Determinants of adoption of balanced nutrient management systems technologies in the Northern Guinea Savanna of Nigeria: A multinomial logit approach

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Abstract: A project on balanced nutrient management systems (BNMS) has been implemented in the northern Guinea savanna (NGS) of Nigeria since 2000 in order to address soil fertility decline. The project has tested and promoted two major technology packages: a combined application of inorganic fertilizer and manure (BNMS-manure) and a soybean/maize rotation practice (BNMS-rotation). This study used a Multinomial Logit model to examine factors that influence the adoption of BNMS technologies. The results indicated that factors such as farmers' perception of the state of land degradation, and extension services were found significant in determining farmers' adoption decision. As farmers got more perception of the state of their land degradation and depletion, the rate of adoption in of BNMS-manure increased by more than 5 times while that of BNMS-rotation was quadruple. Similarly, as farmers have more contacts with extension agents, adoption rate of the BNMS-manure and BNMS-rotation increased by over quadruple. Extension services, the project activities of the International Institute of Tropical Agriculture, and farmer-to-farmer technology diffusion channels were the major means of transfer of BNMS technologies.

Keywords: *Adoption, Multinomial logit, BNMS-manure, BNMS-rotation, northern Guinea savanna (NGS).*

INTRODUCTION

Agricultural growth in the midst of population and socio-economic pressures has led to land degradation and soil nutrient depletion, which have become a major constraint to agricultural productivity in northern Nigeria. It has been argued that effective use of organic soil amendment methods in combination with inorganic fertilizer could help reverse the nutrient depletion trend. Such an approach to tackle the soil fertility problem formed the basis of a project on integrated soil fertility management (ISFM) known as the Balanced Nutrient Management System (BNMS) project introduced by International Institute of Tropical agriculture (IITA) and Katholieke Universiteit (KU) Leuven the Northern Guinea Savanna of Nigeria.

Amongst the soil fertility technological options tested as BNMS technologies, two have emerged as breakthroughs: (i) the combination of organic manure and inorganic fertilizer that allows a saving of about 50% of the expenditure on inorganic fertilizer, and (ii) the use of less available Phosphorus (P) or rock P by grain and/ or herbaceous legumes that appear to have a more efficient mechanism for attracting P from the soil than other crops (Vanlauwe et al. 2001). The BNMS technological package combining organic matter with inorganic fertilizer is simply referred to as the BNMS-manure treatment (BNMS-manure) and the soybean/maize rotation with reduced fertilizer application to maize is the

BNMS-soybean/maize treatment (BNMS-rotation). Evidence from on-station and on-farm researcher-managed trials indicated that combined application of organic and inorganic fertilizer inherent in BNMS technologies gives higher yields than any singular application of either input (Iwuafor et al. 2002). According to Wallys (2003), the average yield per hectare from BNMS-manure was over 3.2 tons. Ugbabe (2005) also reported 3.0 ton/ha in 2004 from demonstration trials. Similarly, the yield from BNMS-rotation in 2004 was 3.4 ton/ha from adaptation trials. These yields were significantly different from those obtained from farmers' practice (about 2 ton/ha or less), though not significantly different from that obtained from the SG2000 package (Ugbabe 2005). SG2000 package consists of the use of hybrid seeds, specified proper plant density, and inorganic fertilizer application practice (Wallays 2003). However, no study has looked into the adoption of these land-improving technologies at farm level. Some studies have looked into the adoption of these technologies using tobit models but none has with multinomial logit model. The objectives of this paper are therefore to (i) determine the rate of the adoption of components as well as the package BNMS technologies; and (ii) analyze the socio-economic, demographic, institutional, policy and technology-related factors influencing the adoption and intensity of use of the technologies.

