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Socio-economic Determinants of Household Fertilizer Use Intensity for Maize-based Production Systems in the Northern Guinea Savannah of Nigeria

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Abstract: This study aimed at understanding current status of soil fertility management and the identification of socio-economic characteristics influencing the decision of households on fertilizer use intensity in maize-based production systems in the northern guinea savanna of Nigeria. A total of one hundred and sixty households involved in maize-based production system (2003/2004) were interviewed using structured questionnaire. Data collected were analyzed using descriptive statistics and binary logit model. Analysis revealed that households combine techniques like application of organic and mineral fertilizer and crop planting pattern in maintaining the fertility of their soils. The ratio of N: P_2O_5: K_2O per hectare from both organic and inorganic sources were 49.5:98.3:56.7 kg in Katsina State and 58.7: 109.4: 53.6 kg in Kaduna State. The estimated logit models revealed that fertilizer use intensity is significantly influenced by previous year's income, land ownership, engagement in off farm activities and years of experience in maize farming.

Key words: Intensification, logit model, maize-based system, Nigeria

INTRODUCTION

The problem of declining soil fertility in the crop-based farming systems of Sub-Saharan Africa has been well documented (Mortimore *et al*., 1990; Donovan and Cassey, 1998; Sanchez, 2002). This problem has raised concerns about the sustainability of agricultural production to keep pace with the increasing population growth rate in these countries. To maintain acceptable yield levels, the use of organic soil amendments, in combination with inorganic fertilizers has been identified to be more sustainable in the cropping systems of the savanna regions. However, their cost, erratic availability coupled with low returns and unreliable markets for agricultural produce frequently deter farmers from using them (Honlonkou *et al*., 1999). The development of soil fertility maintenance options have often focused on technical interventions with little or no consideration to institutional and policy elements as well as farm-household socio-economic characteristics. According to Doppler *et al*. (1999), sustainability in the adoption of soil fertility technology by farmers should take into consideration agro-ecological and socio-economic differences in farm locations and diversity of resources endowment and farmers' social status. Future strategies for increasing agricultural productivity will have to focus on using all available nutrient resources more efficiently and in a sustainable manner, taking into consideration farming activities, non-farm elements and more specifically, off farm activities of the farm-household.

The study focus is in the Northern Guinea Savannah (NGS) of Nigeria where soil nutrient depletion is very high due to intensive farming and inappropriate application of fertilizers causing negative balance in soil nutrients (Adedeji and Kormawa, 2002). The inappropriate management of soil fertility is a serious problem that threatens the sustainability of agriculture in this zone. This study aimed at understanding farmers' perception of soil fertility management and the identification of socio-economic characteristics influencing the decision of households on fertilizer use intensity for maize-based production systems. Maize is one of the most important food grains in the NGS ecological zone of Nigeria. The popularity was enhanced by the fact that it became not only a major food crop for many homes but also a commercial crop on which many agro-based industries depend for raw materials. Kyiogwon *et al*. (2002) indicated that the high potential of maize in the NGS could only be realized through the use of fertilizer because of the low fertility inherent in the savannah soil. Ogunfowora (1996) also asserted that fertilizer is the most important input for

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maize production in terms of its contribution to output and productivity within the shortest possible time. This study will therefore attempt to identify socio-economic factors influencing fertilizer use intensity for sustainable improvement in soil fertility maintenance for maize-based production systems in Northern Guinea Savanna ecological zone of Nigeria.

MATERIALS AND METHODS

The study area: The research was conducted in the Northern Guinea Savannah (NGS) ecological zone of Nigeria representing about 13% of the land-mass in the country (Manyong *et al*., 2001). The zone is located between latitudes 11°07 and 13°22 North and longitudes 6°52 and 9°22 East of Greenwich meridian. Two seasons can be distinguished-the rainy season from May to September/October and a long dry season from October to May. Temperature during the rainy period is between 27.0-34.0°C (maximum) and 18.0-21.0°C (minimum). Soils in this zone have a sandy loam to clay loam textured topsoil with a pH of 5 to 7 and an organic carbon content ranging between 0.5 and 1.5%. The soil properties as described by Norman (1982) are leached ferruginous tropical soil. The surface soil is reddish fine loam clay to sandy loam. The selection of the study area is based on the criteria that the area is prone to nutrient mining as a result of intensive cultivation practices. Two States (Kaduna and Katsina) were used as case studies for the ecological zone. The selection of the states was based on the biophysical and socio-economic features of the area for maize production.

