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Determinants of adoption and intensity of use of balance nutrient management systems technologies in the northern Guinea savanna of Nigeria

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Abstract

As part of a major effort to address soil fertility decline in West Africa, an integrated soil fertility management project promoted two technology packages: a combined application of inorganic fertilizer and manure (BNMS-manure) and a soybean/maize rotation practice (BNMS-rotation) in the northern Guinea savanna (NGS) of Nigeria. This study used a tobit regression model to examine factors that influence the adoption and intensity of use of the technologies. Empirical results showed that within five years of introduction, the adoption of BNMS-rotation had reached 40% while that of BNMS-manure had reached 48%. In terms of land area, BNMS-manure occupied 35% and BNMS-rotation covered 12% of the total maize land in the zone. Factors such as access to credit, farmers' perception of the state of land degradation, and assets ownership were the significant determinant factors of BNMS-manure, whereas off-farm income was found to be significant in determining farmers' adoption decisions on BNMS-rotation.

Keywords: adoption, BNMS-manure, BNMS-rotation, northern Guinea savanna, tobit
JEL: O33

1. Introduction

In northern Nigeria, agricultural intensification due to population and socio-economic pressures has led to land degradation and soil nutrient depletion, which have become a major constraint to agricultural productivity. 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 Systems (BNMS) project. To combat soil nutrient depletion and maintain the soil physico-chemical health, the Belgian Directorate General for International Co-operation approved a collaborative project between International Institute of Tropical agriculture (IITA) and Katholieke Universiteit (KU) Leuven on BNMS for maize-based systems in the moist savanna and humid forest zones of West Africa. During the first phase of 4 years (1997-2000), the project developed and tested management practices that maintained or improved soil nutrients by promoting the use of locally available sources of plant and animal nutrients, maximizing their nutrient use efficiency, and optimizing their combination with inorganic fertilizers.

Amongst the soil fertility technological options tested, 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[1] (UGBABE, 2005). However, no study has looked into the adoption of these land-improving technologies at farm level. Knowledge gaps exist on the level of adoption and utilization of the technologies. The objectives of this paper are therefore to: (i) determine the rate and intensity of the adoption of components as well as the package BNMS technologies; and (ii) analyze the socio-economic, demographic,

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[1] SG2000 package consists of the use of hybrid seeds, specified proper plant density, and inorganic fertilizer application practice (WALLYS et al., 2003).

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. The next section discusses the strategy and dissemination of the BNMS technologies. Section 3 presents the model used in this study and discusses the data and the empirical procedures. Section 4 discusses the results of this study. The conclusion and the recommendations are presented in the final section

BNMS technologies in northern Nigeria

The ISFM approach, with a sound combination of inorganic and organic inputs, is central to the BNMS strategy. Using various combinations of legume rotations, ground covers, green manures, animal manures, and other locally available resources, plus adequate, affordable amounts of inorganic fertilizers, it is possible over time to improve fertility and thereby increase the yield potential of soils in Africa. The overall purpose of this project was to ensure the improvement of rural livelihoods for the disadvantaged, small scale farmers in the West African Savanna. BNMS was designed to overcome soil-related constraints by recycling more biological processes and by using adapted germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling to minimize external inputs and maximize their use efficiency.

The first phase of the BNMS project left important knowledge gaps requiring further research thereby necessitating a second phase of 4 years (2001-2004). The goal was to improve food security and enhance income of the poor farming communities in the moist savanna zones without deleterious effects on biodiversity or environmental resources through the adoption of more environmentally friendly and profitable technologies (IITA and KU LEUVEN, 2000). IITA and K.U. Leuven scientists in partnership with NARS, NGOs and farmers developed tested and promulgated, BNMS technologies specifically adapted to the local biophysical and socio-economic environments of the savanna to enable a sustainable increase in farm productivity and profitability whilst improving overall soil fertility in maize-based farming systems.

The BNMS demonstration and adaptation trials were sited in the three extension zones of northern Nigeria, Maygana, Lere and Birni Gwari. Nine villages participated in the program: four in the Maygana zone, three in Lere and two in Birni Gwari. All the villages were situated in the NGS benchmark area or very close to it. The four villages in the Maygana zone are Kaya, Danayamaka, Fatika and Galadima; Activities in Galadima stopped after the first two years. Krosha, Kayarda and Kadiri Garo are the three villages in the Lere Zone. Birni Gwari zone villages are Kufana and Buruku. In

2000, the first farmer-managed on-farm trials were established by IITA in collaboration with IAR and SG2000. For several years before the introduction of BNMS technologies, the SG2000 and the State Agricultural development Projects (ADPs) had been promoting SG2000 package to farmers (WALLYS et al., 2003). The SG2000 package was reintroduced along with BNMS technologies as a basket of options from which farmers could choose.

