# IMPACTS OF BALANCED NUTRIENT MANAGEMENT SYSTEMS TECHNOLOGIES IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

A.A. Akinola [a,*], Arega D. Alene [b], R. Adeyemo [a], D. Sanogo [c], A.S. Olanrewaju [d]

[a] Department of Agricultural Economics, Obafemi Awolowo University, Ile-Ife, Nigeria.

[b] International Institute of Tropical Agriculture, Lilongwe, Malawi

[c] International Development Research Center (IDRC), Dakar, Senegal

[d] International Institute of Tropical Agriculture, Ibadan, Nigeria

[*] Corresponding author: *E-mail address*: AAkinola@cgiar.org; **aakinola2000@yahoo.com**

## ABSTRACT

As part of a major effort to address soil fertility decline in West Africa, a project on balanced nutrient management systems (BNMS) has been implemented in the northern Guinea savanna (NGS) of Nigeria. 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 two-stage least squares regression models to examine the socioeconomic impacts of the BNMS technologies on household incomes and food security of the adopting farmers. Results showed that average crop yields for maize, sorghum, and soybean increased by more than 200% in the villages covered by the project. Among the adopters, the gross margin per ha from maize production was highest for the adopters of BNMS–rotation and lowest for adopters using inorganic fertilizer only. The two-stage least squares regression estimates indicated that increases in farm income due to adoption of BNMS technologies led to an increase of both calorie and protein intake of adopters. An additional one ha of land under BNMS–manure stimulates an increase in food expenditure by about 52%, while a similar change in land area under BNMS–rotation increases food expenditure by 128%.

*Key words: BNMS–manure, BNMS–rotation, northern Guinea savanna, Nigeria, West Africa.*

## 1. INTRODUCTION

Poverty, food insecurity, and poor nutrition have been identified as persistent problems plaguing the low productive semi-subsistence farming population of many developing countries, especially in northern Guinea savanna (NGS). The NGS covers an area of about 40.6 million hectares in west and central Africa. It is characterized by a length of growing period (LGP) of 151–180 days. Major soils in the agro-ecological zone are Luvisols (36%), Vertisols (12.2%), Lithosols (11.3%), Regosols (8.7%) and Ferralsols (8%) (Jagtap 1995)) The situation in northern Nigeria is particularly aggravated by severe soil degradation and nutrient depletion that has serious implications for agricultural productivity and general livelihood conditions in the area. Concerted efforts at addressing the soil degradation problem have been seen as a major step to improving people's livelihood and wellbeing in NGS of Nigeria.

Many economists and policy makers view improving household income as an entry point to reducing food insecurity. This view holds if higher incomes through technical change translate into better food consumption and nutrient intake as food-based approaches to combating macro- and micro-nutrient deficiencies are often more sustainable than supplementation (Neumann et al. 1993). According to von Braun (1988), agricultural growth via technological transformation leads to expanded food supply which is central to food security. One such conceivable food-based route, especially among rural farmers, involves technical change to increase yield and output.

Based on the foregoing, a project on integrated soil fertility management known, as the Balanced Nutrient Management System (BNMS) project, was initiated in 1997 in northern Nigeria. The project was a collaborative effort between the International Institute of Tropical Agriculture (IITA) and the Katholieke Universiteit, Leuven (KU Leuven). The BNMS project has a general objective of curbing the vicious cycle of plant nutrient depletion in maize-based farming systems through increased yields and income in order to improve food security and rural livelihoods in the area. Amongst the soil fertility technological options tested through the BNMS project, two have emerged as breakthroughs. These options are (1) the combination of organic and inorganic inputs that allows a saving of about 50% of the cost of inorganic fertilizer (Vanlauwe et al. 2001), and (2) the use of less available P or rock P by grain and/or herbaceous legumes that appear to have more efficient mechanisms 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 called BNMS–soybean/maize treatment (BNMS–rotation).

Although the superiority of BNMS technologies has been established in terms of yields (Iwuafor et al. 2002; Wallys 2003; Ugbabe 2005), it is noteworthy that a better yield from any technology does not necessarily translate to a higher income and asset endowment due to certain factors that condition income generation. One of such significant conditions is cost. Two technologies might give the same yield but different incomes because of costs incurred on factors employed in operating such technologies. Farmers' adoption decisions and the subsequent impact on their livelihoods are conditioned by assumed maximization of expected returns subject to such conditions (Rahm and Huffman 1984). Results from adaptation and demonstration trials showed that BNMS technologies gave a higher gross margin than either SG2000 approach characterized by singular application of inorganic fertilizer or farmers' practice. However, it is not known whether these results also hold at the farm level following dissemination of the BNMS packages.

Whether economic gains brought about by technical change through technological adoption in agriculture work their way through to the poor is still debated. Normally, adoption stimulates agricultural growth, improves employment opportunities, and expands food supply—all central to the alleviation of poverty (Binswanger and Haddad 1990). Apparently, BNMS technologies should bring benefits in terms of better livelihoods to the poor if accompanied by appropriate policies. The main objective of the study based on the foregoing is to assess the impact of BNMS technologies in northern Nigeria. The specific objectives are to:

(i) Compare the yields of major crops grown in the study area over the years,

(ii) Compare the effects of BNMS technologies on yields with inorganic fertilizer and traditional on practice,

(iii) Assess the impacts of the BNMS technologies on farm income incomes, and

(iv) Assess the impacts of the BNMS technologies on food security and poverty level

The remainder of this paper is organized as follows. The next section discusses the development and dissemination of the BNMS technologies. This is followed by the presentation of the models used in the study. Section four discusses the data and the empirical procedures for the models used. The study results are reported in section five. The last section presents the recommendations and conclusion of the study.

## 2. BALANCED NUTRIENT MANAGEMENT SYSTEMS TECHNOLOGIES IN THE NGS OF NIGERIA

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 in addition to adequate, affordable amounts of inorganic fertilizers, it is possible to improve soil fertility and thereby increase the yield potential of soils in Africa. In pursuance of the targeted goals of BNMS, trials (both demonstration and adaptation) were sited in three extension zones (Maygana, Lere and Birni Gwari) of the NGS. Nine villages participated in the program: four in Maygana zone, three in Lere and two in Birni Gwari. All the villages were situated in the area known as NGS benchmark (A benchmark has similar socio-economic characteristics with ease of completion of project and extrapolation to other part of the NGS) 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 lin the Lere Zone. Birni Gwari zone villages are Kufana and Buruku.

In 2000, the first farmer-managed on-farm trials were established in the NGS. These trials were set up by IITA in collaboration with the Institute of Agricultural Research (IAR), Zaria, and SG2000. The SG2000 and the State Agricultural Development Projects (ADPs) have been promoting a maize package to farmers consisting of the use of hybrid seeds, proper plant density and fertilizer application practice (Wallays 2003). Thereafter, many on-farm trials have been done in collaboration with farmers in the area. The dissemination of the technologies has been successful, with farmers adopting them rapidly.

