MEDWELL PUBLISHING
Pakistan Journal of Social Sciences 6 (2): 91-98, 2009
ISSN: 1683-8831

Determinants of Fertilizer Use in Northern Nigeria

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Abstract: Farm-level decision concerning the use of fertilizer is governed by socio-economic and institutional factors, asmuch as by agronomic and ecological concerns. Using data from a sample of 320 farm households in 16 geo-referenced villages, this study assessed the determinants of fertilizer use in northern Nigeria. Results show that the intensity of fertilizer use increases with family labor and physical access to fertilizer, but declines with cultivated land and plot distance from homestead. Consistent with the population-induced innovation hypothesis, the evidence suggests that smallholder farmers use fertilizer more intensively than larger farmers. The study concludes with implications for policy aimed at land use intensification through increased fertilizer use among smallholders.

Key words: Soil fertility management, fertilizer, geographic information system, socio-economic domain, tobit

INTRODUCTION

Nutrient limitation, especially Nitrogen (N), is one of the major constraints to agricultural productivity in the cereal dominated savannas of Sub-Saharan Africa (SSA) (Singh *et al*., 2001). Fertilizer has been identified as the main source of soil nutrients for agricultural production in the savanna agroecological zone (Manyong *et al*., 2001, 2002). However, the negative nutrient balances confirm a recent observation that only partial nutrient requirements are oftenmet in West Africa (Singh *et al*., 2001). At the low levels of soil nutrients, it has been noted that fertilizer is highly needed to reverse the declining soil fertility. Within sub-Saharan Africa, successes in substantially raising crop yields have only been achieved with fertilizer (e.g., sorghum) in South Africa and the Sudan and maize in Burkina Faso, mali and Ghana (Sanders and Ahmed, 2001). A moderate addition of N tends to increase net returns and reduce the risk from year-to-year variability in weather and prices (Singh *et al*., 2001).

Available evidence indicates that fertilizer application has remained low in most parts of SSA (Vlek, 1990; Mwangi, 1997). This is also true of the savannas of northern Nigeria where studies (Smith *et al*., 1994; Manyong *et al*., 2001; Vanlauwe and Giller, 2006) indicate low use of fertilizer (Table 1) among the farmers without delving into possible reasons for the low adoption. This has prevented the formulation of effective policy to promote the adoption of fertilizer, increase agricultural production and reduce poverty in the savannas of northern Nigeria. This study, therefore, aims at analyzing the determinants of fertilizer in the savannas (Guinea and Sudan) of northern Nigeria.

Table 1: Recommended and current fertilizer use in certain areas in sub-Sahara Africa

Characteristics	Southern Benin (kg ha^{-1})	Northern Nigeria (kg ha^{-1})	Western Kenya (kg ha^{-1})
Recommended rates at the national level			
N	60	120	AEZ-dependent
P_2O_5	40	600	AEZ-dependent
K_2O	00	600	AEZ-dependent
Average rate currently used at the national level			
N	2.3	1.5	<4.9
P_2O_5	1.1	0.4	<4.0
K_2O	1.3	0.4	<0.5

Vanlauwe *et al*. (2004), Vanlauwe and Giller (2006); AEZ= Agro-Ecological Zone

It is perhaps, the realization of the urgent need to reverse the ugly trend in fertilizer use and reduce food insecurity problem in the continent by African farmers that the African Leaders held the Africa Fertilizer Summit in Abuja, Nigeria from 9-13 June 2006. The summit underscored the urgent need for an Africa-wide revolution through the meeting of stakeholders in the agriculture sector. African heads of state, senior policymakers, key government officials, private sector leaders, representatives of farmer organisations, development agencies, NGOs, scientists and donors were in attendance to create awareness of the role of fertilizer in stimulating sustainable and pro-poor productivity growth in African agriculture and to plan strategies to rapidly increase fertilizer use by African farmers (Roy, 2006).