2. Methodology

2.1 Theoretical model

A tobit model was used to analyze the socio-economic, demographic, institutional, policy and technology-related factors influencing the adoption and intensity of use of BNMS technologies; for this study. The stochastic model underlying tobit (TOBIN, 1958) may be expressed by the following relationship:

$$\begin{aligned} Y_t &= X_t\beta + u_t && \text{if } X_t\beta + u_t > 0 \\ &= 0 && \text{if } X_t\beta + u_t \leq 0 \\ t &= 1,2,\ldots,N, && \end{aligned} \tag{1}$$

Where N is the number of observations, Y_t is the dependent variable, X_t is a vector of independent variables, β is a vector of unknown coefficients, and u_t is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2. Thus the model assumes that there is an underlying, stochastic index equal to $(X_t\beta + u_t)$ which is observed only when it is positive, and hence qualifies as an observed, latent variable.

According to Tobin, the expected value of Y in the model is

$$E(Y) = X\beta F(z) + \sigma f(z) \tag{2}$$

where $z = X\beta / \sigma$, $f(z)$ is the unit normal density, and $F(z)$ is the cumulative normal distribution function (individual subscripts are omitted for notational convenience).

Furthermore the expected value of Y for observation above the limit Y^* is $X\beta$ plus the expected value of the truncated normal error term (AMEMIYA, 1984):

$$\begin{aligned} E(Y) &= E(Y / Y > 0) \\ &= E(Y / u > -X\beta) \\ &= X\beta + \sigma f(z) / F(z) \end{aligned} \tag{3}$$

Therefore, the basic relationship between the expected value of all observations, $E(Y)$, the value conditional upon being above the limit, $E(Y^*)$, and the probability of being above the limit, $F(z)$, is

(4) $E(Y) = F(z)E(Y^*)$.

According to McDonald and Moffit (1980), equation (4) can be decomposed by considering the effect of a change in the ith variable of X on Y :

(5) $\partial E(Y)/\partial X_i = F(z) \times \partial E(Y^*)/\partial X_i + E(Y^*) \times \partial F(z)/\partial X_i$

Thus the total change in Y can be disaggregated into two, very intuitive parts: (1) the change in Y of those above the limit, weighted by the probability of being above the limit, and (2) the change in probability of being above the limit, weighted by the expected value of Y if above the limit.

The two partial derivatives are also calculable (McDONALD and MOFFIT, 1980):

(6) $\partial F(z)/\partial X_i = f(z)\beta_i/\sigma$

and, from equation (3):

(7) $\partial E(Y^*)/\partial X_i = \beta_i[1 - zf(z)/F(z) - f(z)^2/F(z)^2]$

using $F'(z) = f(z)$ for cumulative normal density and $f'(z) = -zf(z)$ for a unit normal density.

2.2 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.

2.3 Empirical model

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

In this study, the dependent variable is the land area under each of the BNMS technology. The estimated model was specified as follows:

$$\begin{aligned} &Y_i = \beta_0 + \beta_{ii} AGE + \beta_2 HHSIZE + \beta_3 SOCKAP + \beta_4 OFFINCOME + \\ &\beta_5 LIVESTOCK + \beta_6 CREDIT + \beta_7 EDUCATION + \beta_8 PERCEPTION + \\ &\beta_9 EXTENSION + \beta_{10} FARMSIZE + \beta_{11} ASSET + \mu \end{aligned} \tag{8}$$

The multidisciplinary independent variables shown in table 1 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 (₦), 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)

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)

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. Following MCDONALD and MOFFIT (1980) and using the LIMDEP software, the tobit estimates were decomposed into four different effects:

- Change in the probability of adoption
- Change among the adopters
- Total change via the current adopters
- Total change via new adopters

3. Results and discussion

3.1 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 was 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 were 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 was 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 years old) is 3.5 per household. Among the adopters, the average number of adult males (>15 years old) 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. 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 ₦3,400. An average BNMS-manure adopter on the other hand possessed ₦53,122 worth of assets and the corresponding value for a BNMS-rotation adopter was ₦25,579. The users of inorganic fertilizer had mean assets of about ₦58,000. 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 ₦14,579; 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.