## 3. THEORETICAL MODELS OF IMPACT OF BNMS TECHNOLOGIES

An important factor in impact measurement is the problem of endogenous explanatory variables. Variables that are endogenous to adoption may influence food security levels, but be unobserved by the econometrician, and thus be correlated with the error term in the regression and cause a bias. The common approach to address these problems is to use instrumental variables (IV) or two–stage least squares (2SLS) estimation.

Suppose $Y_i = \alpha + \beta p_i + \gamma X_i + \mu_i$ (1)

Where:

$y_i$ = welfare indicator,

$p_i$ = Adoption indicator,

$X_i$ = a vector of factors expected to influence $y_i$,

$\gamma$ = a vector representing the marginal impacts of each component $x_i$ on $Y_i$.

Use of IV could remove the correlation effect between $Y_i$ and $\mu_i$ in the above equation. Three steps are involved: (i) Finding variables that are good predictors of $p_i$, but are not correlated with $\mu_i$; (ii) Using those variables to obtain predicted $p_i$ values that are uncorrelated with $\mu_i$; and (iii) Regressing predicted $p_i$ on $Y_i$.

A special case of IV estimation, 2SLS, where $p_i$ a continuous variable is predicted by a first stage least squares regression and the instruments are chosen ‘optimally’ to minimize the asymptotic variance of the estimator Amemiya 1984). However, if $p_i$ is not continuous (e.g., if it is a binary response variable), then it may be predicted using a limited dependent variable model, such as Probit or logit (Pender 2005). In the same way, $p_i$ may also be predicted by using a Tobit model. These methods are employed in this study to analyze the impacts of BNMS technologies on yield, income, food expenditure and poverty level.

The general consumption model is stated as:

$$Q_{ih} = f(Y_h, P_i, P_j .........P_z, H_h, T_h) \quad (2)$$

Where $Q_{ih}$ is the quantity of the commodity $i$ consumed by household $h$ (for a given time); $Y_h$ is the income for household $h$; $P_{i;}$ is the price of price commodity $i$; $P_j \ldots P_z$ represent prices of other commodities $j$ to $z$ that might influence (significantly) the consumption of $i$; $H_h$ is the household size, age, and/or sex distribution); and $T_h$ represents household tastes (perhaps captured by educational, regional, ethnic, and occupational variables) that may influence access the to quantity of the commodity required.

**Conceptual framework**

The framework for this study was adapted from von Braun (1988) and DFID sustainable livelihood framework (http://www.livelihood.org/info) and is shown in Figure 1. The analysis concentrates on the following four key linkages:

Adoption of the BNMS technologies comprising various combinations of inorganic fertilizer and organic manure in different forms to household grown crop (maize).

The reallocation of assets and inputs (labor, seed, land, etc.) as a consequence of adoption of BNMS technologies, resulting in improved yield and income of the household.

The food consumption effects of increased productivity and income deriving from technical change and related changes in yield and income.

The overall effects on poverty level which are manifest in increased livelihood assets (human, physical, social, financial and natural).