The remaining parts of this article are organized as follows. Section 2 presents the model used in this study and discusses the data and the empirical procedures. Section 3 discusses the results of this study. The conclusion and the recommendations are presented in the final section

METHODOLOGY

Theoretical model

A Multinomial logit model is based on the random utility model. The utility to an adopter of an alternative (U_i) is specified as a linear function of the farmer and farm-specific, the attributes of technology and other institutional as well as a stochastic component. The model is simply specified as:

$$U_i = \beta_i X_i + \varepsilon_i \quad \text{.......................... (1)}$$

Suppose the observed outcome (dependent variable) = choice j. If $U_j > U_k$ and $j \neq k$, then

$$\beta_j X_j + \varepsilon_j > \beta_k X_k + \varepsilon_k \quad \text{.................... (2)}$$

The chance of choosing an alternative is equal to the probability that the utility of that particular alternative is greater or equal to the utilities of all other alternative in the choice set. The dependent variable for a multinomial model is a discrete variable taking the values 0, 1, 2, 3… N, where n is the number of technology choices available to farmers. That is

$$\text{Prob (choice } j\text{)} = \frac{\exp(\beta_j X)}{\sum_j^n \exp(\beta_j X)} \quad \text{......... (3)}$$

A Multinomial model assumes that the choices of technologies by farmers are mutually exclusive.

Data source and sampling procedure

A household survey was conducted in the eight demonstration and adaptation trial villages. A total of 400 household heads were interviewed using a well-structured questionnaire. To determine household sample size per village, household heads in the villages were listed and random selection was made based on the population of each village. The share of total sample size was as follows: Fatika (18.5%), Kaya (23.5%), Danayamaka (9.25%), Buruku (18.75%), Kufana (5.7%5), Kroasha (6.25%), Kadiri Gwari (9) and Kayarda (9%). The household survey was supplemented with a community-level survey using the focus group discussion (FGD) method.

Empirical model

Collected survey data were analyzed using descriptive statistics and econometric models. These models were analyzed using the statistical software packages SPSS and LIMDEP.

A Multinomial logit model was used to package all the various categories of technologies into a one-model scenario. The dependent variable in this model was a discrete variable taking the value 0, 1, 2 and 3 for cases of non-adopter, inorganic fertilizer only, BNMS-manure and BNMS-rotation respectively.

The estimated model was specified as follows:

$$Y_i = \beta_0 + \beta_{ii}AGE + \beta_2 HHSIZE + \beta_3 SOCKAP + \beta_4 OFFINCOME + \beta_5 LIVESTOCK + \beta_6 CREDIT + \beta_7 EDUCATION + \beta_8 PERCEPTION + \beta_9 EXTENSION + \beta_{10} FARMSIZE + \beta_{11} ASSET + \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The multidisciplinary independent variables included farmer, farm and institutional factors postulated to influence technology adoption. These variables were age (*AGE*) of the household head in years, the household size (*HHSIZE*), measure of social interaction resulting from membership in farmers' organization (*SOCKAP*), off-farm income from non-farm activities (*OFFINCOME*) measured in Nigerian naira (N), livestock ownership of the households (*LIVESTOCK*) measured in Tropical Livestock Unit, access to credit (*CREDIT*), education of household head (*EDUCATION*) measured by the number of years of formal education, perception of the state of land degradation and depletion (*PERCEPTION*), effective extension contacts (*EXTENSION*) measured in dummies by the regularity of visits by extension agents, farm size (*FARMSIZE*), and asset (*ASSET*). Off-farm income and Naira value asset of ownership transformed in natural logarithm. Social capital, access to credit and extension were included in the model as dummy variables.

The rationale for inclusion of these factors was based on *a priori* expectation of agricultural technology adoption literature. The effect of age on BNMS technological adoption decisions may be negative or positive. Younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear risk and adopt new technology because of their longer planning horizons. The older the farmers, the less likely they are to adopt new practices as they place confidence in their old ways and methods. On the other hand, older farmers may have more experience, resources, or authority that may give them more possibilities for trying a new technology. Thus for this study, there is no agreement on the sign of this variable as the direction of the effect is location- or technology-specific (Feder et al. 1985; Nkonya et al. 1997; Oluoch-Kosura et al. 2001; Bekele and Drake 2003). Education was hypothesized to influence the adoption of integrated soil fertility technologies positively since, as farmers acquire more, their ability to obtain, process, and use new information improves and they are likely to adopt. Education increases the ability of farmers to use their resources efficiently and the allocative effect of education enhances farmers' ability to obtain, analyze and interpret information. Several studies reviewed by Feder et al. (1985) indicate positive relationship between education and technological adoption (Alene et al. 2000; Nkoya et al. 1997; Oluoch-Kosura et al. 2001