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Further, past studies have documented some of the factors that influence the adoption and use intensity of fertilizer in SSA. Adesina (1996) found that major factors that positively influence farmers use of fertilizers in rice fields were mechanization, farm size and land pressure, whereas plot distance from the village and distance of village to major market negatively influenced fertilizer use. Nkonya *et al.* (1997) found that larger farms tended to use fertilizer less than smaller farms. Chianu and Tsujii (2004) found that the probability of adoption of fertilizer increases with increased targeting of farmers from Guineas savanna zone: younger farmers, better educated farmers and farmers who diversified into many crops. This study, therefore, draws inspiration from past studies to empirically identify the factors determining fertilizer use in the savannas of northern Nigeria.

MATERIALS AND METHODS

Village selection: This study was carried out in 16 villages of northern Nigeria. The Northern Guinea Savanna (NGS) and the Sudan Savanna (SS) Agro-Ecological Zones (AEZs) were represented by the Kaduna and Kano States as bench mark areas, respectively (Manyong *et al.*, 2006). Eight villages were randomly selected using the table of random numbers from the pool of villages generated from the geo-referenced villages in each AEZ (Fig. 1). These included Suddu, Richifa, Ungwa Tamuwa, Ungwa Geri, Ungwa Pa, Awai, Gangara and Turawa in Kaduna state with 600-1.200 mm annual rainfall and Jalli, madachi, Babban Ruga, Bambarawa, Hugungumai, Duguji, Zugachi and Waga in Kano State with 300-600 mm annual rainfall. Rainfall has a unimodal distribution in both ecologies. The methodology of Length of Growing Period (LGP) was adopted in stratifying the sample by global AEZ (FAO/IIASA, 2000). The AEZ methodology follows an environmental approach that provides a standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. The LGP is 150-180 days for the NGS and 90-150 days for the SS. The Guinea and Sudan savannas were included to capture the influence of agro-ecology on resource constraints and agricultural performance. The NGS and the SS were chosen because these 2 zones support the highest concentration and density of livestock in Nigeria and have potentials for crop-livestock integration and fertilizer market development in West Africa (Thornton *et al.*, 2002; Manyong *et al.*, 2006).

Four socio-economic domains of the clusters of similar resource and farming conditions resulting from a combination of low and high population density areas with low and high market access areas were generated through a geo-spatial mapping derived using the ArcGIS software. In deriving the population factors, a rural population density of <100 people km^{-2} was estimated and identified as Low Population density (LP), while a population density of 100-500 people km^{-2} was estimated and identified as High Population density (HP). Anything otherwise was defined as an urban population. A 20 km distance to a town or city was defined as High Market access (HM), with others defined as Low Market access (LM). These domains reflect differences in opportunities and correspond to agricultural intensification, which is in turn strongly influences population density and access to markets (Devendra and Pezo, 2002).

Household survey: A sample of 20 farm households was randomly selected from each of the selected 16 villages by using the random number table that resulted in 320 farm households for the study area. From each of the randomly selected villages, a list of households was generated and structured questionnaire was administered on the household heads. Information on fertilizer use was collected as quantity of fertilizer used per farm and per crop.

Analytical framework: Since the dependent variable of main interest is the adoption of and intensity of fertilizer use, a Tobit model was used. The Tobit model has the advantage of yielding results that can be interpreted for information on the intensity of use of fertilizer in addition to that of classification of farmers into user or non-user of fertilizer. Other exponential growth models including Probit and Logit models had equally been used (Polson and Spencer, 1991; Lapar and Pandey, 1999; Oluoch *et al.*, 2001; Omolehin and Nuppenau, 2003; Nunez and McCann, 2004; Chianu and Tsujii, 2004), but they explain only the probability and not the intensity of resource use (Manyong *et al.*, 2006).

The Tobit model is known as the censored normal regression model because some of the observations on IA^* (those for which $IA^* \leq 0$) are censored (Maddala, 1988). Censoring occurs when there is an underlying continuous variable, but some subsets of the range of values of the variable are coded to one number, thereby creating a mass point.