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

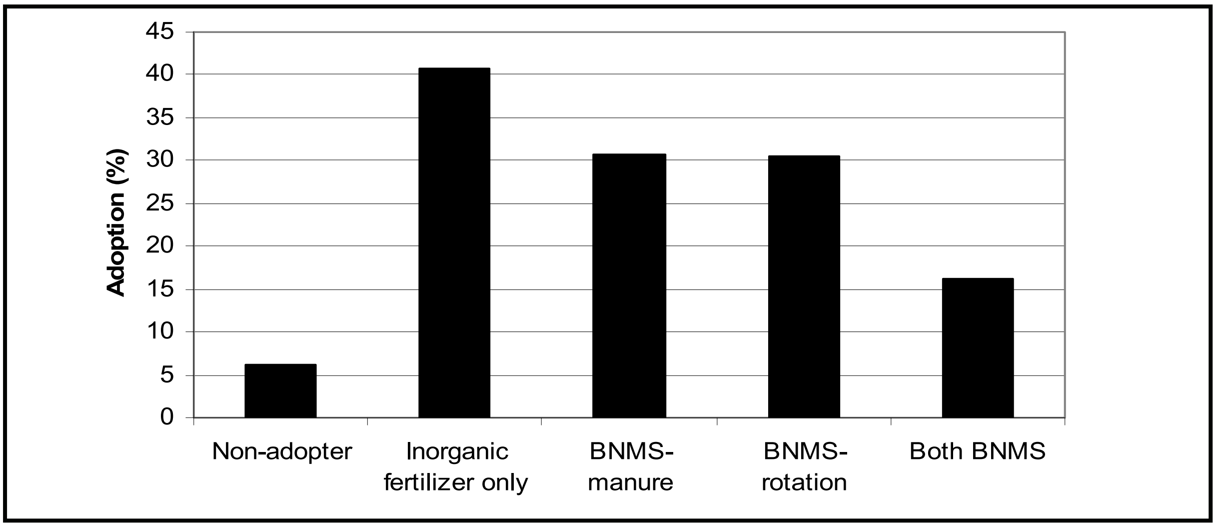
Variable	Non-adopters	Inorganic fertilizer only	BNMS manure	BNMS rotation	All sample
Age	50	40.8	44.5	43.5	42.5
Literacy rate (%)	33.3	46.3	48.4	43.3	46.3
Years of formal education of head	5	8	7.3	7.3	7.6
Household size	9.7	10.6	12.4	12.6	11.5
No. of adult males >15	2	3.3	3.7	3.6	3.5
Farm size	2.6	3.5	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 (₦)	2,500	11,717	17,217	19,615	14,579
Access to credit (%)	0	16	24	12	17.5
Asset	3,420	57,915	53,122	25,579	50,129
Membership of association (% belong)	50	50	58	49	55

Source: own survey

3.2 Adoption of BNMS technologies

Certain constraints such as accessibility and affordability of inorganic fertilizer as well as paucity of organic manure prevented the farmers from using the recommended levels of inputs constituting a technological package. Therefore, a minimum threshold was set for different technological packages. Respondents were classified into non-adopters of land-improving technologies, users of inorganic fertilizer only, adopters of the BNMS-manure and BNMS-rotation. The classification was based on the quantities of inorganic fertilizer and organic inputs used by farmers in the area. Farmers were categorized as non-adopter, if they did not use inorganic fertilizer, manure or practice alternating maize in rotation with a legume, particularly with soybean. On the other hand, users of inorganic fertilizer only were the farmers who used at least 30kg N/ha of inorganic fertilizer but did not combine the use with organic inputs such as manure or practice maize-soybean rotation. The adopters of BNMS-manure were the farmers who combined the application of inorganic fertilizer and manure together on the same plot of land with up to 30 kg N/ha of inorganic fertilizer and at least 3,000 kg/ha manure. BNMS-rotation adopters alternated soybean with maize on the same plot and used more than 30 kg N/ha of inorganic fertilizer on their maize land. The minimum 30 kg N/ha threshold used for fertilizer follows the work of MANYONG et al. (2001). Figure 1 shows the adoption typology of soil fertility-enhancing technologies in the survey area. Non-adopters of any of the technologies were just 6.1%. The adopters of inorganic fertilizer only represented 40.8% of the sample. About 38.8% of the respondents in the survey sample adopted BNMS-manure and 30.6% adopted BNMS-rotation. There were farmers (16.3%) who adopted both BNMS technologies.