Sampling procedure: A multi-stage sampling procedure was applied to select 160 households involved in maize based production system in Katsina and Kaduna States. In the first stage, eight local government areas were purposively selected based on the intensity of maize production, four in each state. The selection was done to reflect the most typical situation for maize-based farming systems. Secondly, one village was also purposively selected from each of the local government areas using the above criterion. Finally, 20 households were selected at random from the list of households in the village to make up a sample size of 160. However, only 147 questionnaires were retrieved and analyzed. The surveyed villages were Kaya, Saminaka, Tashan Saibu and Makarfi in Kaduna State and Dandume, Machika, Mahuta and Daudawa Katsina State.

Data collection: The data used in this study came from both primary and secondary sources. Secondary data on recommended levels of N, P_2O_5 and K_2O were obtained from results of on station trials conducted by the Institute for Agricultural Research, Samaru-Zaria. A survey of households was conducted to collect data from the household heads. A structured questionnaire was used to gather both qualitative and quantitative information covering all aspects of social and economic activities, land use pattern, cropping systems, perception of soil fertility management, use of organic and mineral fertilizer for maize production, preferences, production expenses and output levels. The reference period for the survey was 2002/2003 agricultural year.

Analytical framework: Binary logistic regression was estimated to identify the factors influencing fertilizer use intensity in the study area using Statistical Package for Social Sciences (SPSS 10). Data on quantities of both organic and mineral fertilizers were converted into three basic nutrient components (N, P_2O_5 and K_2O). The fertilizer use intensity is the fertilizer input (sum of N, P_2O_5 and K_2O) expressed as a ratio of total land area cultivated for maize based production.

Binary logistic regression is a type of regression where the dependent variable is converted into a dichotomous binary variable coded 0 and 1. Farmers with low fertilizer use intensity, those households who apply less than 25% of the recommended fertilizer rate-311.46 kg ha^{-1} (120 N, 137.46 P_2O_5 (60 P) and 54 K_2O (45 K)) were assigned the value of zero while those who applied above 25% were assigned the value of 1. Earlier studies (Manyong *et al*., 2001; Carsky and Iwuafor, 1999) have shown that application of at least 25% of the recommended rate of fertilizer is required to expect appreciable gain on yield. Thus households applying this rate were assumed not to be deriving much benefit from this input. Ten household socio-economic variables were hypothesized to influence the decision of households to use fertilizer intensively on maize-based farms: total cropped area, age of household head, years of formal schooling, number of years of experience in maize farming, engagement in off farm activities (dummy = 0 not involved and 1 if involved), previous season's farm income, land ownership (dummy = 0 if hired or leased/borrowed and 1 if inherited or bought), number of livestock units, farmers' perceived soil fertility and household size. The data for the two states were pooled together to increase efficiency in model estimation. Dummy variables (Kaduna = 1 and Katsina = 0) were used to account for difference in fertilizer use between the two states.

The logit model is based on the cumulative logistic distribution function expressed as:

$$p_i = \frac{1}{1+e^{-z}} \quad (1)$$

If p_i is the probability of intensive use of fertilizer then the probability otherwise is $1-p_i$, which in logitistic function can be expressed as ;

$$1 - p_i = 1 - \frac{1}{1 + e^{-z}} \quad (2)$$

$$= \frac{1}{1 + e^{z}} \quad (3)$$

The ratio of Eq. 1 and 3 will give the odd ratio;

$$\frac{p_i}{1 - p_i} = \frac{1 + e^{-z}}{1 + e^{z}} \quad (4)$$

$$\frac{p_i}{1 - p_i} = e^{z} \quad (5)$$

Equaion 5 is the odd ratio in favor of greater use of fertilizer. It is the ratio of the probability that a household will intensively use fertilizer to the probability that it will not.