The Tobit model is constructed as follows (McDonald and Moffit, 1980): Let IA = intensity of adoption of fertilizer and IA* = the solution to utility maximization problem of intensity of adoption subject to a set of constraints per household conditional on being above a certain limit. IA* means the value of IA for the

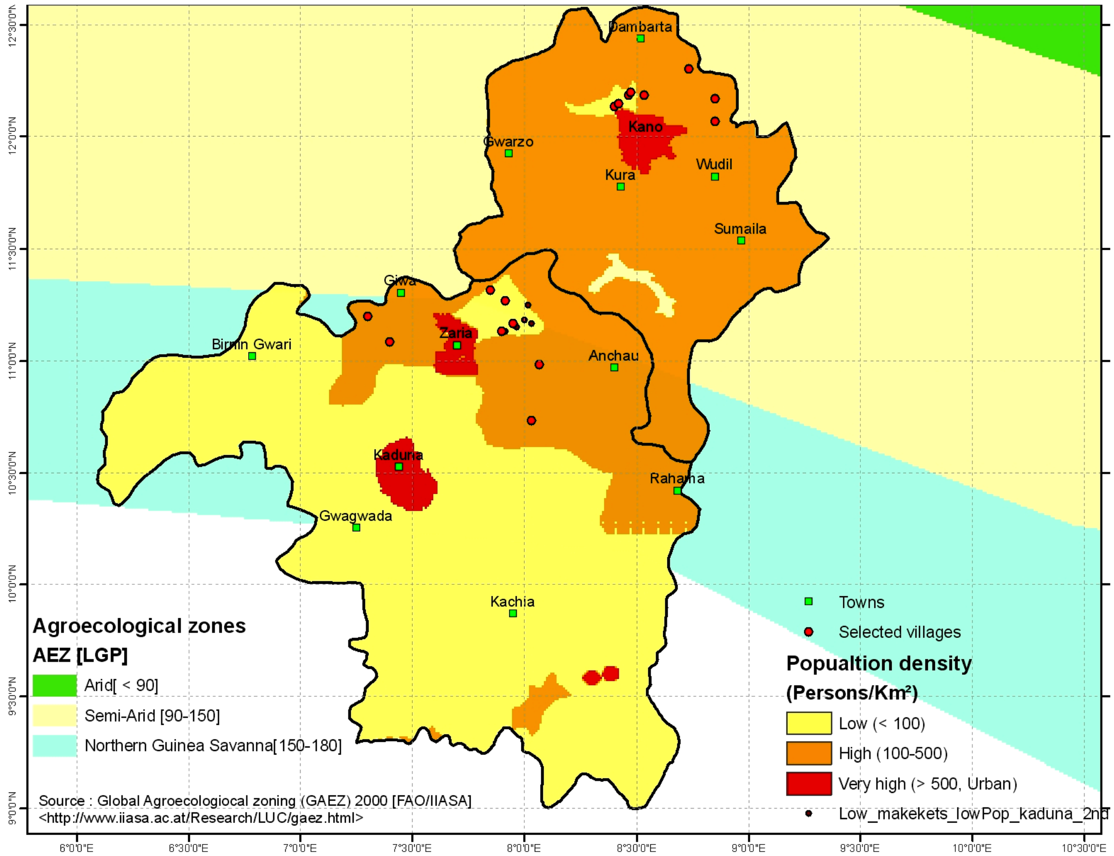

Fig. 1: Kaduna and Kano state showing population density and locations of survey villages

farmers that use fertilizer and IA_0 denotes the minimum technology adoption intensity per household. Here, IA_0 = fertilizer application/ha. Therefore,

$$IA = IA^* \text{ if } IA^* > IA_0 = 0 \text{ if } IA^* \leq IA_0 \quad (1)$$

Equation 1 represents a censored distribution of intensity of adoption of fertilizer since the value of IA for all non-adopters equals zero.