Figure 1. Adoption typology of ISFM technologies

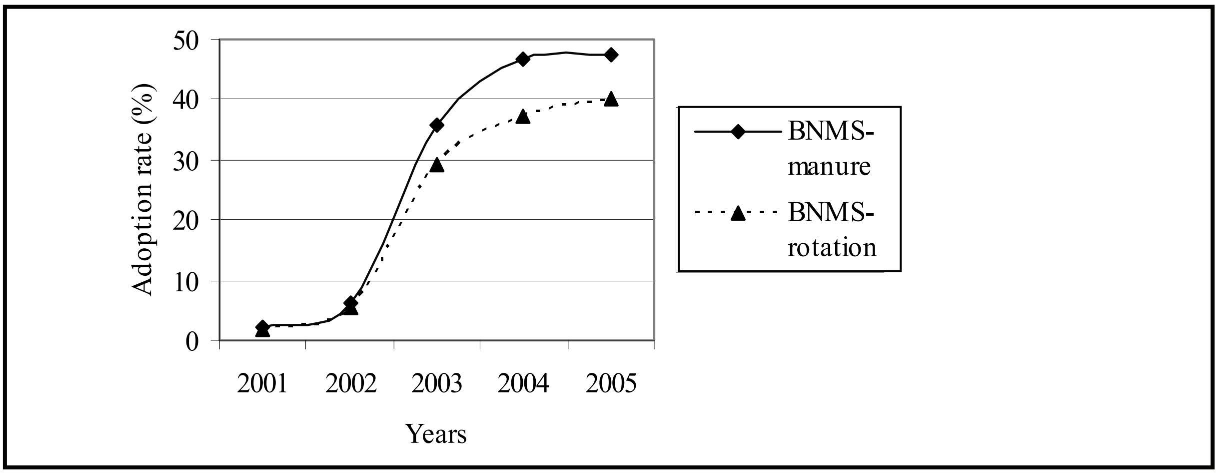


Source: own survey

3.3 Intensity of use and trend in the adoption of BNMS technologies

The land-improving technologies of BNMS introduced to farmers in the NGS had been adopted at different rate. Descriptive statistics shows that BNMS-manure and BNMS-rotation had covered 35 and 12% of the total maize land, respectively. Use of inorganic fertilizer only and farmers' practices covered up to 53% of the total maize land. On intensity of the technologies, the results show that 30.6% of the farmers (adopters of the BNMS-rotation technology) covered 12% of land allocated to maize, whereas 38.8% of them (adopters of BNMS-manure practice) covered 35% of the maize land. The study reveals that adoption of BNMS technologies started in 2001 and the rate of adoption was very rapid (figure 2). At the end of 2002, less than 10% of the sample households had adopted either of the BNMS technologies. One year later, by the end of 2003 about 20% of the farmers in the study area had adopted BNMS-rotation while about 30% of them were using BNMS-manure. Between 2002 and 2003, a significant proportion of the sample households adopted the BNMS technologies. By the end of 2005, 37% the surveyed households sample had adopted BNMS-rotation and 46% BNMS-manure. The results show that there were consistently more adopters of the BNMS-manure technology than the BNMS-rotation practice.

Figure 2. Cumulative adoptions of BNMS technologies



Source: own survey

The staff of IITA and extension agents from the NARS were the main channel through which information concerning BNMS-manure was disseminated to the farmers (66%), followed by farmer-to-farmer interaction that transferred the information to 19% of the respondents. National Agricultural Research Institute, local NGO and mass media transferred information about BNMS-manure to 15% of the sample households. The same trend was observed in the BNMS-rotation. About 64% of the respondents had knowledge of the technology through IITA and extension agents. Nineteen percent of the farmers had their own awareness of the BNMS-rotation through other farmers. Over 69% of the sample farmers received extension visit in the last cropping season on the adoption and use of integrated soil fertility technologies. Similarly, field days on the technologies witnessed a large turn-out of the surveyed farmers. About 34% of respondents received extension visits monthly; some were visited weekly (12%) or fortnightly (10%).