Institutional factors of social capital, extension contact and access to credit were hypothesized to influence the adoption positively as these support services facilitate the uptake of new technologies. Membership of associations, such as cooperative societies, has been found to enhance the interaction and cross-fertilization of ideas among farmers (Bamire et al. 2002). Farmers who are not members of associations are expected to have lower probabilities of adoption and a lower level of use of BNMS technologies. The extension contact variable incorporates the information that the farmers obtain on their production activities on the importance and application of innovations through counseling and demonstrations by extension agents on a regular basis. It is hypothesized that the respondents who are not frequently visited by extension agents have lower possibilities of adoption than those frequently visited (Adesina and Zinnah 1993; Shiferaw and Holden 1998; Oluoch-Kosura et al. 2001; Bamire et al. 2002). The variable was measured as dichotomous with respondents 'contact during the period scoring one, and zero for no extension contact on the use of BNMS technologies.

Access to credit takes cognizance of farmers' access to sources of credit to finance the expenses relating to the adoption of innovations. Access to credit boosts farmers' readiness to adopt technological innovations. It was hypothesized that the variable has a positive influence on the probability of adoption and use of land improving technologies (Zeller et al. 1998; Oluoch-Kosura et al. 2001; Bekele and Drake 2003). It was measured as a dichotomous variable with ''access'' being one, and zero for ''no access''. Measures of wealth such as livestock, off-farm income and the household's asset ownership are also hypothesized to influence adoption positively. They are generally considered to be capital that could be used either in the production process or be exchanged for cash or other productive assets. They are expected to influence the adoption of BNMS technologies positively (Shiferaw and Holden 1998; Zeller et al. 1998; Negatu and Parikh 1999). Livestock and household assets increase the availability of capital which makes investment in land-enhancing technologies feasible. Livestock, particularly oxen, are used as working assets to perform farm operations, including the use of BNMS technologies, which increases the possibility of timeliness effects.

To the extent that liquidity is a constraint to adoption, off-farm income will have a positive effect on adoption. The level of off-farm income, however, may not be exogenous but be affected by the profitability of the farming operation that in turn depends on technology adoption decisions. Thus, the adoption of BNMS technologies and the level of off-farm income may be determined simultaneously. This arises due to the labor allocation decisions of the households about farm and non-farm activities. However, the off-farm income of the household surveyed is mostly derived from the remittances of family members in non-farm business activities and from employment in non-farm sector. As the skill requirements for these jobs are likely to be different from those of farming, the farm and non-farm employment may be considered as non-competitive activities. In this situation, the level of non-farm income would be largely exogenous to the adoption decision (Lapar and Pandey 1999).

Perception of the state of degradation of farmer's land (1, if the land was perceived to be degraded, 0, otherwise) was also hypothesized to influence adoption positively. Farmers who perceived their land degraded and soil depleted are more likely to adopt land-improving technologies (Shiferaw and Holden 1998). Household size, which includes all people living under the same roof and who eats from the same pot as the household head, has been identified to have either a positive or a negative influence on adoption (Manyong and Houndekon 1997, Zeller et al. 1998; Oluoch-Kosura et al. 2001; Bamire et al. 2002; Bekele and Drake 2003). Larger family size is generally associated with greater labor force availability for the timely operation of farm activities. The negative relationship of the variable with adoption has been linked to the increased consumption pressure associable with a large family. It is therefore difficult to predict this variable '*a priori'* in this study.