Following the Tobit decomposition, the expected intensity of adoption of a given technology E (IA) is:

$$E(IA) = X\beta F(z) + \sigma f(z) \quad (2)$$

where:

X = A vector of explanatory variables
F (z) = The cumulative normal distribution of z
f (z) = The probability density function or value of the derivative of the normal curve at a given point (i.e., unit normal density)
z = The Z-score for the area under normal curve
β = A vector of Tobit maximum likelihood estimates
σ = The standard error of the error term

McDonald and Moffit (1980) show that the marginal effect of an explanatory variable on the dependent variable is:

$$\delta E(IA)/\delta X_i = F(z)\beta_i \quad (3)$$

However, where the cumulative density function of adoption, F (z), is almost one, the total changemay be close to the β estimates of the adoption parameter. The marginal effects of an explanatory variable (Eq. 3) can further be decomposed into total change in the probability via new adopters and total change in intensity due to current adopters. This is given as:

$$\delta E(IA)/\delta X_i = [f \beta_i z + f^2 \beta/F] + F\beta_i [1 - zf/F - f^2/F^2] \quad (4)$$

Also, the change in the probability of adopting a technology as the independent variable X_i changes is:

$$\delta F(z)/\delta X_i = f(z)\beta_i/\sigma \quad (5)$$

And the change in intensity of adoption with respect to a change in the explanatory variable among the adopters is:

$$\delta E(IA^*)/\delta X_i = \beta_i [1 - zf(z), F(z) - f(z)^2/F(z)^2] \quad (6)$$

Further, the signs of the coefficients of the Tobit model show the direction of the change in the probability and the marginal intensity of adoption as the respective explanatory variable changes (Nkonya *et al*., 1997).

Empirical model: The empirical model for the study is specified as:

$$\ln Y_i = f(X_i; \beta)$$

where:

- $\ln Y_i$ = The natural logarithm of fertilizer use (kg ha^{-1}) of the ith farmer
- X_i = The vector of explanatory variables of probability of adoption and use intensity of fertilizer
- β = The vector of parameter estimates of the explanatory variables hypothesized to affect the probability of adoption and intensity of fertilizer use

Factors influencing adoption: The aim of this study was to determine factors affecting the adoption and intensity of fertilizer use among farmers in northern Nigeria. The explanatory variables (Table 2) hypothesized to affect the adoption of fertilizer were identified based on extensive review of previous adoption literature on the adoption of technologies and soil fertility management practices (Rogers, 1983; Feder *et al*., 1985; Akinola, 1987; Polson and Spencer, 1991; Adesina and Zinnah, 1993; Adesina, 1996; Nkonya *et al*., 1997; Williams, 1999; Alene *et al*., 2000; Oluoch *et al*., 2001; Cornejo *et al*., 2001; Sunding and Zilberman, 2001; Bamire *et al*., 2002; Ersado *et al*., 2004; Nunez and McCann, 2004; Asfaw and Admassie, 2004). Any strategy aimed at promoting the adoption of fertilizer must be based on an understanding of the factors that affect fertilizer use. A farmer's decision regarding adoption of technologies depends on farmer's characteristics, farm characteristics and the perceived characteristics of the technology. Therefore, factors that were hypothesized to influence the adoption and use intensity of fertilizer derive from the theory of soil fertility management as well as empirical studies on the adoption of technologies. These variables include farmers' characteristics, land use characteristics, village characteristics, cropping pattern and agro-ecological and population and market access characteristics.

Table 2: Description of variables used for the Tobit analysis of fertilizer use

Variables	Mean	SD	Minimum	Maximum
Dummy for AEZ (1 = NGS; 0 = SS)	0.50	0.50	0.00	1.00
Dummy for high population density and high market access (1= HPHM; 0 = otherwise)	0.25	0.43	0.00	1.00
Distance of village to tarred road (km)	1.03	1.26	0.00	3.00
Age of farmer (years)	46.96	10.25	28.00	70.00
Year of formal education	2.53	3.75	0.00	14.00
Household size	11.86	5.63	3.00	43.00
Total land area cropped (ha)	5.93	3.30	1.00	26.00
Proportion of own land cultivated	0.98	0.09	0.00	1.00
Proportion of distant farm cultivated	0.58	0.32	0.00	1.00
Proportion of less fertile field	0.30	0.38	0.00	1.00
Crop diversification index †	0.31	0.12	0.13	0.98
Cultivation intensity‡	0.95	0.11	0.50	1.00
Nutrient intake index §	0.24	0.03	0.17	0.33
Tropical livestock units	3.93	3.19	0.20	21.50
Interactions dummy for agro-ecological zone and resource domains (1 = NGS and HPHM; 0 = otherwise)	0.13	0.33	0.00	1.00
Availability of fertilizer (i.e. if the farmer has physical access to fertilizer) (1 = Yes; 0 = otherwise)	0.91	0.28	0.00	1.00