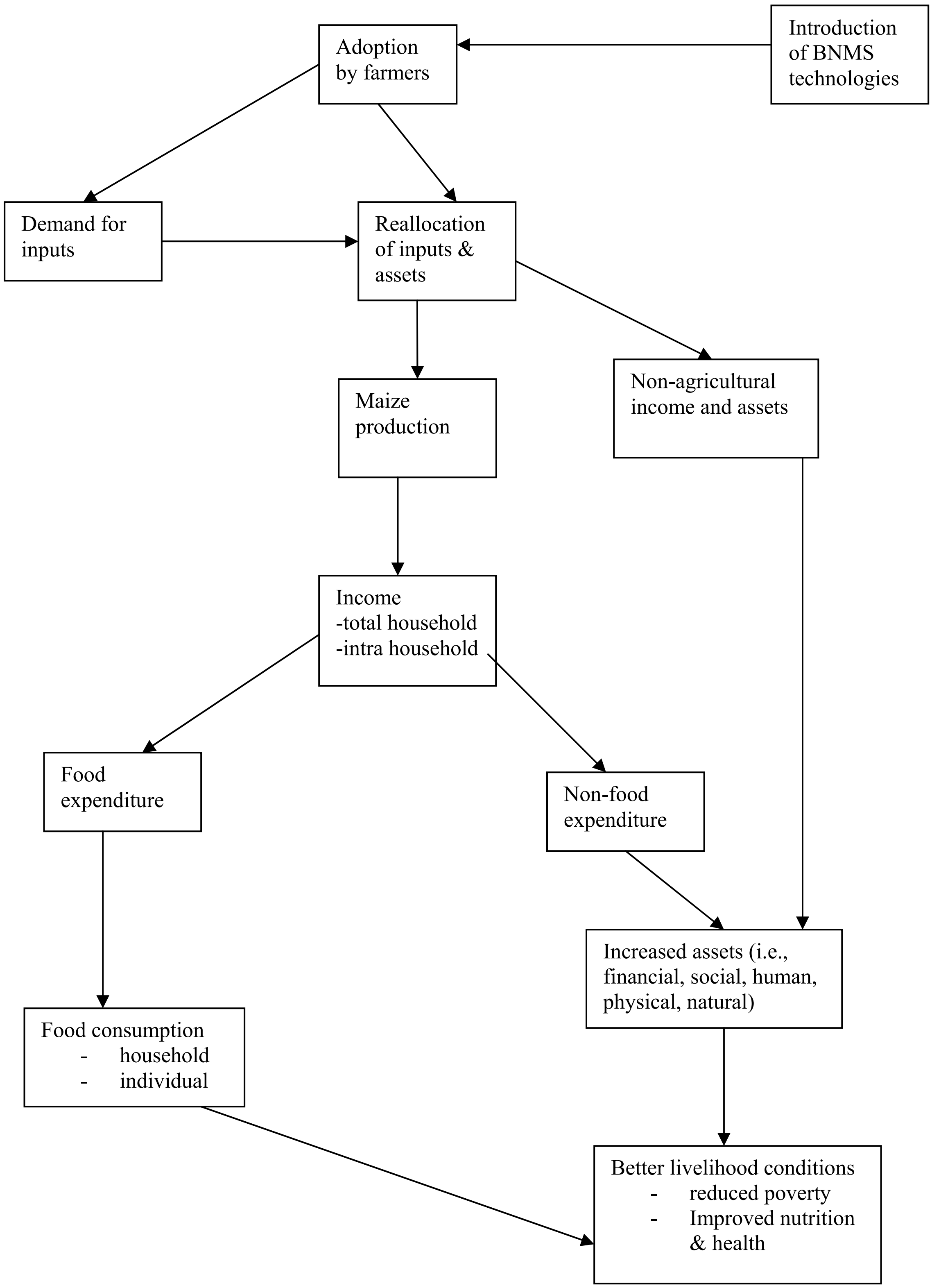


**Figure 1: Structural framework for the study**

## 4. DATA AND EMPIRICAL PROCEDURES

Demonstration and adaptation trials were sited in three agricultural zones of Maygana, Birni Gwari and Lere. These three agricultural zones were purposively selected. The villages in the three agricultural zones are Fatika, Kaya, Danayamaka, Buruku, Kufana, Kayarda Kadiri garo and Kroasha. Consequently, these eight villages were purposively selected for this study. The share of random selection in respective villages was as follows- Fatika (18.5%), Kaya (23.5%), Danayamaka (9.25%), Buruku (18.75%), Kufana (5.75%), Kroasha (6.25%), Kadiri Garo (9%) and Kayarda (9%). Four hundred household heads were interviewed during a household level survey using a well-structured questionnaire. Community-level surveys were also conducted using focus group discussions (FGDs). Data collected during these surveys were completed by baseline data collected in 1997 at the beginning of the project. Descriptive statistics analysis, benefit–cost analysis and econometric models (using SPSS 11 and LIMDEP software) were employed.

### Food Security Models

Calorie and protein consumption and food expenditure were used as proxies for measuring food security. A calorie/protein consumption model was specified and estimated for the 2005 cropping season in the NGS. The dependent variable is the total calorie/protein consumption per capita per day. The natural log of calorie/protein was used for better approximation into normal distributions. Consumption consists of household produced and purchased food whether raw, boiled, roasted or fried. Technological change via the BNMS may impinge on food consumption through its effects on income, local prices and determinants mediated via the control over and pattern of the income stream in the household.

We hypothesized the following conventional demand theory, that calorie/protein consumption is determined by age (*AGE*), education in the household, price (maize price (*MZPRICE*)—being the major crop in the area, household size (*HHSIZE*), income-total expenditure (EXP), income squared, proportion of cash, and asset. Total expenditure was used as a proxy for income and the natural logarithm of expenditure (*LNEXP*) and expenditure squared (*LNEXPSQ*) were used. Education was disaggregated into household head education status (*EDUCATION*), the number of adult males (*SECONDM*) and females (*SECONDF*) that had attended secondary school.

Secondary school was used in the disaggregation because significant numbers of the households (over 95%) did not have tertiary education.

We hypothesized that the age and education of the household had a positive consumption effect. As people grow older they consume more. Education gives the educated higher leverage in the society and thereby better access to food. Price is hypothesized to be positively related with calorie/protein consumption because farmers in the NGS were net sellers of maize. Maize was a cash crop in the area. The income effect of price change is expected to be greater than the substitution effects, making the farmers more food secure as a result of higher income. Income squared is used because we assume a non-linear relationship between consumption of calorie/protein and income which estimates first increases until after a point when decline sets in. Asset (*ASSET*) here refers to readily cash-convertible possessions of the household that can be used for the consumption of calorie/protein. Finally, we hypothesized that an increase share of income in the form of cash (*PROPCASH*) reduces the consumption of calorie/protein when income level is controlled. Readily fungible cash may end up in non-food expenditure or more luxury purchased foods than subsistence food income (von Braun, 1988).

The stated hypotheses led us to the following model specification with each household:

$$\begin{aligned} LNCALORIE / LNPROTEIN &= \alpha_0 + \alpha_1 AGE + \alpha_2 EDUCATION + \alpha_3 SECONDM \\ &+ \omega_4 SECONDF + \omega_5 MZPRICE + \omega_6 HHSIZE + \omega_7 LNEXP + \omega_8 LNEXPSQ \\ &+ \omega_9 PROPCASH + \omega_{10} ASSET + u_i) \end{aligned} \tag{3}$$

The approach used in studying the determinants of food expenditure in the NGS is based on modeling the natural logarithm of total/food daily per capita consumption expenditure—our welfare indicator—of survey households. We use the logged welfare indicator for better approximation to a normal distribution. The models' specifications are as follows:

$$LnC_j = \lambda m_j + \gamma Y_j + n_j \quad \text{and}$$

$$Y_j = \beta X_i + \mu_i, \tag{4}$$

Where $C_j$ is the total daily per capita consumption of household $j$ in Nigerian Naira, $m_j$ is a set of exogenous determinants that include household and community characteristics, $n_j$ is a random error term (Mukherjee and Benson 2003). $Y_i$ are the predicted values from Tobit in the second stage OLS regressions. Because of the endogenous nature of $Y_i$ in $C_j$, the use of instrumental variables is imperative and a special case of instrumental variables called 2SLS was employed. The IVs used in these models were perception, access to credit, and social capital. It is expected that the perception of the state of land degradation would motivate farmers to use land-improving technologies but not yield or farm income. Perception influence is direct on adoption of BNMS technologies. Access to credit is also expected to determine the adoption and use intensity of BNMS technologies but not productivity or profitability.

According to Pender (2005), where market do not function well, community- and household-level socio-economic characteristics may influence households' decision about BNMS technologies and use of agricultural inputs, and such factors often can be used as instrumental variables, since these may not influence productivity directly. Credit is a community- and household-level factor whose access by farmers has been observed to be extremely limited and inadequate in northern Nigeria (Alene and Manyong 2006). Hence, it is justified as an IV. In the same way, social capital is also a community- and household-level characteristic that determines the adoption decisions of BNMS technologies and not productivity or profitability. Place et al. (2005) used a similar approach in analyzing the impact on the poor in Westtern Kenya of fertility replenishment practices based on agro-forestry.

For the dependent variable, the natural log of total food per capita consumption and expenditure was used. This variable (unlogged) was made up of total food consumption, whether purchased or produced in any form by the household. The set of regressors ($m_j$) chosen as possible determinants of poverty included factors related to demography, education, and asset endowment, and access to services and utilities. Demographic characteristics include age (*AGE*) and household size (*HHSIZE*). Square of household size (*HHSIZESQ*) was also included because a non-linear relationship was assumed between household size and welfare levels. Educational variables used are the education level of the household head (*EDUCATION*), the number of males that attended secondary school (*SECONDM*) and the number of females that attended secondary school (*SECONDF*).