Previous studies have found a positive relationship between farm size and technological adoption (Manyong and Houndekon 1997; Negatu and Parikh 1999; Oluoch-Kosura et al. 2001; Bekele and Drake 2003). For this analysis, farm size is included as the total cropland available to the farmer. Operators of large farms are likely to spend more on land improving technologies. In many cases, large farm size is associated with increased availability of financial capital, which makes investment in ISFM more feasible. A positive relationship is hypothesized with adoption of land-enhancing technologies (Table 1).

Table 1: Explanatory variables for adoption evaluation

Variable	**Variable Descriptions**	**Units**
PERCEPTION	An ordinal variable measuring farmer's own views regarding the fertility status of their land. 1 if the soil is degraded, 0 if not.	
EDUCATION	Number of years of formal education completed by the household head.	Years
AGE	Age of the household head in years.	Years
EXTENSION	An ordinal measure of effective contact of extension agents. 1 if contact was made, 0 if not.	
SOCKAP	Farmer's involvement in social activities measured by membership in social organization. 1 if farmer was a member, 0 otherwise.	
HHSIZE	Number of people living together under the same roof and eating from the same pot.	
FARMSIZE	The total farmland possessed by the household.	Ha
LIVESTOCK	Livestock holdings of the household as probable source of wealth or manure.	Tropical Livestock Units

CREDIT	Access to credit measured by the farmer's access to a source of credit such as co-operative society at a reasonable cost. 1 if there was access, 0 otherwise.	
OFFINCOME	Income in Naira generated from off-farm activities.	Naira
ASSET	Value of household and farm assets possessed by the household	Naira

Source: Own computation, 2006

RESULTS AND DISCUSSION

Socio-economic characteristics of sample households

Survey results indicate that there was a variation in the demographic and socio-economic characteristics among adopters of BNMS technologies as well as between the adopters and non-adopters. The average age of all respondents in the study is 42.5 years. The farming population is relatively young in the BNMS project area; this is of immense importance to the availability of labor for agricultural activities in general and for testing of agricultural innovations. When the result was examined very closely, it was found that technology adopters are much younger than non-adopters. The average age of the adopters ranged from 40.8 to 44.5 years while the average age of non-adopters was 50 years. Many studies on the adoption of agricultural innovations in Africa found that age is a significant determinant of technology adoption among farmers. The overall average literacy rate is 46.3% and the literacy rate of technology adopters (43.3% to 48.4%) was higher than that of non-adopters (33.3%). Among the adopters, those adopting BNMS-manure had the highest level of literacy, followed by the adopters of inorganic fertilizer only and the adopters of BNMS-rotation. The average years of formal education completed by household head was 7.6. The average number of years of formal education completed by technology adopters (7.3–8) was higher than the average number completed by non-adopters (5). Altogether, technology adopters are younger and more educated than non-adopters (See Table 2). The average household size in the study area was large (11.5 persons/household). For all the adopters, average household size was more than 10 persons while for non-adopters it was below 10. Overall average number of adult males (>15) is 3.5 per household. Among the adopters, the average number of adult males (>15) was highest for the adopters of BNMS-manure (3.7 per household) followed by adopters of BNMS rotation (3.9 per household) and adopters of inorganic fertilizer only (3 per household). Non-adopters have fewer adult male (>15) per household compared with the adopters.

Table 2: Demographic and socio-economic characteristics of farmers (mean)

Variable	Non-adopters	Inorganic fertilizer only	BNMS manure	BNMS rotation	All sample
Age	50	40.8	44.5	43.5	42.5
Literacy rate (%)	33.3	46.3	48.4	43.3	46.3
Years of formal education of head	5	8	7.3	7.3	7.6
Household size	9.7	10.6	12.4	12.6	11.5
No. of adult males >15	2	3.3	3.7	3.6	3.5