Field survey; †Crop Diversification Index (CDI) is used to capture the cropping pattern adopted by farmers and calculated using the Herfindahl index defined as: $CDI = \sum_{i=1}^{n} P_i^2$ where, Pi = Proportion of net farm income from the ith crop in the combination. n = Number of crop enterprises owned by the farm household; ‡Cultivated intensity (Ndubuisi *et al*., 1998) is measured as follows: DI = Cultivated land area/Total land area owed; §The nutrient intake index is given as: $NII = \frac{1}{2}\sum_{i=1}^{n} W_i T_i$ (ni =1, 2, …, n) where: Wi = particular weight assigned to the ith class of crop (cereals = 3, vegetable = 2 and legumes = 1); Ti = Type of crop planted n = number of crop in a combination

RESULTS AND DISCUSSION

Farmers' characteristics: Table 2 shows that the mean age of respondents in the study area was 47 years, whereas an average farmer had had 2.5 years of formal education, which indicated that most of the farmers had less than primary school education, with their level of education merely equivalent to an adult education program. The mean household size was 12 people, also suggesting large family size, which has implications for farm labor demand in the study area.

The major share of crop type planted had implications for the fertility status (replenishing or depleting) of the soil. For instance, farmers regard maize and sorghum (major cereal crops planted in the study area) as soil nutrient-depleting and legume crops (soybean, groundnut and cowpea) are regarded as soil fertility-enriching (Manyong *et al*., 2001) and hence, the need for repeated use of fertilizer as soil fertility amender in the study area. Only 30% of the total cropped land was considered to be fertile.

The average cropped land in the study area was about 6 ha, which is consistent with Manyong *et al*. (2006) and Chianu *et al*. (2004) reporting average farm sizes of 6.5 and 5.85 ha, respectively. The results also indicated that farmers are now intensifying more on their farm resources. About 70% of cultivated land was perceived to be fertile by the farmers. The mean cultivation intensity of 0.95 is indicative of a high level of intensification of land resources in the study area (Ndubuisi *et al.*, 1998; Omolehin and Nuppenau, 2003) and suggests that there were very low practices of land fallow and shifting cultivation in the study area.

Fertilizer use: Fertilizer use is an important soil fertility management practice in the study area. The results showed that 98% of the sample farmers used fertilizer. However, 81% of the fields received <120 kg ha^{-1}. Farmers attributed the low level in the usage of fertilizer to inherent non-availability at the time required and high value-to-cost ratio. This result on the constraint of fertilizer use supports recent findings on the importance of the availability of fertilizer at the time needed limits its use or demand (Minot *et al.*, 2000; Bamire *et al.*, 2002; Nagy and Edun, 2002; Vanlauwe and Giller, 2006).

Results in Fig. 2 show that the average fertilizer use in the study area was 68 kg ha^{-1}. A break down by AEZ, however, showed on average that the farmlands in the NGS received 72 kg ha^{-1}, while the SS had 64 kg ha^{-1}. The LP areas show little difference in the intensification level of fertilizer use in the NGS, but there was higher intensification in the SS as explained by HM. Given high population, there was an increasing trend in fertilizer use from LM to HM area in the NGS. This was not the case however, in the SS as the intensification of fertilizer use plummeted from HPLM to HPHM socio-economic resource domains. This result was not expected and the factors that were responsible may be connected with socio-economic domains. Controlling for LM, there was decrease along the fertilizer use trend line from the LP area to HP in the NGS and a decrease in the SS. Also, while controlling for high market access, the NGS showed an increasing trend in fertilizer use, but the SS exhibited a decreasing trend in fertilizer use intensity.