Asset endowment-related factors include per capita land (*PCLAND*), per capita livestock (*PCLIVESTOC*K) measured in Tropical Livestock Units, crop diversification (*CROPDIVERT*) measured as the number of crops grown apart from maize and household asset values (ASSET) measured in natural logarithm. Access to services and utilities were proxied by distance to the main market (*MARKETD*) and health centre (*HEALTHD*) measured in km. The technology-related factors obtained from first stage adoption model of Tobit were *B1AREA* and *B2AREA*, which are the predicted values for areas in ha under BNMS–manure and BNMS–rotation respectively. $\tau_i$ is the stochastic error terms. The empirical model for food expenditure is stated thus:

$$\begin{aligned} LNEXP = {} & \psi_0 + \psi_1 AGE + \psi_2 HHSIZE + \psi_3 HHSIZESQ + \psi_4 SECONDM + \\ & \psi_5 SECONDF + \psi_6 EDUCATION + \psi_7 MARKETD + \psi_8 HEALTHD + \\ & \omega_9 PCLAND + \psi_{10} OFFINCOME + \psi_{11} CROPDIVERT + \psi_{12} PCLIVESTOCK + \\ & \psi_{13} ASSET + \psi_{14} B1AREA + \psi_{15} B2AREA + \tau_i \end{aligned} \quad (5)$$

All variables with the exception of *HHSIZESQ* were hypothesized to have positive relationship with welfare levels. *HHSZESQ* is expected to be negative (Mukherjee and Benson 2003). The model was then analyzed with OLS estimating method.

## 5. RESULTS AND DISCUSSION

### Socio-economic characteristics of sample households

The average age of all respondents in the study was 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 the 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, the average age of non-adopters is 50 years.

The overall average literacy rate is 46.3% and the literacy rate of technology adopters (43.3–48.4%) was higher than that of non-adopters (33.3%). Among the adopters, the adopters of BNMS–manure had the highest level of literacy followed by adopters of inorganic fertilizer only and the adopters of BNMS–rotation. The overall average years of formal education completed by household heads were 7.6 years. The average number of years of formal education completed by technology adopters (7.3–8 years) was higher than the average number of years completed by non-adopters (5 years). Altogether, technology adopters were younger and more educated than non-adopters (See Table 1). 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) was 3.5/household. Among the adopters, the average adult male (>15) is highest for the adopters of BNMS–manure (3.7/household) followed by adopters of BNMS–rotation (3.9/household) and adopters of inorganic fertilizer only (3/household). Non-adopters have fewer adult males (>15) per household than the adopters.

**Table 1: Demographic and socio-economic characteristics of farmers (mean)**

| | 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 household 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 years | 2 | 3.3 | 3.7 | 3.6 | 3.5 |
| Total livestock units | 1.2 | 3 | 4.12 | 3.9 | 3.5 |
| Farm distance (km) | 3 | 4.5 | 4.8 | 5.4 | 4.7 |

Source: Own survey.

The average household (TLU) in the study area is 3.5. Adopters of BNMS–manure would require livestock to produce manure, consequently findings showed that they had the largest

TLU (4.12), followed by adopters of BNMS-rotation (3.9) and adopters of inorganic fertilizer only (3). Non-adopters of BNMS technologies have the smallest TLU (1.2).

**Yield analysis of BNMS technologies**

Crop yields are important markers for food security and the opportunity to obtain cash income for the farmer households. It is a function of a number of factors, both endogenous and exogenous. Furthermore, it is an indicator of how resources (inputs) are efficiently allocated and utilized for agricultural productivity. Many studies have pointed out that crop productivity is declining in the NGS of Nigeria as a result of poor soil fertility, inadequate use of soil amendments, parasitic weeds, drought, lack of improved technologies and scarcity of agricultural inputs (for example, Chianu et al. 2004). However, a comparison of the results obtained before and after the introduction of the BNMS project showed that average crop yields in the BNMS pilot villages increased substantially for maize (225.9%), sorghum (278.3%) and soybean (266.9%).

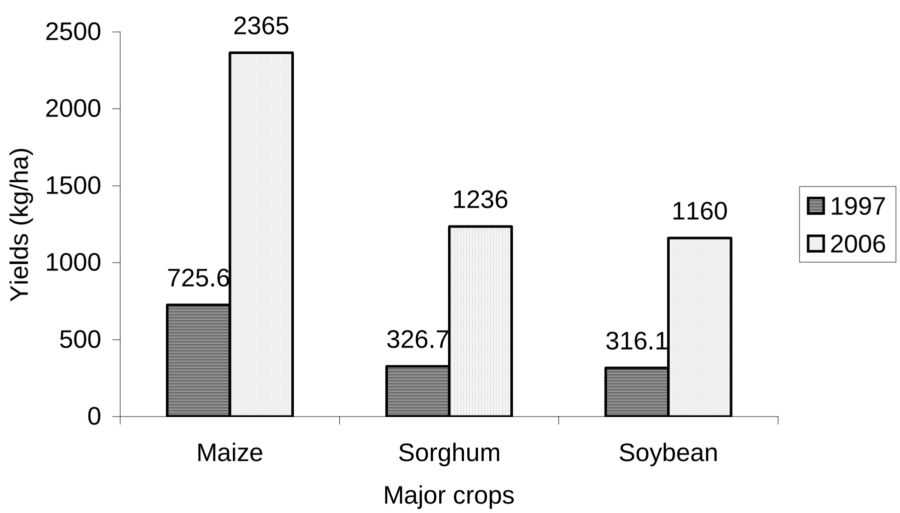


**Figure 2: Relative yields of major crops**

Results of the study showed that there is a wide variation in the average maize yield/ha between adopters of BNMS (2368 kg/ha) and non-adopters (1000 kg/ha). Adopters of the BNMS–rotation obtained a better maize yield/ha (2673.8 kg/ha) than adopters of inorganic fertilizer only (2287.6 kg/ha) and BNMS–manure (2353.8 kg/ha). The average yield of sorghum for the adopters of inorganic fertilizer only was 1.21 t/ha; BNMS–manure, 1.25 t/ha and BNMS–rotation, 1.32 t/ha while non-adopters of BNMS technologies got a comparatively low level of 0.84 t/ha. The result obtained on soybean also indicated that average yield of soybean for adopters was far better than that of non-adopters.

**Gross margin analysis of BNMS technologies**

All the inputs used in production were taken into consideration in the gross margin analysis. The inputs were fertilizer, manure, labor and seed. Inorganic fertilizer was sold in a 50 kg bag. The commonest one used by farmers was NPK (15-15-15), which cost about ₦2500.00 per bag, which implies ₦50.00 per kg. Manure, on the other hand, in a 100 kg bag costing ₦100.00 per bag, which means one kg of manure cost ₦1.00. Labor wages included the cost of land preparation, tillage, ridging, manure and inorganic fertilizer application and all other operations involved until harvesting of maize and other crops.

The wage for one man-day of labor ranged from ₦150.00 to ₦300.00 with an average of ₦200.00. Maize seeds cost between ₦40.00 to ₦50.00 per kg. Soybean and cowpea seeds in some places cost up to ₦60.00 per kg. Where no direct costs were available, the opportunity costs were used. This was particularly the case of household labor which was the major source of labor in the study area. A summation of all the costs incurred in each practice gave the total variable costs. Total value of crops was calculated by multiplying the price at the end of the harvest by the yield level. For example, one kg of maize, on average, cost N40. 00, rice ₦35.00, millet and sorghum ₦32.00.