Farm size	2.6	3.5	3.8	3.5	3.58
Total livestock unit	1.2	3	4.12	3.9	3.5
Farm distance (km)	3	4.5	4.8	5.4	4.7
Perception (% degraded)	33	82	94	72	83
Extension contact (%)	40	70	72	68	69.3
Off-farm income (N)	2500	11,717	17217	19,615	14,579
Access to credit (%)	0	16	24	12	17.5
Asset	3,420	57915	53,122	25,579	50,129
Membership of association (% belong)	50	50	58	49	55

Source: Own survey

The average number of TLU in the study area was 3.5. Adopters of BNMS-manure would require possession of livestock to produce manure, consequently findings showed that they had the largest number of TLU (4.12), followed by adopters of BNMS rotation (3.9) and adopters of inorganic fertilizer only (3). Non-adopters of BNMS technologies had the smallest TLU (1.2). Farm size of the respondents ranged from 2.6 ha for non-adopters to 3.8 ha for adopters of BNMS-manure. Access to credit in the study area was generally low (less than 25%). Fifty eight percent of the adopters of the BNMS-manure belonged to one association or another while about 50% of the farmers in other categories are members of either farmers' group, cooperative societies or religious groups. The table shows the values of farm and household assets possessed by the households. Non-adopters of any of the land-improving technologies had average total asset worth of N3400. An average BNMS-manure adopter on the other hand possessed N53, 122 worth of assets and the corresponding value for a BNMS-rotation adopter was N25, 579. The users of inorganic fertilizer had mean assets of about N58, 000. The table reveals the high values of farm and household assets.

As regards the perception of the state of land degradation, more than 70% of the adopters of land-enhancing technologies perceived that their lands were degraded and needed urgent replenishment while only 33% of the non-adopters had an appreciation of the extent of land degradation. Extension contacts were high in the study area with an average of 69% of the survey households having regular contacts with extension agents though the number was lower among non-adopters. Average off-farm income of farmers for the sample area is N14, 579; FGDs revealed that this off-farm income came from activities like "Okada" (motor cycle taxi service) practiced generally by young men. Other activities contributory to this income included small scale trading, food processing and sales, and manual jobs such as digging wells and bricklaying.

Multinomial logit model estimates

Adopting a particular technology in the Multinomial logit model should not imply that farmers exclusively looking for a single technology. They are rather looking for integrated soil fertility management technologies with a different intensity of preferences. This analysis is concerned with the factors that could motivate farmers to a higher rating or preference for a specific technology. These factors are shown in Table 3.

Overall, the estimated Multinomial logit model was highly significant in explaining farmers' adoption decisions for ISFM technologies. The log likelihood ratio of -426.81 between the dependent variable and the set of explanatory variable indicates the fitness of the model. This together with Chi-squared value of 88.75 supports the adequacy of the model.

The key and significant variables determining the adoption decisions of integrated soil fertility management technologies were extension and perception. The results showed that extension and perception would increase the adoption of inorganic fertilizer only, BNMS-manure and BNMS-rotation. The findings agree with Wallys (2003) claimed that the technologies as good but being promoted as a basket of options from which the farmers can make a choice. As extensions visits to the household increased, the adoption of BNMS-manure and BNMS-rotation increased. As extension visit reduced, more inorganic fertilizer would be adopted.

Table 3: Multinomial logit model estimates of the determinants of adoption of ISFM technologies