Determinants of adoption and use intensity of fertilizer in Northern Nigeria: Results of the Tobit model in Table 3 indicate that household size, crop nutrient demand, availability of fertilizer, land area cropped and distant farm land influenced the probability of adoption and intensity of fertilizer use in the study area. As expected, Household Size (HHSIZE) has a positive and significant influence on the probability of adoption and use intensity of fertilizer in the study area. This result could be explained by the fact that household size provided a proxy for farm labour, especially in the transportation and field application of fertilizer. This result is consistent with previous findings (Minot *et al.*, 2000;

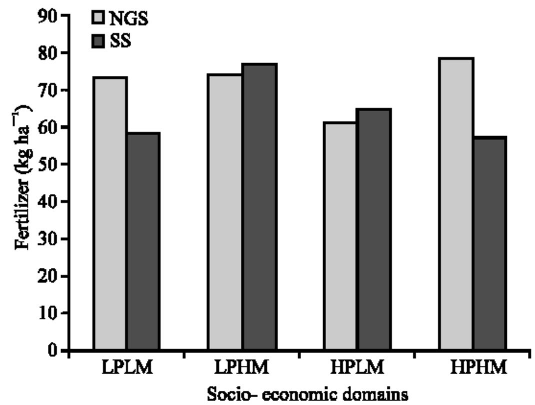

Fig. 2: Fertilizer applied by resource use domains

Bamire *et al.*, 2002) that observed a positive influence of household size on the adoption of fertilizer in the derived savanna of Nigeria.

As anticipated, the estimated parameter of the nutrient intake index (demand) variable was positive and significant at 0.05 level. The variable exerted the greatest effect on the probability of fertilizer adoption and use intensity. The implication of the result is that the predominance of the cereals and other heavy-feeder crops in the cropping systems influenced positively the probability of adoption and use intensity of fertilizer in northern Nigeria. Each additional increase in the hectare of land on heavy feeder crops increased the probability of adoption of fertilizer by 0.001. On average, each additional hectare of high nutrient demanding crops increased fertilizer use intensity by 4.746 kg ha^{-1} for the entire sample.

The availability of fertilizer (AVACHEM) had a positive and significant influence on the probability of adoption and use intensity of fertilizer in northern Nigeria. The effect of land area cropped (LCROPPED) on the probability of adoption and use intensity of fertilizer in the study area was negative and significant. The implication of the result is that farmers intensified the use of fertilizer on small area of land to maximize agricultural production. The result satisfied the a priori expectation that farmers with less land would use fertilizer more intensively and further suggests that smallholder farmers are more likely to adopt soil fertility management practices (Oluoch *et al.*, 2001). It has also been noted that new cultivable areas are limited so that the long-term production gains must come through intensification of land already under cultivation (McIntire and Powell, 1995).

Distant farmland also had a negative and significant effect on adoption and intensity of fertilizer use in the study area. This confirms the fact that fertilizer application competes for family labour and is hence, more convenient for fields closer to the homestead than for distant fields.

Table 3: Tobit model results of the adoption and intensity of use of fertilizer in northern Nigeria