Taking the natural log of both sides of Eq. 5;

$$L_i = \ln \frac{p_i}{1 - p_i} = z \quad (6)$$

L_i = the log odds ratio, which is also referred to as the logit.

$$z = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots\ldots\ldots + \beta_k x_k + \mu \quad (7)$$

Where:

x_i = The household specific indicators hypothesized to influence intensity of fertilizer use.

β_i = Vector of parameters to be estimated using maximum likelihood method.

μ_i = Error term which is normally distributed with zero mean and variance;

$$\delta^2 = \frac{1}{N_i p_i (1 - p_i)} \quad (8)$$

N_i = number of observations.

Although z is a linear combination of variables that have both upper and lower bounds, no bounds can be assigned to the variable z itself, as values assumed by z will depend on the values of the unknown parameters β_i s' also. In order to obtain the value of z, the likelihood of observing the sample was formed by introducing a dichotomous response variable Y_i such that:

Y_i = 1 if household used fertilizer intensively and 0 if otherwise.

The maximum likelihood estimates of the logit model were obtained using SPSS Version 10.

RESULTS AND DISCUSSION

Resource use pattern and households' perception of soil fertility maintenance: The socio-economic profile of the farm-household is presented in Table 1. The age of respondents ranged between 21 and 75 years with an average of 43 years in Katisna State and 47 years in Kaduna State. Most (75%) of them had only Quranic education while only about 9% went through secondary school. Pattern of livelihood sources revealed that about 92% of the household took farming (crop and livestock) as their major occupation, while others were traders involved in both agricultural and non-agricultural products. Other sources of livelihood are hunting and civil service. The average number of household members varied from 4 to 26 people per household with an average of nine persons per family. The proportion of household labour capacity is only about one fourth of the total indicating that most of the labour requirement on the farm has to be sourced from outside the household. Average number of years of experience in maize farming was 19 and 25 years in Katsina and Kaduna States, respectively. The average total land size per household was 7.56 and 9.32 ha in Katsina and Kaduna States respectively. Land was acquired mainly through inheritance (59%), while about 17, 4, 13 and 7% of the total area cultivated by the sampled households were purchased, gifted, leased and rented, respectively. The implication of this distribution is that most (80%) of the households owned the land they cultivated while only about 20% rented or leased farmlands. The land ownership pattern in the two states is an indication of stability and security of the farming systems. Investment in long term land management options is dependent on the ownership status of land, as some of the benefits of these investments may take a long time to reap. None of the household had access to formal credit while only about 13% took credit from friends and relations at little or

Table 1: Some socio-economic profile of farm households in the study locations

Variable	Katsina (n = 71)	Kaduna (n = 76)	Pooled (n = 147)
Age of household head (years)	43.00	47.0	44.00
Educational status (years in school)	3.00	5.0	4.00
Farm size (ha)	7.56	9.3	8.02
Household size (Number of persons)	10.00	7.0	9.00
Experience in maize farming (years)	19.00	25.0	21.00
Number of livestock unit	1.70	0.8	1.30

no interest rate. The low capital base of rural farmers makes access to low cost credit inevitable to increasing adoption of productivity enhancing technologies. It is therefore not surprising that the level of adoption of fertility management strategies (particularly inorganic fertilizer) is low in the study location.

About twelve maize-based cropping patterns were identified in the study locations. Maize was cropped as a sole crop by about 64 and 75% of the sampled households in Katsina and Kaduna States, respectively. The predominant maize-based mixtures in the study locations were maize-sorghum, maize-cowpea, maize-sorghum-cowpea, maize-cocoyam, maize-cotton, maize-groundnut, maize-sorghum-soybean, maize-millet, maize-millet-cowpea, maize-rice and maize-soybean. The average farm size allotted to maize-based crops varies from 0.8 to 23 ha with an average of 5.3 ha in Katsina State and 6.5 ha in Kaduna State.