Table 2 shows that, on average, the total variable cost on maize by adopters of inorganic fertilizer only was ₦28, 600. The total variable cost incurred by adopters of BNMS–rotation was ₦26, 100 and BNMS-manure was ₦27, 300.00 while it was ₦28, 100 for the adopters of inorganic fertilizer only. The variable cost incurred by a non-adopter was ₦54, 500. On the other hand, the mean value of maize per hectare was ₦93, 700 for the entire sample. However, with respect to adoption typology, the values were ₦107, 000 for BNMS-rotation, ₦94, 200.00 BNMS-manure and ₦91, 500 inorganic fertilizer.

These invariably gave gross margin/ha of maize for adopters of BNMS–rotation (₦80, 900), BNMS–manure (₦66, 900), inorganic fertilizer (₦63, 400). For non-adopter, the gross margin was negative. The low value of gross margins of non-adopters shows the gravity of land depletion in the study area. This implies that if appreciable gross margin is desired, then the use of land-enhancing technologies is essential. Nevertheless, Table 2 shows that the BNMS–rotation gave the best gross margin while there was no significant difference between the adopters of BNMS–manure and inorganic fertilizer only. These findings agree with Ugbabe (2005) where BNMS–rotation was seen as the best option for farmers. However, for all crops put together, there was no significant difference between the gross margins given by the land-improving technologies. This agrees with the findings of Wallys (2003) that said that the technologies are being promoted as a basket of options to farmers where farmer can choose any.

**Table 2: Gross margin analysis**

| | Adoption typology | | | | |
|---|---|---|---|---|---|
| | Non-adopter | Inorganic fertilizer only | BNMS–manure | BNMS–rotation | All sample |
| Value of crop (₦ '000) | | | | | |
| Maize | 7.9 | 205.6 | 281.1 | 220.1 | 228.1 |
| All crops | 188.8 | 332.7 | 372.5 | 347.4 | 345.2 |
| Variable costs (₦ '000) | | | | | |
| Maize | 81.8 | 65.7 | 76.0 | 58.7 | 67.6 |
| All crops | 80.1 | 77.0 | 85.1 | 80.5 | 80.1 |
| Gross margin (₦'000) | | | | | |
| Maize | -73.9 | 139.9 | 205.1 | 169.4 | 160.5 |
| All crops | 108.7 | 255.7 | 287.4 | 266.9 | 265.1 |
| Value of crops per hectare (₦'000/ha) | | | | | |
| Maize | 13.2 | 91.5 | 94.2 | 107.0 | 93.7 |
| All crops | 86.4 | 105.4 | 110.4 | 109.4 | 107.3 |
| Variable costs per hectare (₦'000/ha) | | | | | |
| Maize | 54.5 | 28.1 | 27.3 | 26.1 | 28.6 |

| | | | | | |
|---|---|---|---|---|---|
| All crops | 46.1 | 32.4 | 32.8 | 34.5 | 33.1 |
| Gross margin per hectare (₦'000/ha) | | | | | |
| Maize | -41.3 | 63.4 | 66.9 | 80.9 | 65.0 |
| All crops | 40.2 | 73.1 | 77.6 | 74.9 | 74.3 |

Source: Own survey.

**Marginal rate of return (MRR), residuals and benefit-cost (B-C) ratios**

Marginal analysis helps to reveal how the benefit from an investment increases as the amount invested increases. A farmer who changed from farmers' practice (non-adopter of any land enhancing technology) to the practice of inorganic fertilizer only has MRR of return of 397%, while the farmer that changed to BNMS–manure has MRR of 398 % while the farmer that changed to BNMS–rotation has MRR of 430 %. This means that the farmers every ₦1 invested in inorganic fertilizer and its application in moving from non-adopter to adopter of inorganic fertilizer only, the farmer recovered the ₦1, and obtained an additional ₦2.97.Every ₦1 invested in manure and its application in the practice of BNMS–manure in moving from non-adopter to adopter of BNMS–manure, delivered an additional ₦2.98. Similarly, an additional ₦1 invested in labor, seeds and other activities in BNMS–rotation as the farmer moved from non-adopter category to adopter of BNMS–rotation, delivered an additional ₦3.30. Though the full potentials of the technologies have not been realized as indicated by MRR to BNMS–rotation (1233%), BNMS–manure-free (717%), and SG2000 (490%) by Ugbabe (2005) the technologies are still profitable to the farmers. To make further recommendation from a marginal analysis, it is necessary to estimate the minimum rate of return acceptable to the farmers.

A farmer's acceptable minimum rate of return (AMRR) is estimated by the sum of the cost of capital and the returns to management. Alimi and Manyong (2000) estimated the cost of capital with regard to maize production in Nigeria. They assumed that the interest rate on informal loans in Nigeria varied from 3 to 10%/month, and that the gestation period of maize (the period between farm land preparation and realization of income from maize output) was 6 months. If the interest, the cost of capital is 18% (3%/month x 6 months), and it is 60% (10%/month x 6 months) if the interest is 10%.

The second thing that has to be estimated is the return to management. An estimation of 65% is realistic. In this case, the AMRR will be 83% for 3% and 125% for 10% interest rate per month. Assuming that a significant proportion of farmers obtained loans at 10%, then an AMRR of 125% is retained for further analysis. This AMRR is an estimate, and because the value is less than that obtained from the practices, there is no problem with the accurateness of the estimation. These results agree with Mekuria and Waddington (2002) in Zimbabwe, Place et al. (2002) in Kenya and Wallys (2003) in the NGS of Nigeria, indicating the higher productivity of BNMS compared with inorganic fertilizer only. The higher productivity of BNMS–rotation compared with BNMS–manure is in conformity with Ugbabe (2005). The conclusions of marginal analysis were checked by using the concept of residuals. Residuals can be calculated by first multiplying the total variable costs by the farmers' AMRR of 125% for each practice to obtain the acceptable minimum returns for the practice. By subtracting the return that the farmer requires from the net benefits, the residuals are calculated. The residuals were ₦28, 275 for inorganic fertilizer only, ₦32, 775 BNMS-manure and ₦48, 275 BNMS-rotation. Benefit-cost ratio for non-adopters was 0.75, inorganic fertilizer only was 2.26, BNMS–manure was 2.45 and BNMS–rotation was BNMS–rotation was 3.09.

**Welfare indices**

Findings from this study showed that the overall average total expenditure/capita/day for the sample was ₦192. Among the adopters of BNMS packages, the average total expenditure/capita/day was highest for the adopters of BNMS manure (₦203), followed by the adopters of inorganic fertilizer only (₦189) and the adopters of BNMS rotation (₦188). For non-adopters, the average total expenditure/capita/day was ₦116. Furthermore, the overall average total income/capita/day for the sample was ₦98. Among the adopters of BNMS packages, the average total income/capita/day was highest for the adopters of inorganic fertilizer only (₦102), followed by the adopters of BNMS-manure (₦99) and the adopters of BNMS rotation (₦87). For non-adopters, the average total income/capita/day was a meager ₦42.

