is usually analysed using a binary dependent variable models of which probit model is among the prominent models of binary dependent variable.

Assuming a normal distribution and constant variance, following Greene [14] the standard cumulative normal distribution function of probit model can be expressed as:

$$\text{Prob}(Y = 1/x) = \int_{-\infty}^{x'\beta} \delta(t)dt = \varphi(x'\beta) \quad (38)$$

where  $\varphi(\cdot)$ ; is a common notation for the standard normal distribution. According to Wooldridge [39] probit model can be derived based on a particular latent variable model. Assuming  $Y^*$  is an unobserved latent variable such that

$$Y^* = \beta_0 + x\beta + e, \quad y = 1[y^* > 0] \quad (39)$$

Then the response probability for  $y$  is expressed as:

$$P(y = 1|x) = P(y^* > 0|x) = P[e > -(\beta_0 + x\beta)|x] \\ = 1 - \Phi[-(\beta_0 + x\beta)] = \Phi(\beta_0 + x\beta) \quad (40)$$

where  $\Phi$  is a function that takes values between zero and one, i.e.  $0 < \Phi(z) < 1$  for all values of  $z$ .

In its empirical form, the probit model for fertiliser adoption can be expressed as:

$$P(\text{Adoption} = 1|x) = \Phi(\beta_0 + \beta_1 \ln \text{HHHI}_i + \beta_2 \text{PRICE}_i \\ + \beta_3 \ln \text{PRICE}_i^2 + \beta_4 \text{FARMSIZE}_i \\ + \beta_5 \ln \text{LABOUR}_i + \beta_6 \ln \text{EXTEN}_i \\ + \beta_7 \text{MFERTAPP}_i) \quad (41)$$

where adoption takes value 1 if a farmer adopt at least 1 bag of fertiliser, otherwise, zero (0).

Furthermore, OLS, Poisson and instrumental variable regression models were estimated to assess the efficiency of fertiliser use on the farmers' productivity in rural areas of Kano State. In this case, the dependent variable is the quantity of output produced.

The empirical estimate of the instrumental variable regression model that was used to estimate the efficiency of fertiliser use, on the farmers' productivity is presented in Eq. (42)

$$\ln \text{OUTPUT}_i = \alpha_i + \beta_1 \text{FARMSIZE}_i + \beta_2 \ln \text{HHHI}_i \\ + \beta_3 \ln \text{LABOUR}_i + \beta_4 \text{MFERTAPP}_i \\ + \beta_5 \ln \text{FERTCON}_i \quad (42)$$

Equation (42) is the empirical estimated instrumental variable model of fertiliser efficiency in rural areas of Kano State. However, the first-stage regression model for Eq. (42) is expressed in Eq. (43) as:

$$\ln \text{FERTCON}_i = \alpha_i + \beta_1 \ln \text{HHHI}_i + \beta_2 \text{PRICE}_i \\ + \beta_3 \ln \text{PRICE}_i^2 + \beta_4 \ln \text{AGE}_i + \beta_5 \text{AGE}_i^2 \\ + \beta_6 \ln \text{LABOUR}_i + \beta_7 \ln \text{EXTEN}_i \\ + \beta_8 \text{MFERTAPP}_i \quad (43)$$

Equations (42) and (43) are the instrumental variable model estimated inform of two-stage least-square regression model. Equation (42) is the main model expressing the relationship between output production at farm level and other factors influencing the level of productivity including the quantity of fertiliser used (fertcon). However, the quantity of fertiliser consumption at a farm level is also influenced by other factors, the relationship which is indicated by Eq. (43) known as the first-stage regression model of the two-stage least-square regression. The result of the estimates for Eqs. (42) and (43) is shown in Table 5.

Table 1 indicates that the average quantity of fertiliser use by a single farmer in Tofa local government area during the study period is about 5 bags of 50 kg bag. On the other hand, the average size of farm owned by a single farmer is about 10 ha of land area. This means that the average rate of fertiliser used during the study period and also based on the data obtained from the selected samples is about 25 kg of fertiliser per hectare compared to the recommended level of about 200 kg per hectare. This reflects the extent of low rate of fertiliser use in rural areas of Nigeria. Furthermore, Table 2 indicates the categories of farmers based on adoption or otherwise of modern fertiliser.

