ECONOMIC ANALYSIS OF BALANCED NUTRIENT MANAGEMENT TECHNOLOGIES FOR MAIZE PRODUCTION IN KADUNA STATE, NIGERIA

BY

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DECLARATION

I hereby declare that this Thesis has been written by me and that it is a record of my own research work under supervision. It has not been presented before in any previous application for a higher degree. All borrowed ideas have been duly acknowledged by means of references and quotation marks.

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CERTIFICATION

This Thesis entitled “ECONOMIC ANALYSIS OF BALANCED NUTRIENT MANAGEMENT TECHNOLOGIES FOR MAIZE PRODUCTION IN KADUNA STATE, NIGERIA" by Ugbabe, Omadachi Ogbodo meets the regulations governing the award of the Degree of Master of Science in Agricultural Economics of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the ALMIGHTY GOD whose grace and favour provided the funding for this study; to my late father Mr. Isaiah Ogbodo Ugbabe who inspired me with the zeal for higher education; to my mother Mrs Onyeka Ugbabe who caught her husband's vision and invested heavily in my early education and to my darling wife Mrs Amina Ugbabe whose love, understanding and friendship sustained me throughout the duration of the study.

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ABSTRACT

In Kaduna State Nigeria (Northern Guinea Savannah), three improved maize-based technologies have been tested since 2000 in a series of farmer-managed field trials. The first technology is a continuous maize treatment mainly characterised by high fertilizer rates (SG 2000). In the second technology, half of the fertilizer quantity is replaced by organic manure (BNMS-manure). The third technology, a soybean-maize rotation treatment with the fertilizer rates to the maize reduced by half also (BNMS-soybean/maize).

The broad objective of this study was to conduct economic analysis of the three introduced BNMS maize-based technologies with the farmers' own practice of maize production. The specific objectives of the study were to: determine the costs and returns to the BNMS technologies and farmers' practice; determine the optimum farm plans for the technologies at farmers' level and to examine the farmers' perception of the BNMS technologies.

The study relied on both primary and secondary data. The primary data were collected by interviewing the participating farmers by means of questionnaires. The secondary data were mainly on types and rates of fertilizers applied, seed rates and type planted, and data on other vital areas of the introduced technology gotten from the BNMS programme manual. The tools used for analysis of the data were: partial budget analysis to determine the costs and returns to the introduced BNMS technologies and farmers' practice; linear programming technique to determine the optimum farm plans for the technologies at farmers' level and the scoring technique to examine the farmers' perception of the BNMS technologies.

Findings from the partial budget analysis showed that, BNMS-soybean/maize was the best in both the demonstration and adaptation trials by having the highest gross margins of ₦18,462 and ₦19,785 per hectare respectively, with the inorganic fertilizer cost constituting over 50% of the total production cost. BNMS-soybean/maize practice was accepted in the optimum farm plan at 1.51 hectare of land resource usage, while the three remaining maize practices were rejected. Operating capital was the most limiting of the resources at ₦50,000 per hectare. Farmers' practice came out of the linear programming analysis also as the least efficient of the four maize-based technologies because if it is forced into the optimum farm plan, the farmer will suffer a very high loss of over ₦40,000 because of its very low returns. The farmers gave overall best perception to both the BNMS-soybean/maize and the BNMS-manure technologies.

Some key recommendations based on findings from the study are: (i) That farmers should be enlightened to adopt the maize after soybean practice because of its profitability; (ii) There should be favourable policy that would boost the adoption of new varieties of soybean through efforts to support agricultural research in developing new and high yielding varieties; (iii) Government should provide the enabling environment for investors to establish fertilizer blending plants to bring down the prices of inorganic fertilizers.

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CHAPTER ONE

INTRODUCTION.

Since independence, agriculture has been the most important economic sector in terms of its contributions to the Gross Domestic Product (GDP) after oil (Adegeye, 2002). The sector contributes about 41% of the country's GDP, employs about 65% of the total population and provides employment to about 80% of the rural population. Available statistics show that total food production increased from 54.76 million grain equivalent in 1997 to 57.70 million grain equivalent in 2001. Agricultural growth rates increased modestly from 4.25% in 1997 to 4.5% in 1999 and 4.7% in 2001, all of which are nevertheless higher than the population growth rate of 2.7% (CBN, 2002).

The contribution of agriculture to GDP declined from an average of 33% in 1973 to 22% in 1980. It fluctuated between 21% and 23% between 1981 and 1985. This has obviously shown that the contribution of the agricultural sector to GDP has declined overtime due to slow growth rate of the sector as compared with other sectors of the Nigerian economy (CBN, 1991). The contribution of the agricultural sector to GDP at current factor cost in 1997 was 31% (CBN, 1997), thus the development of agriculture in relation to its potentials, especially in such areas as livestock, arable farming and horticulture has been limited.