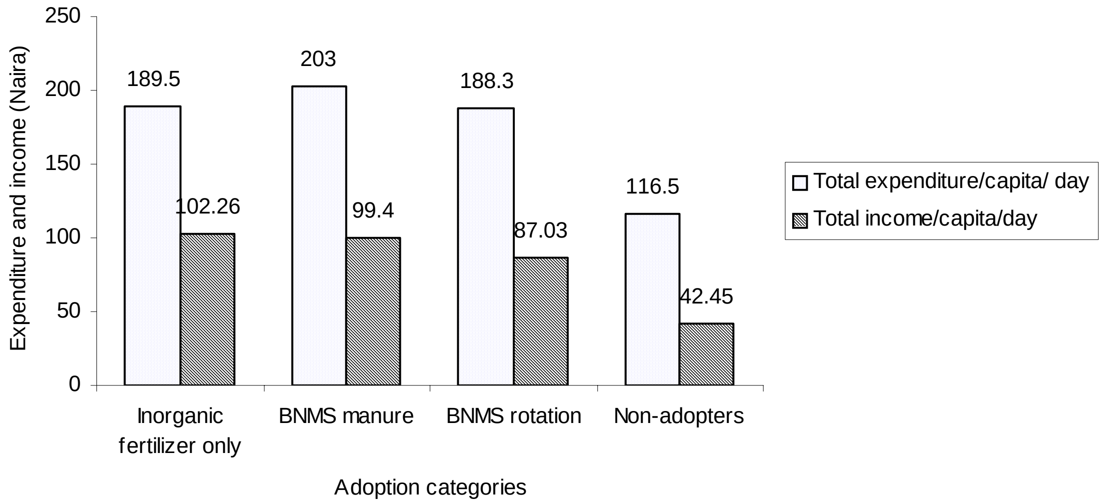


**Figure 3: Households' expenditure and income per capita/day**

The mean food consumption in the study area was 2440 kcal/capita/day. The amounts consumed by adopters of BNMS technologies were 2544 for inorganic fertilizer only, 2377 BNMS-manure and 2307 kcal/capita/day. On the other hand, per capita calorie consumption for non-adopter was 1633 kcal/capita/day. Per capita protein consumption per day was 26.7 g for inorganic fertilizer only, 25.8 g BNMS-manure, 23.6 g BNMS-rotation. It was 19.1 g for non-adopters. Total expenditure per capita per day was about N200 for adopters of BNMS technologies while it was ₦117 for non-adopters. With the poverty line of ₦128 ($1), about 67% were still poor among non-adopters. However, level of poverty among different categories of BNMS adopters were 41% in inorganic fertilizer only, 35% BNMS-manure, 42% BNMS-rotation.

**Econometric results**

**Food consumption and expenditures**

Table 3 presents the regression results of the determinants of calorie and protein consumption per capita per day. It reveals that calorie/protein consumption per capita per day is significantly income elastic. This is very important and agrees with our expectation that technical change through technological adoption is manifested through improved income increased calorie/ protein intake. As income increased through the increased area under BNMS technologies, calorie/protein intake increased. An additional ₦1 increased in farm income by the use of BNMS technologies increased calorie and protein intake by 5. However, with increased income the increase in calorie/protein consumption is reduced, as indicated by the negative parameter estimated for the squared term. This implies that there was no significant difference between the manner the households with increased income consumed calorie/protein and households whose income did not increase. Calorie and protein consumption at this level was being seen as necessities. The finding is in agreement with von Braun (1988). Age was positive and statistically insignificant in influencing calorie and protein consumption. This implies that there was no difference between the calorie and protein consumption of the households headed by young farmers and households headed by old farmers. Education of the household head was positive but not significant. Educational status of the household head did not contribute significantly to calorie and protein consumption. However, the number of adult males who completed secondary school was positive and significant. This indicates that as the numbers of males that attended secondary school in a household increased, calorie and protein intake increased. An increase in the number of people, who attended secondary school by 1 person, raised the calorie consumption by 9% and protein consumption by 7%. Households with young educated males consumed significantly more than households full of illiterates. The negative sign of the female education variable is not expected and might be due to the facts that young females in northern Nigeria are restricted in many things which could negate the roles of education in improving calorie and protein intake.

As expected, an increase in maize price (*MZPRICE*) increases calorie/protein consumption. There was a significant and positive relationship between price of food and consumption. Demand for calorie/protein was price elastic. An increase in maize price by ₦1 increased calorie intake by about 3% and protein by 2%. This might be connected with maize being a cash crop in the area. Adopters of the BNMS-technologies were net sellers. The income effect of price change is greater than the substitution effect. Hence, the higher the price, the more food secure was the households in the NGS. Households consumed increased amount of calorie and protein as price increased. The results are consistent with that of von Braun (1988) regarding rice in the Gambia.

Household size (*HHSIZE*) was negative and statistically significant, implying that an increase in the size of household reduced calorie and protein consumption. As household size increased by one additional member, calorie intake deceased by about 3% and protein by 4%. The result indicates that an average member of a small-sized household relatively consumed more calories than a big-sized household. An increased share of cash income did not—as hypothesized—reduce calorie consumption once household income is controlled. Increased monetization of the economy in this NGS setting appears not to be adverse for food consumption. Calorie consumption per capita per day was positive but not statistically significantly asset elastic.

Table 3 presents the parameter estimates of the regression model for the determinants of food security through food expenditure measure. Since the dependent variable is in natural log form, the estimated regression coefficients measure the percentage change in capita consumption within the household resulting from a unit change in the independent variable. As shown (Table 3) the age of the household (*AGE*) has a negative impact on the food expenditure of the household. This implies those households headed by older individuals, holding all other variables constant, tended to spend less on food than those headed by younger individuals though it was statistically insignificant. Household size, on the other hand, has a negative but statistically significant relationship on the food expenditure of the households. This parameter estimate implies that as the number of people residing in a given household increased, the household food expenditure decreased. However, as indicated by squared household, after getting to a point when the increase in numbers resulted in producing non-dependent household members, food expenditure increased.

In terms of the education variables (*EDUCATION, SECONDM, SECONDF*), the parameter estimates were statistically insignificant but positive except for the female members of the household who completed secondary school (*SECONDF*)which was negative. The attainment of higher level of education by household head and male members would tend to increase the welfare situation. The negative and insignificant estimate of adult female members can reasonably be explained by the fact that households with uneducated young females would tend to spend less on food. Access to utilities—market and heath services—have a negative but statistically insignificant influence. Considering the parameter estimate of per capita land (*PCLAND*), households with higher per capita land, spent more on food expenditure than those with less. In other words, increasing per capita land by one ha in a household raised the food expenditure by about 22%. Off-farm dummy measuring access to off-farm income (*OFFINCOME*), ASSET and per capital livestock (*PCLIVESTOCK*), on the other hand, has negatively insignificant relationship with food expenditure. This implied that what was generated from all non-farm activities and livestock were not being used to raise food consumption expenditure but directed elsewhere. Crop diversification was positive but insignificant.