Table 2 indicates that most of the farmers argued that they use modern fertiliser as one of the farming inputs use in their farms.

**Table 1** Description of the variables used in the models

Variables	Description	Mean	SD	Min	Max
Fertcon	Quantity of fertiliser consumed per 50 kg	4.93	5.73	0	40
HHHI	Total household income in Naira value monthly	18,690.08	20,002.57	250	158,333
Price	Cost (in Naira) of fertiliser used per 50 kg bag	5637.88	1515.09	1500	9000
Price2	Square of the price of fertiliser use to test for the nonlinear relationship				
Farmsize	Size of the total land cultivated during the period of the study measured by hectare	10.09	16.45	0.4	120
Labour	Number of labour units use on the farm	6.71	5.98	1	30
Extension	Number of contact with extension agents during the farming year	1.94	3.59	0	30
Mfertapp	Method of fertiliser application 1 if the farmer use a modern method of fertiliser use, otherwise 0				
Age	Number of years of the farmer	33.7	13.18	11	80

**Table 2** Categories of farmers based on the use of modern inputs or other wise

Categories	Number	Percentage
Farmers that use modern farm inputs	73	73
Farmers that do not use modern inputs	27	27
Total	100	100

**Table 3** Coefficients of the probit estimates and marginal effects of fertiliser adoption

Variables	(1) Probit	(2) ME
Income	0.338* (0.195)	0.058* (0.033)
Age	− 0.518 (0.697)	− 0.089 (0.122)
Farmsize	0.319 (0.201)	0.054 (0.035)
Labourer	0.741*** (0.262)	0.126*** (0.047)
Extension	0.612* (0.330)	0.126* (0.063)
Fertcost	− 0.00171*** (0.000583)	− 0.0003*** (0.0001)
Fertcost2	0.411*** (0.157)	0.070*** (0.032)
Constant	− 23.51*** (8.066)	− 23.51*** (8.066)
Pseudo- <i>R</i> <sup>2</sup>	0.39	

Robust standard errors in parentheses, \*\*\**p* < 0.01, \*\**p* < 0.05, \**p* < 0.1

## Results and Discussion

As explained earlier, this study analyses two issues namely; fertiliser adoption and fertiliser use efficiency, which has led to the estimation of different models. In this section, the

results and findings from the estimated models were presented and discussed. Table 3 shows the estimated probit model.

Table 3 exhibits the estimated coefficients and marginal effects of the probability of rural farmer adoption of fertiliser based on probit model. Out of the total number of seven variables included in the model, five were found to be statistically significant in explaining the probability of fertiliser adoption by rural farmers in Tofa local government area Kano state Nigeria. For instance, the value of the marginal effect for income was found to have positive relationship with the probability of fertiliser adoption by farmers of Tofa local government area, Kano. A 1% increase in the farmer’s income will raise the probability of fertiliser adoption by about 0.06%. This implies that when a farmer’s income in the study area increases, the probability of such farmer to adopt modern fertiliser for farming also increase, all things being equal. This variable was found to be statistically significant at 10% level; this conforms to a priori expectation and was also inconformity with the findings of Paudel et al. [27]. Furthermore, the value of coefficient of this variable was also found to be statistically significance and positively related to the probability of fertiliser adoption.

The variable representing the number of labour units working on farm also increases the probability of fertiliser adoption. The marginal effect value of this variable shows that the higher the labour force working on a farmland, the higher the probability of fertiliser adoption. This is because, when a farmer employs more labour on his farm, it indicates that it is a large-scale farming which has more probability of fertiliser adoption than their small scale counterpart. This variable was statistically significant at 1% level. And these findings conform to a priori expectation and also strengthen the findings of Olayide et al. [26].