The perception of the farmers with regards to the fertility status of the farms revealed that about 82% perceived that the soils are inherently not fertile, while only about 18% indicated that the soils were fertile. The infertility of the soil was attributed to inadequate fertilizer, particularly mineral fertilizer and organic manure and inadequate farmland resulting in continuous cultivation on the same piece of land. Techniques used by the households in maintaining soil fertility as indicated in Table 2 include application of mineral fertilizer (93% of the households), farmyard manure (78% of the households), crop rotation (45% of the households), cultivating crops in mixtures (cereal-legume) (68% of the households) and fallow (3% of household). Applications of organic and mineral fertilizer are the most commonly used method. Even with the high cost of mineral fertilizer, farmers indicated that one cannot obtain much from maize without applying this input, thus most of the farmers interviewed used mineral fertilizer at varying levels. Organic manure represents one of the important means of maintaining soil fertility in the study location. About 90 and 52% of the households sampled in Katsina and Kaduna states used farmyard manure on their farms, respectively. The manure was mainly from cattle, sheep, goat and chicken droppings/bedding materials, household waste, cooking ash and municipal waste (refuse dumps). The households indicated awareness of the importance of organic manure not only in enriching the fertility of soils but also in improving soil physical properties. However, they preferred applying mineral fertilizer because of ease of application, the manageable quantity required per time and the efficiency in increasing crop yield.

Fertilizer use intensity, measured by the ratio of ($N + P_2O_5 + K_2O$) and the total area cultivated for all maize-based crops were 204.5 and 221.7 kg ha^{-1} in Katsina and Kaduna state, respectively (Table 3). The ratio of N: P_2O_5: K_2O per hectare was 49.5:98.3:56.7 in Katsina State and 58.7:109.4:53.6 in Kaduna State. The sources of these nutrients were N:P:K (15:15:15), single super phosphate, urea, farmyard manure, livestock droppings and household waste. Analysis of the nutrients applied indicates that less than half of the recommended 120 kg N was used while the ratios were higher for P_2O_5 and K_2O in both locations. This was attributed to the higher content of available P_2O_5 and K_2O from organic manure compared to the available nitrogen. The major source of nitrogen (N) was from inorganic fertilizers accounting for about 85% of the total N. The quantities of both the organic and mineral fertilizer used were observed to be low. The low rate of mineral fertilizer used by the households was attributed to the high cost of fertilizer, low cash income of the household and lack of credit facilities. Reasons for low use of organic manure were mainly associated with the small number of livestock kept which could not produce enough manure in a season and the free-range system that does not allow efficient collection and management of manure. Also, marketing of manure was limited in the study locations due to the fact that most of the households do not have enough for their own farms.

Table 2: Techniques used in maintaining soil fertility (% of household studied)

Techniques	Katsina (n = 71)	Kaduna (n = 76)	Pooled (n = 147)
Mineral fertilizer	92	100	96
Organic manure	90	52	74
Crop rotation	51	42	45
Mixed cropping	37	29	33
Fallow	4	2	2

Table 3: Rates of fertilizer use by the respondents in the study locations (kg ha^{-1})

	Katsina	Kaduna	Pooled
N	49.5	58.7	53.4
P_2O_5	98.3	109.4	101.7
K_2O	56.7	53.6	54.1
FUI	204.5	221.7	217.9

FUI = Fertilizer Use Intensity

Socio-economic factors influencing fertilizer use intensity: The hypothesis that a certain socio-economic profile induces the extent of application of fertilizer on maize-based farms can be accepted based on the estimated logistic regression model presented in Table 4. The model fits the data with significance at ($p<0.001$) as indicated by the chi-squared goodness of fit statistic. The percentages of correct prediction were good at 83.7%. Besides, the Nagelkerte goodness of fit test shows that the models significantly fit the data for the study location. The good fit of the models proved that the variables tested in this study were valid to explain the extent of

Table 4: Socio-economic variables influencing household decision to use fertilizer for maize-based crops