With respect to BNMS technologies, areas under the BNMS–manure (*B1AREA*) and BNMS–rotation (*B2AREA*) have a statistically significant influence and positive influence on welfare (food expenditure). As expected, technological change through the adoption and use of the BNMS technologies translated into increased food expenditure. Increase in the land area under BNMS–manure by 1 ha increased food expenditure by about 52 % while the same unit increase in the area of land under BNMS–rotation increased food expenditure by over 128%. The results unambiguously indicate that BNMS technologies contributed to increase food expenditure in northern Nigeria.

**Table 3: Econometric results from second-stage regressions of the determinants of food security**

| Variable | Estimates | | |
|---|---|---|---|
| | Calorie | Protein | Food expenditure |
| Constant | 1.22754 | 0.47882 | 4.812*** |
| | (0.902) | (0.400) | (23.767 |
| *AGE* | 0.00088 | 0.00177 | -0.004 |
| | (0.288) | (0.660) | (-1.406) |
| *HHSIZE* | 0.00055 | 0.00124 | 0.006 |
| | (0.076) | (0.194) | (0.982) |
| *SECONDM* | 0.08797** | 0.07020* | 0.041 |
| | (2.132) | (1.932) | (1.141) |
| *SECONDF* | -0.05417 | -0.03351 | -0.031 |
| | (-0.465) | (-0.327) | (0.344) |
| *MZPRICE* | 0.02672*** | 0.01970*** | - |
| | (5.151) | (4.314) | |
| *HHSIZE* | -0.03225*** | -0.03588*** | -0.103*** |
| | (-5.886) | (-7.436) | (-9.757 |

| | | | |
|---|---|---|---|
| *HHSIZESQ* | - | - | 0.00067** |
| | | | (2.272) |
| *LNEXP* | 1.02978** | 1.03287** | - |
| | (2.066) | (2.354) | |
| *LNEXPSQ* | -0.04670 | -0.04866 | - |
| | (-0.965) | (-1.142) | |
| *PROPCASH* | 0.30919 | 0.04995 | - |
| | (0.844) | (0.155) | |
| *ASSET* | 0.02008 | 0.01507 | -0.005 |
| | (1.046) | (0.892) | (-0.248) |
| *MARKETD* | | | -0.001 |
| | | | (-0.578) |
| *HEALTHD* | | | -0.004 |
| | | | (-0.508) |
| *PCLAND* | | | 0.220*** |
| | | | (3.672) |
| *OFFINCOME* | | | -0.115** |
| | | | (1.687) |
| *CROPDIVERT* | | | 0.008 |
| | | | (0.529) |
| *PCLIVESTOCK* | | | -0.006 |
| | | | (-0.076) |
| *B1AREA* | | | 0.520*** |
| | | | (4.118) |
| *B2AREA* | | | 1.283 |
| | | | (2.527) |
| $R^2$ | 0.44 | 0.49 | 0.49 |
| Adjusted $R^2$ | 0.42 | 0.48 | 0.47 |
| F | 30.34 | 37.23 | 24.87 |
| Degree of freedom | 389 | 389 | 384 |

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

Source: Own computation.

## Conclusions and recommendation

In spite of the lower application of inputs that form each technology, the results of this study have demonstrated the superiority of the technologies over the traditional practice as well as the superiority of BNMS technologies over the use of inorganic fertilizer. These can be clearly seen in the yield gap between the adopters of BNMS technologies, inorganic fertilizer and non-adopters. The mean gross margins per hectare for the adopters of BNMS technologies were also significantly different from others. However, the yields are still less than those obtained in on-farm trials. Understanding of these contributions via the BNMS technologies has increased demand for the technologies. In terms of productivity and profitability, BNMS–rotation gave the highest yield per hectare, net benefits, MRR and the residuals. Nonetheless, all the BNMS technologies were profitable in the study area by giving positive gross margins.

The incidence of poverty was still high in the area, particularly among the non-adopters of BNMS and inorganic fertilizer technologies. The poverty line was about $1 per capita per day. Daily calorie intake of non-adopters was far less than the minimum recommended for the country; those of adopters were marginally adequate. However, protein consumption was particularly lower than recommended amount in all categories of adoption typology, though, adopters consumed more than non-adopters. The findings showed that the BNMS technologies contributed to improved food security and thereby poverty alleviation through calorie and protein intake and food expenditure. The results revealed that large households having many young educated members, favored by high price and had adopted BNMS technologies consumed more calorie and protein than others. Such households were more food-secure and therefore more prosperous.

Appropriate policies that create better access for farmers to these technologies at the right time will help to reduce hunger and poverty in the area. Existing land should be used optimally with BNMS technologies to maintain or improve the soil fertility in the area. Since, the probability of increasing the existing land may be difficult. Therefore, concerted efforts must be made to transfer the technologies to other areas in order to eradicate poverty and hunger in northern Nigeria. Negative influence of household size to calorie and protein intake has been indicated by this study. The households in the NGS consist principally of children with many of them living with household heads. This could be caused by little or no understanding of family planning in the area. A policy plan that strengthens the rural health centers with qualified medical practitioners that would educate the farming households on family planning will also help to reduce poverty through a decrease in high dependency ratio in the study area.

**References**

Alene, A. D. and Manyong, V. M. 2006. Farmer-to-farmer technology diffusion and yield variation among adopters: the case of improved cowpea in northern Nigeria. *Agricultural Economics*, Volume 35, pp 203-211.

Alimi, T. and Manyong, V.M. 2000. "Partial budget analysis for on-farm research". *Research Guide No*. 65. International Institute of Tropical Agriculture, Ibadan

Amemiya, T. 1984. Tobit models: A survey. *Journal of Econometrics*, Volume. 24, pp 3-61

Binswanger, H. P. and Haddad, L. J. 1990. *Agricultural commercialization, nutrition and the rural poor: A study of Philipine farm households*. Lynne Riener Publishers, Boulder, Colorado, USA. 191pp.

Chianu, J. N., Tsujii, H. and Kormawa, P .2004. Agriculture in the savannas of northern Nigeria: Pressures, transformation, damage and coping strategies. *Outlook on AGRICULTURE*, Volume 33, No 4, pp247-253

DFID (Department for International Development). 2001. Sustainable Livelihood Guidiance Sheets. www.livelihoods.orgs/info/info_guidianceSheets.htm#6 Greene, W. H. 1998. Microsoft "Econometric software. LIMDEP

IITA and KU Leuven .2003. Achieving development impact and environmental enhancement through adoption of Balanced Nutrient Management Systems by farmers in the West African Savanna (BNMS II). Report No.2 (Annual Report, 2003). A collaborative project between the International Institute of Tropical Agriculture (IITA), the Katholieke Universiteit Leuven (K.U Leuven), the Institut National des Recherches Agricolos, Benin (INRAB), Institut Togolais des Recherches Agricoles (ITRA), and the Institute for Agricultural Research (IAR), Zaria, Nigeria.