Moreover, the marginal estimates of the variable representing the number of farmer’s contact with extension agent yearly was found to be positively related to the



fertiliser adoption and statistically significant at 10% level. This implies that the probability of fertiliser adoption increases with increase in the farmers contact with agricultural extension workers. This is because agricultural extension workers are expert in farming activities that usually serve as free consultants to farmers. They usually encourage farmers to adopt modern farming practices of which the adoption of chemical fertiliser is inclusive. This commensurate with a priori expectation and is in line with the findings of Akpan et al. [2] and Kormawa et al. [18]. Additionally the cost of fertiliser per 50 kg bag was found to be statistically significant in influencing the adoption of fertiliser or otherwise by farmers in the study area. The result shows that this variable has a negative impact on the probability of fertiliser adoption. Based on the value of the marginal effect of this variable, a ₦1000 increase in the price of 50 kg bag of fertiliser will reduce the probability of fertiliser adoption by 3%, all things being equal. This conforms to a prior expectation, and also supports the findings of Saweda and Tasje [30]. Similarly, the square value of this variable was found to have a significant impact on the probability of fertiliser adoption implying that there exist a significant non linear relationship between the variable and the probability of fertiliser adoption. The positive sign taking by the square of the variable of fertiliser cost implies that the inverse relationship between the

quantity of fertiliser purchase and the fertiliser cost is not forever, but there are some instances whereby by more of fertiliser will be bought despite increase in the price of fertiliser. Such as a subsidised fertiliser and or during a severe shortage of fertiliser supply.

Additionally, the estimated coefficients of the probit model further validated the above conclusion, in that, they take the same sign as in the marginal effects and all the variables were statistically significant in influencing the probability of fertiliser adoption, except two variables namely age of the farmer and farm size though they take sign that conforms to a prior expectations.

Furthermore, OLS and Poisson regression models were estimated to assess the efficiency of fertiliser use, on the farmers' productivity in rural areas of Kano State. In this case the dependent variable is the quantity of output produced. Table 4 exhibits the result of the estimated OLS model, the coefficients and the marginal effects of the Poisson model.

Table 4 shows the results of the estimated OLS and Poisson models for fertiliser use efficiency in Tofa local government area, Kano State. The dependent variable for the estimated OLS model is the log of quantity of output produced while the rate of output Production per hectare was used as the dependent variable for the estimated Poisson model. Since Poisson model can be used for estimating the determinants of a rate of production per space [1, 12].

The results have shown that there is a positive relationship between the quantity of fertiliser use and the level of the productivity. The estimated OLS model indicates that additional use of 1 bag of fertiliser increases the level of productivity by about 5.4%. Similarly, the estimated Poisson model indicates that an additional 1 bag of fertiliser use on a farm increases the productivity per hectare by about 0.02 units which represents on average about 4.5% increase as shown by the estimated marginal effect of this variable. This is in line with a priori expectation and also supports the findings of other previous studies [17, 25]. Moreover, the result of the estimated OLS model indicates that farmers that adopt modern fertiliser in their farm tend to have more productivity on average by about 43% higher than those that do not use modern fertiliser. In the same vein, the Poisson model indicates that adoption of modern fertiliser increases the yield per hectare by about 0.75 units. Years of fertiliser use experience was also found to have positive impact on productivity. The estimated OLS model indicates that an additional year of fertiliser use experience increases the productivity by about 17% all things being equal. Furthermore, the estimated Poisson model shows that an additional year of fertiliser use experience on average increases the yield per hectare by about 0.02 units, all things being equal. Other variables such as; income, age

**Table 4** OLS and Poisson estimates of fertiliser efficiency in Tofa LGA Kano, Nigeria

Variables	(1) OLS	(2) Poisson	(3) Poisson ME
Income	0.140* (0.0838)	0.0644 (0.0628)	0.124 (0.121)
Farmsize	0.00389 (0.00451)	− 0.141*** (0.0146)	− 0.271*** (0.0153)
Fertiliser	0.0536*** (0.0141)	0.0236*** (0.00806)	0.0453*** (0.0162)
Fertcost	− 2.29e−05 (0.000233)	0.0278 (0.183)	0.0534 (0.350)
Labourer	0.202* (0.110)		
Fertadoption	0.429** (0.212)	0.751*** (0.186)	1.163*** (0.250)
Age		0.439** (0.215)	0.844** (0.417)
Yearsoffert	0.173* (0.101)	0.0157* (0.00842)	0.0302* (0.0163)
Constant	− 1.321 (3.205)	− 1.049 (1.679)	1.163*** (0.250)
R-squared/Pseudo-R <sup>2</sup>	0.56	0.32	