Variable	Coefficients	SE	Sig.	Exp (B)
Total area cropped	- 0.020	0.196	0.921	0.981
Age of household head	- 0.050	0.043	0.245	0.951
Years of formal schooling	0.098*	0.060	0.101	1.103
Experience in maize farming	0.113**	0.047	0.016	1.119
Involvement in off-farm activities	1.626***	0.621	0.009	5.083
Previous year's income	0.000***	0.000	0.002	1.000
Land ownership	1.637***	0.519	0.002	5.140
Livestock unit	0.088	0.073	0.226	1.092
Household labor force	0.002	0.041	0.955	1.002
Perceived fertility status	0.137	0.234	0.560	0.873
State	0.632	0.515	0.219	0.531
Constant	-3.604**	1.808	0.046	0.027

Percentage prediction = 83.7%, Goodness of fit Chi-square (df = 11) = 63.57 ($p<0.001$), Nagelkerte $R^2 = 0.522$,* = ($p<0.10$) ** = ($p<0.05$) and *** = ($p<0.01$)

fertilizer use for maize-based cropping system in the study area. The coefficient of dummy variable for state was not significantly different from zero implying that there was no apparent difference in the levels of fertilizer use in Kaduna and Kano states.

With the exception of farm size and age, all other variables in the model had positive influence on the extent of application of fertilizer on maize-based farms, which is in accordance with a priori expectation. The probability or decisions by households to use fertilizer intensively were significantly influenced by the following household socio-economic variables: previous year's income, land ownership, engagement in off farm activities and experience in maize farming. Conversely, age of household head, number of years in school, farm size, household size and number of livestock units and farmers perceived fertility status had no significant influence on fertilizer use. Involvement in off farm activities, previous year's income and land ownership significantly ($p<0.01$) and positively influenced the extent of fertilizer use. The model revealed that involvement in off-farm activities enhances the chances of intensifying the use of fertilizer by 5.083 times. Engagement in off farm activities promotes intensive use of fertilizer since cash availability is considered as the most important constraints. Income from off-farm activities can be used to invest in purchasing fertilizer for crop production. This result agrees with what has been reported by Green and Ng'ong'ola (1993). They found out that income from off-farm employment significantly influences farmers decision to adopt fertilizer in Malawi.

Ownership of farm induces greater use of fertilizer by the households by 5.14 times. This is expected because farmers tend to invest more in soil fertility management strategies if they own the land than when borrowed or rented. The result also supports the hypothesis that previous year's income and experience in maize farming have positive impact on farmers' decision to use fertilizer on maize-based crops. That is, farmers with more years of experience in maize production are likely to use fertilizer more intensively than those who do not. Years of experience in farming contribute to human capital development and therefore, household who are more experience in maize farming are supposed to be knowledgeable on the need for greater use of fertilizer to boost maize output. The age of household head and the total area cultivated were however, found to negatively influenced fertilizer use, though the coefficients of these variables were not significant. The observed insignificance of the coefficient of farm size implies that there are no real variations in the extent of application of fertilizer with respect to variation in farm size.

CONCLUSIONS

The study aimed at identifying farm-family specific variables that were detrimental in the decision to use fertilizer and increase productivity of maize-based production systems. Mineral fertilizer was the most important input for replenishing soils in the study locations, however, the rate of application was found to be low due to reasons ranging from high cost of fertilizer, low output price/cash income of the household and lack of credit facilities. The most important factors influencing household decision to use fertilizer intensively are; engagement in off-farm activities, previous year's income, years of experience in maize farming and type of land ownership. Structural transformation that would induce optimum application of fertilizer to increase productivity among rural farm families will need to take into consideration access to credit not only for fertilizer but also to diversity income into off-farm sources. Engagement in off farm activities promotes intensive use of fertilizer since cash availability is considered as the most important constraints. Income from off-farm activities can be used to invest in purchasing fertilizer for crop production. A change in the land tenure system to ensure more security on land ownership is also indispensable for encouraging intensification in fertilizer use. The policy recommendation from this study is that strategies towards improving land productivity through effective soil fertility management should induce farmers to adopt integrated soil fertility management options. The high cost of inorganic fertilizer, low capital base of rural farmers coupled with long term adverse effect of chemical fertilizers on soils, necessitates development of strategies that will integrate all possible options towards sustainable soil fertility management.

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