Variables	ML estimate	Change in probability	Change in intensity among users	Total change	Total change via new users	Total change via current users
Constant	3.145 (3.446)***	-	-	-	-	-
Ecological zone (AEZ)	0.139 (0.898)	0.001 (0.732)	0.139 (0.898)	0.139 (0.898)	0.001 (0.733)	0.138 (0.898)
Socio-economic domains (population density and market access)	-0.122 (0.651)	-0.001 (-0.579)	-0.122 (0.651)	-0.122 (0.651)	-0.001 (-0.580)	-0.121 (0.651)
Distance to tarred road	-0.044 (-0.918)	-0.001 (-0.743)	-0.044 (-0.918)	-0.044 (-0.918)	-0.001 (-0.744)	-0.043 (-0.918)
Age of farmer	-0.003 (-0.419)	-0.001 (-0.398)	-0.003 (-0.419)	-0.003 (-0.419)	-0.001 (-0.398)	-0.002 (-0.419)
Year of formal education	0.013 (0.848)	0.001 (0.704)	0.013 (0.848)	0.013 (0.848)	0.001 (0.705)	0.012 (0.848)
Household size	0.029 (2.448)**	0.001 (1.123)	0.029 (2.448)**	0.029 (2.448)**	0.001 (1.127)	0.028 (2.448)**
Land area cropped	-0.041 (-2.123)**	-0.001 (-1.088)	-0.041 (-2.123)**	-0.041(-2.123)**	-0.001 (-1.092)	-0.040 (-2.123)**
Own land cultivated	0.404 (0.689)	0.001 (0.605)	0.404 (0.689)	0.404 (0.689)	0.001 (0.605)	0.403 (0.689)
Distant farm land	-0.287 (-1.655)*	-0.001 (-1.006)	-0.287 (-1.655)*	-0.287 (-1.655)*	-0.001 (-1.009)	-0.286 (-1.655)*
Proportion of land less fertile	-0.211 (-1.440)	-0.001 (-0.950)	-0.211 (-1.440)	-0.211 (-1.440)	-0.001 (-0.953)	-0.210 (-1.440)
Tropical livestock units	0.009 (0.529)	0.001 (0.488)	0.009 (0.529)	0.009 (0.529)	0.001 (0.488)	0.008 (0.529)
Crop diversification	-0.832 (-1.576)	-0.001 (-0.987)	-0.832 (-1.576)	-0.832 (-1.576)	-0.001 (-0.990)	-0.831 (-1.576)
Cultivation intensity	-0.585 (-1.165)	-0.001 (-0.856)	-0.585 (-1.165)	-0.585 (-1.165)	-0.001 (-0.858)	-0.584 (-1.165)
Nutrient intake	4.746 (2.459)**	0.001 (1.126)	4.746 (2.459)**	4.746 (2.459)**	0.001 (1.130)	4.745 (2.459)**
Interaction of ecological zone and socio-economic domains	0.217 (0.872)	0.001 (0.718)	0.217 (0.872)	0.217 (0.872)	0.001 (0.719)	0.216 (0.872)
Availability	0.416 (2.208)**	0.001 (1.095)	0.416 (2.208)**	0.416 (2.208)**	0.001 (1.099)	0.415 (2.208)**

Log likelihood function = -430.29, δ(sigma) = 0.92, Z = 1.31, F (z) =0.90, f (z) = 0.17; Values in parentheses are t-values; ***, ** and * represent significance at 1, 5 and 10% probability levels, respectively

Other variables which had positive (as expected) but insignificant effects on the probability of adoption and use intensity of fertilizer included variables capturing agro-ecological zone, formal education, proportion of own land cultivated and livestock ownership. On the other hand, market access, distance to tarred road, age, proportion of farmland perceived to be less fertile by the farmers, crop diversification activities and cultivation intensity turned out to have negative but in significant effects on fertilizer use.

CONCLUSION

This study used a Tobit model to assess the determinants of adoption and intensity of use of fertilizer in northern Nigeria. Results showed that household size, crop nutrient demand and availability of fertilizer had a positive and significant influence on adoption and use intensity of fertilizer. On the other hand, cultivated land and distance of farmland to homestead had a negative and significant influence on adoption and use intensity of fertilizer. Therefore, other things being equal, farmers with more family labor, greater physical access to fertilizer, small land holdings and cultivating crops with high nutrient demand (mainly cereals) are likely to use fertilizer more intensively than others. Consistent with the observation that nearly all sample farmers used fertilizer but at sub-optimal levels, many socio-economic variables had their largest marginal effects on the intensity of fertilizer use. The results point to the need for policy strategies aimed at intensifying smallholder systems through increased fertilizer use.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial and logistical support provided by IITA and K.U. Leuven under the joint project Achieving Development Impact and Environmental Enhancement through Adoption of Balanced Nutrient management systems by farmers in the west African Savanna financed by the Belgian Development Cooperation (DGDC).

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