IITA. 1996. Ecoregional program for the humid and sub-humid tropics of sub-Saharan Africa-EPHTA: Mechanism for sustainability and partnership in agriculture. (IITA), Ibadan, Nigeria, 29pp.

Iwuafor, E. N. O., Aikou, K., Vanlauwe, B, Diels, J., Sangiga, N, Lyasse, O. Deckers, J, and Merckx, R. 2002. On –farm evaluation of the contribution of sole and mixed applications of organic matter and urea to maize grain production in the savanna. In: Vanlauwe, B., Diels, J., Sanginga, N., and Merckx, R. (eds). *Integrated Plant Nutrient Management in Sub-Saharan Africa*. CABI Publishing, New York, pp.185-197.

Jagtap, S. S. 1995. Environmental characterization of the moist lowland savanna of Africa. In: Kang, B. T., Akobundu, I. O., Manyong, V. M.,Carsky, R. J., Sanginga, N. and Kueneman, E. A. (eds*), Moist savannas of Africa: Potential and constraints for crop production*. Proceedings of an IITA/FAO Workshop held from 19-23 September 1994, Cotonou, Republic of Benin, pp 9-30.

Jahnke, R. 1982. Livestock production systems and livestock development in Tropical Africa. Kieler Wissenschaftsverlag vauk.

Manyong, V.M., Makinde, K. O., Sanginga, N, Vanlauwe, B. and Diels, J. 2001.Fertilizer use and definition of farmers' domains for impact-oriented research in the Northern Guinea Savanna of Nigeria. *Nutrient Cycling in Agroecosystems*, Volume 59, pp 129-141.

Manyong, V.M., Makinde, K. O. and Ogungbile, A. G. O. 2002. Agricultural transformation and fertilizer use in the cereal-based systems of the Northern Guinea Savanna, Nigeria. In: *Integrated Plant Nutrient Management in Sub-Saharan Africa: From concept to practice*. (eds) Vanlauwe, B., Diels, J., Sangiga, N. and Merckx, R. CABI Publishing, pp 75-85.

Mekuria, M. and Waddington, S. 2002. Initiatives to encourage farmers' adoption of soil fertility technologies for maize-based cropping systems in Southern Africa. Pp. 219-234. In: Barrett, C. B., Place, F. and Abdillahi, A. (eds.): *Natural resources management in African agriculture: understanding and improving current practices*. CABI, Wallington, UK.

Mukherjee, S. and Benson, T. 2003. The determinants of poverty in Malawi, 1998. *World Development.* Volume 31, pp 339-358.

Neumann C., Bwibo, N. O. and Sigman M. 1993 *Diet quantity and quality: Functional effects on rural Kenyan families*. Kenya project final report, phase 11—1989-1992. Human Nutrition Collaborative Support Program, Office of Nutrition, USAID, Washington, DC, USA

Pender, J., Gebremedhin, B, Benin, S. and Ehui, S. 2001. Strategies for sustainable development in the Ethiopia highlands. *American Journal of Agricultural Economics* 85(5), pp1231-

1240.

Pender, J. 2005. Econometric methods for measuring natural resource management impacts: Theoretical issues and illustrations from Uganda. In *CAB International 2005*; Natural Resource Management in Agriculture: Methods for assessing Economic and Environmental Impacts (eds) B. Shiferaw, H. A Freeman and S.M Swinton. Pp 127-154.

Place, F., Franzel, S., Dewolf, J., Rommelse, R., Kwesiga, F., Niang, A. and Jama, B. 2002. Agroforestry for soil fertility replenishment: evidence on adoption processes in Kenya and Zambia. Pp. 275-286. In: Barrett, C. B., Place, F. and Abdillahi, A. (eds.): *Natural resources management in African agriculture: Understanding and improving current practices*. CABI, Wallington, UK.

Place, F., Adato, M., Hebinck, P. and Omosa, M. 2005. The impact of agro forestry-based soil fertility replenishment practices on the poor in Western Kenya. *IFPRI: Research Report* 142, pp 165.

Rahm. M. R. and Huffman. W. E. 1984. The adoption of reduced tillage: The role of human capital and other variables. *American Journal of Economics*, pp 405-413.

Sanginga, N., Dashell, K. E., Diels, J., Vanlauwe, B., Lyasse, O., Carsky, R. J., Tarawali, S., Asafo-Adjei, B., Menkir, A., Schulz, S., Singh, B. B., Chikoye, D., Keatinge, D., Ortiz, R. 2003. Sustainable resource management coupled to resilent germplasm to provide new intensive cereal−grain−legume−livestock systems in the dry savanna. *Agriculture Ecosystems & Environment* 100, pp 305-314

Ugbabe, O. O. 2005. Economic analysis of Balanced Nutrient Management Technologies for maize production in Kaduna state, Nigeria. MSc thesis submitted to Ahmadu Bello University, Zaria. Pp 66.

Vanlauwe, B., Diels, J., Sanginga, N., Carsky, R. J, Deckers, J. and Merckx, R. 2000. Utilization of rock phosphate by crops on a representative sequence in the Northern Guinea Savanna zone of Nigeria: response by maize to previous herbaceous legume cropping and rock phosphate treatment. *Soil Biology and Biochemistry* 32, 2079-2090.

Vanlauwe, B., Aihou, K., Aman, S., Iwuafor, E.N.O., Tossah, B., Diels, J., Sanginga, N., Lyasse, O., Merckx, R. and Deckers, S. 2001 Maize yield as affected by organic inputs and urea in the West African moist savanna. *Agronomy Journal*. No.93.Pp 1191-1199.

von Braun, J. 1988. Effects of technological change in agriculture on food consumption and nutrition: Rice in a West African setting. *World Development*, Volume16, No.9, pp.1083-1098

von Braun, J. 1995. Agricultural commercialization: Impacts on income and nutrition and implications for policy. *Food Policy*, Volume 20(3), pp 187-202.Wall, J. R. D. 1997. Land resources of the central Nigeria agricultural development possibilities. The Kaduna Plain Volume 5. In: Wall , J. R. D. (eds) Land Resources Development Center, Ministry Of Overseas Development, Tolworth Tower, Surbiton, KT6 7DY, Surrey, England, Land resource study 29.

Wallys, K., Tollens, E. and Manyong V. M.2003. Socioeconomic analysis of promising Balanced Nutrient Management Systems in northern Nigeria. An MSc. thesis, KU-Leuven, Belgium.

Zeller, M. and Sharma, M. 1998. "Rural finance and poverty alleviation". *Food Policy Report*, International Food Policy Research Institute, Washington, USA. June 1998. pp 1-32.