3.4 Intensity of use of BNMS-manure

Table 3 shows the results of the tobit model of the adoption and intensity of use of BNMS-manure. The household size variable (*HHSIZE*) has a positive and significant relationship with the adoption and use of BNMS-manure. This finding agrees with OLUOCH-KOSURA et al. (2001) and is supported by findings from the descriptive statistics, indicating that the adopters of the BNMS-manure are from relatively larger farm households. Access to credit (*CREDIT*) positively and significantly influences the adoption and use intensity of BNMS-manure. The probabilities of adoption of the BNMS-manure technique increase as household have more access to formal and/or informal source of credit. We found that household's access to an additional source of credit increased the probability of adoption of BNMS-manure by 11% while a change in farmland area among adopters increased by 0.33 ha. An explanation for this could be that the availability of credit enables households to pay for external hired labor and other expenses incurred in the process of adoption and use of BNMS-manure. This result is in line with previous findings by ZELLER et al. (1998) and OLUOCH-KOSURA et al. (2001), as they show that capital in the form of either accumulated savings or access to capital markets is necessary to finance the uptake of new technologies. In addition, the results of this study shows that total changes in crop areas by new and current adopters as a result of the change in access to credit source were 0.25 and 0.08 ha, respectively. So 76% of the total change in crop areas under the new technology was brought about by new adopters against 24% for existing adopters. Efforts to bring new adopters would be a better strategy to promote adoption of BNMS-manure practice than trying to increase the intensity of use of the technology by existing users.

Asset endowment (*ASSET*) of the household was also found to have a positive and statistically significant influence on the adoption and level of use of BNMS-manure. In this study, livestock and household assets were used as a proxy for liquidity or access to cash. In Northern Nigeria, farmers rely on their own cash sources such as owned assets to invest in innovations such as the BNMS technologies. Each additional unit to the household asset endowment increased the probability of adoption of the BNMS-manure technology for this household by 2.7%, while the crop areas under the new practice increased by 0.08 ha (table 3). The changes in crop areas under BNMS-manure practice were brought through the new and current adopters were 6 and 2%, respectively. So that 75% of the total change was brought about by new adopters against 22% by current adopters. Consequently, the land area under BNMS-manure technology would increase faster if households with higher assets endowment adopted the technology, compared to the area increase that could be brought about through farmers that are already using this cropping practice.

Table 3. Results of tobit model of the adoption and intensity of use of BNMS-manure technology in the NGS

Variable	Maximum likelihood estimate	Change in probability of adoption	Change in intensity of adoption	Total change	Total change via new adopters	Total change via current adopters
Constant	-10.163*** (-5.247)					
AGE	0.022 (0.874)	0.002 (0.876)	0.005 (0.875)	0.005 (0.874)	0.004 (0.874)	0.001 (0.872)
HHSIZE	0.042 (1.032)	0.003 (1.032)	0.010 (1.032)	0.010 (1.031)	0.008 (1.032)	0.002 (1.028)
SOCKAP	0.077 (0.215)	0.006 (0.215)	0.018 (0.215)	0.018 (0.215)	0.014 (0.215)	0.004 (0.215)
OFFINCOME	-0.048 (-0.378)	-0.004 (-0.378)	-0.011 (-0.378)	-0.011 (-0.378)	-0.008 (-0.378)	-0.003 (-0.378)
LIVESTOCK	0.021 (0.375)	0.002 (0.375)	0.005 (0.375)	0.005 (0.375)	0.004 (0.375)	0.001 (0.375)
CREDIT	1.425** (2.135)	0.110** (2.124)	0.331** (2.136)	0.328** (2.117)	0.252** (2.124)	0.076** (2.085)
EDUCATION	0.004 (0.066)	0.000 (0.066)	0.001 (0.066)	0.001 (0.066)	0.001 (0.066)	0.000 (0.066)
PERCEPTION	2.709*** (2.967)	0.210*** (3.070)	0.630*** (3.026)	0.623*** (3.039)	0.478*** (3.042)	0.145*** (3.001)
EXTENSION	0.293 (0.496)	0.023 (0.496)	0.068 (0.496)	0.068 (0.496)	0.052 (0.496)	0.016 (0.495)
FARMSIZE	0.053 (0.459)	0.004 (0.459)	0.012 (0.459)	0.012 (0.459)	0.009 (0.459)	0.003 (0.458)
ASSET	0.348** (1.968)	0.027** (1.960)	0.081** (1.973)	0.080** (1.962)	0.062** (1.966)	0.019** (1.940)
Log likelihood function	-449					
z	66					
$F(z)$	0.23					
$f(z)$	0.30					
σ	0.26					
Model size (observations)	400					