Standard errors in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

**Table 5** Two-stage least-square (2SLS) estimates of fertiliser efficiency in Tofa LGA Kano, Nigeria

Variables	2SLS: first stage (DV: Infertcon)	2SLS: second stage (DV: output)
Fertcon	–	0.3426* (0.1835)
Farmsize	– 0.0010 (0.0052)	0.0110*** (0.0040)
Income	0.2061** (0.0924)	0.1322 (0.1120)
Labourer	– 0.0434 (0.0275)	0.0376** (0.0149)
Methodoffert	0.3525*** (0.1167)	0.4982*** (0.0744)
Fertcost2	0.1816* (0.0918)	–
Fertcost	– 0.0007** (0.0003)	–
Age	1.8465*** (0.6982)	–
Age2	– 0.0007*** (0.0002)	–
Extension	0.3414* (0.1798)	–
Constant	– 16.0951*** (4.6692)	0.3597 (1.0239)
R <sup>2</sup>	0.43	48

Robust Standard Errors are in parenthesis

\*\*\*, \*\*, \* denote significant levels at 1, 5 and 10%, respectively

of the farmer and farm size which are among the control variables in the model, were found to be statistically significant in explaining the productivity yield on farm. Moreover, the rest of the control variables were not significant based on the results of the estimated models.

Furthermore, the result of the estimated instrumental variable regression model based on 2SLS regression is shown in Table 5.

Variables in the estimated 2SLS model in Table 5 were found to be statistically jointly significance at 1%. The result shows that there is a positive significant relationship between the level of farm productivity and the quantity of fertiliser consumption. A 1% increase in the amount of fertiliser use at farm level increases the level of output production by about 0.34%. This is in line with a priori expectation and also supports the findings of other previous studies [17, 25]. Furthermore, the estimated value of the coefficient of farm size indicates a positive significant relationship with the level of output production. The result indicates that an additional one hectare of land increase the level of productivity by about 1.10%. This is in line with a priori expectation that the larger the size of the farm

land, the higher the level of productivity all things being equal. In addition, the estimated coefficient of number of labour was found to have a positive significant impact on the level of output production. An additional unit of labour increase the level of output production by about 3.76% all things being equal. Lastly, the estimated value of the coefficient of method of fertiliser application indicates that farmers that use a modern method of fertiliser application have higher productivity by about 49.82% compared to the farmers that use a traditional method of fertiliser application.

## Conclusions

This study analyses fertiliser adoption and its efficiency in rural areas of Kano State, Nigeria. Tofa local government area was used as the case study. Probit regression model was employed to examine the impacts of some socio-economic factors on fertiliser adoption. On the other hand, OLS Poisson and instrument variable regression models were estimated to assess the efficiency of fertiliser adoption. Quantity of fertiliser used and the years of fertiliser use experience have positive impacts on the productivity at farm level. Therefore, based on the results obtained from the estimated models in this study, the study made the following recommendations.

Firstly, the result shows that the increase in farmers' income encourages fertiliser adoption. This is very relevant for policy making because the intensity of farmers' fertiliser use in rural areas of Kano State can be increased via the implementation of policies that may increase the income of farmers. Such as given training to farmers on some off-farm jobs to increase their income to enable them afford more fertiliser. Secondly, ensuring regular extension agents' visit to farmers will encourage the farmers to adopt the use of modern fertiliser. The reason is that agricultural extension agents encourage farmers to use more fertiliser by providing information and training on the importance of fertiliser use on farm yields and on how to efficiently use fertiliser. Thirdly, there is need to make available, the modern tools of fertiliser as it use increase the efficiency in the level of output production. Lastly, supporting the farmers to engage in large scale production will encourage the farmers to employ more inputs both labour and capital of which chemical fertiliser is inclusive. Provision of adequate storage facilities and good market environment will encourage farmers to produce more thereby increasing their fertiliser use intensity.

However, despite the ability of this study to provide information on farmers' fertiliser use intensity, three issues serve as the limitations of this study.

Firstly, the study did not analysed the determinants of fertiliser use intensity since it has been captured by some previous studies such Danlami et al. [9]. Secondly, the study did not incorporate the influence of fertiliser subsidy on fertiliser adoption because of the non-availability of data related to this issue in the study area. Lastly, the study is a static analysis, it fails to analyse the influence of time dimension on fertiliser adoption.

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