Variable	Estimated coefficients for different adoption typologies					
	Inorganic fertilizer only		BNMS-manure		BNMS-rotation	
	Estimate	Marginal effects	Estimate	Marginal effects	Estimate	Marginal effects
CONSTANT	-3.058 (-0.430)	0.837	-6.766 (-0.960)	-0.652	-5.785 (-0.820)	-0.185
AGE	-0.065 (-1.440)	-0.005	-0.045 (-0.980)	0.003	-0.044 (-0.920)	0.002
EDUCATION	-0.042 (-0.250)	0.000	-0.033 (-0.190)	0.003	-0.061 (-0.360)	-0.003
SOCKAP	-0.864 (-0.710)	0.021	-0.880 (-0.720)	0.007	-1.084 (-0.870)	-0.028
LIVESTOCK	0.967 (1.440)	-0.009	1.000 (1.480)	0.005	1.013 (1.500)	0.005
EXTENSION	3.961** (2.340)	-0.081	4.203** (2.460)	0.028	4.452*** (2.600)	0.053
FARMSIZE	0.693 (1.370)	-0.007	0.737 (1.450)	0.009	0.692 (1.360)	-0.002
OFFINCOME	0.185 (0.570)	-0.038	0.278 (0.850)	0.007	0.461 (1.410)	0.032
ASSET	0.312 (0.470)	-0.015	0.368 (0.560)	0.009	0.375 (0.570)	0.006
CREDIT	30.111 (0.000)	0.024	30.281 (0.000)	0.064	29.499 (0.000)	-0.088
HHSIZE	0.048 (0.400)	-0.001	0.057 (0.470)	0.002	0.037 (0.300)	-0.002
PERCEPTION	4.808*** (2.750)	-0.126	5.995*** (3.350)	0.287	4.003** (2.260)	-0.160

Chi-squared 88.75
Log likelihood function -382.44
Restricted log likelihood function -426.81

Note: *** = Significant at 1 percent, ** = Significant at 5 %, * = Significant at 10%, Figures in parentheses represent asymptotic *t*-ratios

Source: Field survey

This implied that farmers are fully aware of the importance of inorganic fertilizer and additional visits will lead only to the adoption of BNMS-manure and BNMS-rotation. Incidentally, the BNMS-technologies were still being seen in the study area as new technologies and intensified efforts from the extension agents will increase their adoption. This is in line with the results from data description, where extension service could lead to adoption of the BNMS technologies. But as perception decreased, adoption of BNMS-rotation and inorganic fertilizer increased. By and large, the age and the education of the household head, and social capital have opposite impact on the adoption of inorganic fertilizer only, BNMS-manure and BNMS-rotation. However, as farmers have more contacts with extension agents, adoption rate of the BNMS-manure and BNMS-rotation increased by over quadruple.

Perception of the state of land degradation and soil depletion is an important variable. As farmers got more perception of the state of their land degradation and depletion, the rate of adoption in of BNMS-manure increased by more than 5 times while that of BNMS-rotation was quadruple. The variable was significant for inorganic fertilizer only and BNMS-rotation and BNMS-manure. However, as perception increased, inorganic fertilizer only and BNMS-rotation were less used while BNMS-manure was adopted more.

With respect to other variables, none was statistically significant. Experience, as proxied by age, was negative and insignificant for all categories of technologies. Education and interaction provided by social capital were also statistically insignificantly negative. However, livestock, farm size, off-farm income, assets and household size were positive for all integrated soil fertility management technologies but were insignificant. The foregoing reveals that extension service and perception were the most important variable conditioning the adoption of integrated soil fertility management technologies. BNMS technologies were more responsive than inorganic fertilizer only to extension contacts. BNMS-rotation and inorganic fertilizer only had positive marginal effects with respect to perception.

CONCLUSION AND RECOMMENDATIONS

This study assessed the determinants of adoption of BNMS technologies in northern Nigeria. Results confirmed the importance of extension services and perception of the state of land degradation in the adoption and use intensity of BNMS technologies. By way of scaling the technology up and out, policies and strategies that improve access to extension services should be instituted. Towards this end, there is an urgent need for upgrading the quality and adequacy of the extension services in target areas (to disseminate the technologies and create greater awareness of the state of land degradation) via better training for technical and communication skills. This could be achieved through pre-service as well as in-service training with agricultural development strategy that places high emphasis on the adoption and usage of BNMS technologies. Apart from this, farmers should also be visited regularly at the point of introduction of the new technologies.

The same results could also be achieved through organization of field days as revealed by FGDs. Fields days provide the farmers, extension agents, and researchers with a chance to interact and share ideas and experiences on a given technology. Farmers have the opportunity to learn about the best way of using new technologies to benefit from them. They are able to share ideas about possible problems they might face in adopting and using these technologies.

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