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

Source: own computation

Farmers' perception of the state of land degradation (*PERCEPTION*) and soil depletion has also a positive and statistically significant effect on the adoption and use intensity of BNMS-manure technology. The probability of adoption of the BNMS-manure technique is higher for farmers who perceive their cropping land as degraded or soil depleted than for households who do not have such perception. This result confirms our expectation and similar findings by SHIFERAW and HOLDEN (1998). An additional unit of the degree of perception of land degradation and soil depletion increases the probability of adoption and the intensity of use of the BNMS-manure technology by 21 and 0.63%, respectively. On average, an increase of the degree of perception of land and soil degradation by one unit stimulates an increase of the crop areas under BNMS-manure practice by 0.61 ha. Changes of the crop area under BNMS-manure technique by new and current adopters are 0.48 and 0.15, respectively. So that about 79% of the total change in cropping areas under BNMS-manure practice is brought about by new adopters. Efforts to increase the total crop areas under BNMS-manure technique through farmers who perceive degradation and/or soil depletion of their farming land should target new adopters of the technology.

Intensity of use of BNMS-rotation

Table 4 shows the results of the tobit model of the adoption and intensity of use of BNMS-rotation farming practice. These results indicated that off-farm income (*OFFINCOME*) was the main variable that significantly influenced the intensity with which the BNMS-rotation was used. A positive and significant relationship was observed between off-farm income and adoption and intensity of use of BNMS-rotation. Households that had non-farm activities to provide them additional income were more likely to adopt BNMS-rotation practice than those who did not earn extra income. This could be that additional income enables households involved in off-farm activities to have better access to improved soybean seeds, which are essential to BNMS-rotation. The FGDs revealed that farmers who have unhindered access to improved soybean seeds (TGx-1448-2E) readily adopted BNMS-rotation.

This result agrees with LAPAR and PANDY (1999) who reported a positive relationship between adoption of soil conservation and non-farm income in the Philippine uplands. In this study we found that each additional Naira earned by the household from non-agricultural activities increased the probability of adoption by 2.9% and the crop area under BNMS-rotation technique by 0.03 ha among adopters. Our results also show that 83% of this change in crop area under BNMS-rotation from income earning was brought about by new adopters of the technology. This indicates that efforts to increase the intensity of use (through increase crop area) of the BNMS-rotation practice should rather target farmers who earn extra income from off-farm and have not yet adopted the technology.

Table 4. Results of tobit model of the adoption and intensity of use of BNMS-rotation technology in the NGS

Variable	Maximum likelihood estimate	Change in probability of adoption	Change in intensity of adoption	Total change	Total change via new adopters	Total change via current adopters
Constant	-1.590** (-2.294)					
AGE	0.011 (1.131)	0.002 (1.135)	0.002 (1.135)	0.002 (1.134)	0.001 (1.134)	0.000 (1.129)
HHSIZE	-0.011 (-0.737)	-0.002 (-0.739)	-0.002 (-0.739)	-0.002 (-0.739)	-0.001 (-0.739)	-0.000 (-0.738)
SOCKAP	-0.088 (-0.525)	-0.016 (-0.526)	-0.017 (-0.525)	-0.013 (-0.526)	-0.010 (-0.526)	-0.003 (-0.525)
OFFINCOME	0.158*** (3.228)	0.029*** (3.408)	0.031*** (3.325)	0.023*** (3.319)	0.019*** (3.334)	0.005*** (3.215)
LIVESTOCK	0.022 (1.103)	0.004 (1.107)	0.004 (1.106)	0.003 (1.105)	0.003 (1.106)	0.001 (1.101)
CREDIT	-0.417 (-1.485)	-0.078 (-1.506)	-0.081 (-1.495)	-0.062 (-1.495)	-0.050 (-1.496)	-0.012 (-1.486)
EDUCATION	-0.017 (-0.753)	-0.003 (-0.756)	-0.003 (-0.755)	-0.003 (-0.755)	-0.002 (-0.755)	-0.001 (-0.754)
PERCEPTION	-0.787*** (-3.072)	-0.147*** (-3.150)	-0.153*** (-3.134)	-0.117*** (-3.094)	-0.094*** (-3.111)	-0.023*** (-2.991)
EXTENSION	0.133 (0.591)	0.025 (0.594)	0.026 (0.592)	0.020 (0.592)	0.016 (0.592)	0.004 (0.592)
FARMSIZE	-0.008 (-0.201)	-0.002 (-0.201)	-0.002 (-0.201)	-0.001 (-0.201)	-0.001 (-0.201)	-0.000 (-0.201)
ASSET	0.039 (0.637)	0.007 (0.638)	0.008 (0.637)	0.006 (0.637)	0.005 (0.637)	0.001 (0.637)
Log likelihood function		-210				
		-24				
		0.15				
		0.23				
		0.12				
Model size (observations)		400				

Note: *** = significant at 1% , ** = significant at 5% * = significant at 10%.
Figures in parentheses represent asymptotic t-ratio.

Source: own computation

Perception of the state of land degradation (*PERCEPTION*) has a negative statistically significant effect on adoption and intensity of use of BNMS-rotation. As farmers get more aware of the state of land degradation and soil depletion of their farming land, they are less likely to adopt BNMS-rotation. The negative sign on the perception of the state of land degradation though unexpected and may be due to negative correlation between this variable and other determinants (e.g., farm size, household size, age) of adoption of BNMS-rotation. The other probable explanation is that farmers would rather adopt the BNMS-Manure as revealed by the results in the preceding section. The BNMS-manure technology is more likely to have a more immediate effect on production through the direct application of inorganic and organic fertilizers.

The estimated coefficient of age of the household head is statistically non-significant though it has the expected positive sign. Household size has also negative and non significant influence on the adoption of BNMS-manure. Social capital has negative and statistically insignificant influence on the adoption of BNMS-rotation. The estimated value of social capital is not expected. The estimated parameters for livestock and assets have a positive but statistically insignificant influence on the use of BNMS-rotation. Farm size has negative and insignificant effect on the adoption and use intensity of BNMS-rotation. The coefficient of extension contact was positive but this factor does not have a statistically significant effect on BNMS-rotation adoption and use intensity. The positive sign is consistent with our expectation which implies that households that had regular contacts with extension would tend more to adopt the BNMS-rotation. As a matter of fact, the focus group discussions have revealed that farmers in the study area were highly dependent on government extension services, which assisted them in developing their awareness of and interest in adoption of improved technologies.

4. Conclusion and recommendations

This study assessed the extent and determinants of adoption and intensity of use of BNMS technologies in northern Nigeria. Results confirmed the importance of extension services 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 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.

Focus group discussions have also made a strong case for the organization of field days as a good strategy for promoting the adoption of BNMS technologies. 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. Discussions in the group meetings also revealed the importance of the concept of farmer-to-farmer diffusion in efforts to scale up and out the BNMS technologies. This concept has worked effectively in northern Nigeria for the dissemination of improved cowpea seeds among farmers (ALENE and MANYONG, 2006). It involves building the capacity of lead farmers by first demonstrating the technologies to them so that they will adopt the technologies themselves, and then training them on what and how they should communicate to others. The farmer-to-farmer diffusion effects are expected to bring about cost-effective knowledge diffusion and financial sustainability that may not be present in other approaches.

The results of the econometric model have indicated the importance of access to credit and household assets endowment in increasing (scaling up/out) the cropping areas under the BNMS-manure technology. Household assets represent an alternative source of credit to the rural dwellers in northern Nigeria that helps in solving liquidity problems. Both household assets and formal and informal credit enable the farmers to have resources needed to buy fertilizer during critical cash scarcity times of the year, settle down payments for fertilizer use, and to hire labor needed for transporting inorganic fertilizer and manure to the farm and applying them on the crops. Policy intervention that institutionalizes micro-finance activities targeting existing adopters of the BNMS-manure technology in the rural area will help solve the problem of low access to credit.

The results of the study have also shown the important role of off-farm income in increasing the adoption and use intensity of BNMS-rotation practice. Extra earnings from off-farm activities helped small-scale farmers overcome serious liquidity constraints in the study area. This off-farm income enables them to buy improved seeds of soybean at times when they face critical liquidity constraints. Therefore, strategies designed to increase off-farm income earning activities should be encouraged. Low rates of market participation are leading correlates of both poverty and low adoption of sustainable agricultural intensification through increased investment in the land (BARRETT and CARTER, 1999; REARDON et al., 1999; PLACE et al., 2005). Major efforts should thus be made to make agricultural commercialization more attractive to small farmers. The promotion of high value agricultural enterprises is one policy direction that is likely to generate increased income and investment in BNMS technologies.

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