Renewable natural resources, which comprise the environmental base for agriculture and most other activities in rural areas, are under threat throughout the developing world. Farmland is eroding and water is being wasted, mismanaged, and polluted on a grand scale. Tropical forests rich in flora and fauna are being converted rapidly into pasture and cropland, much of which is of marginal quality and deteriorates rapidly when exposed to the elements (Sanders et. al, 1995).

Raising agricultural production is a pre-requisite for improving standard of living of the rural farmers. This can be done by raising income level from the sale of farm proceedings (Isah, 1999). However, for some decades now, the ability of the agricultural sector in Nigeria to fulfil this role has varied widely over the past two decades and appeared to be correlated to the nature of technology practised by peasant farmers (Isah, 1995). In the Asian Tigers and Japan, enhancement of basic resources (land, labour and capital), productivity of factors of production (skills and knowledge or innovation), has been central to the brilliant performance in all sectors of their economies.

The efficiency of agricultural productivity in any country is a reflection of the level of technology prevailing in it (Stewart, 1970). Marilyn (1978) pointed out that for an agrarian economy to succeed in higher productivity, the technologies adopted should be simple and cheap enough to harmonize with local human and material resources and land to achieve widespread production.

Shumacher (1973) introducing the theory and need for appropriate technology, emphasized that it should be a technique of production by the masses and not mass production. In his words,

> *"appropriate technology is the technology of production by the masses, making use of the best modern knowledge and experience conducive to decentralization, compatibility with ecology, gentle in its use of scarce resources, and designed to serve human person instead of making him the servant of machines".*

There is a necessity as a result of the decline in agricultural production to use introduced soil improvement crop technologies to increase crop production. "The traditional method of maintaining soil fertility and productivity in Nigeria and most parts of tropical Africa has, hitherto, been the bush-fallow system whereby arable land is allowed to revert to fallow after three to four years of continuous cultivation. The system evolved out of natural exigencies, and the degree of regeneration of soil fertility is generally dependent on the length of fallow period, which, in turn, is related to the availability of land. In view of growing human population and other socio-economic pressures, attempts were made to shorten the fallow period from about seven to ten years to two to three years by planting leguminous crops and grass fallows" (Aduayi et. al, 2002).

When farmers no longer have the option to expand cultivated area economically or to rely on fallow to restore fertility, they need to increase the productivity of the land. Fortunately, many of the techniques for increasing land productivity also conserve natural resources (Sanders et al, 1995). In the past 25 years, 90% of the doubling of world food production came from increased yields and only 10% from area expansion (World Bank, 1992). In Nigeria, the fallow system was replaced with the use of manure, particularly where there was large number of animals. This brought into eminence the agricultural value of Farm Yard Manure (FYM), including poultry dropping, dung and household refuse. By the late 1940s the benefits of FYM had been so established that penning of cattle on the farm and mixed farming were being actively encouraged by the Nigerian government (Aduayi et. al, 2002).

However, with agriculture becoming more and more intensive, coupled with the introduction of higher yielding and more nutrient demanding crop varieties, it became obvious that FYM could not be obtained in sufficient quantities to meet the farmers' demand. Even where available, transportation problem and labour costs (unavoidably) limited its use on a routine basis. In the circumstance, attention was turned to mineral fertilizers as the alternative (Aduayi et. al, 2002).

The BNMS came up with maize crop technologies that used the combined application of organic matter (OM) and fertilizer to arrest soil nutrient depletion in sub-sahara Africa. For many years, Sasakawa-Global 2000 (SG2000) in collaboration with the state Agricultural Development Projects (ADPs) in northern Nigeria, has been promoting a maize package among farmers consisting of the use of hybrid seeds, proper plant density and fertilizer application practice, and the use of fertilizer rates that are quite high for the region (136 kg N, 20kg P, and 37 kg K ha^{-1}). The SG2000, the Institute for Agricultural Research (IAR), Zaria, and IITA agreed to compare this package with a practice in which part of the fertilizer quantity is replaced by animal manure. In addition, it was agreed to also include a maize-soybean rotation, again with reduced fertilizer rate to the maize. Farmer-managed demonstration trials were initiated in 2000 in northern Nigeria in collaboration with IAR and SG 2000. In 2002, 28 farmers in nine villages in the NGS benchmark area of Kaduna State established demonstration trials. In 2003, two additional farmers joined. The objectives of this trial were to (i) demonstrate the three packages for maize-based systems to farmers and extension workers (ii) assess labour input, management practice and farmers' feedback (iii) assess adoption/adaptation of the three packages for maize-based systems and (iv) solicit for opinion of farmers and extension workers during the field days (IITA and Leuven, 2003).

Manyong et al (2002) posited that high fertilizer application rates (136 kg N, 20kg P, and 37 kg K ha^{-1}) in the Nigeria's major cereal areas prompted concern about the sustainability of the system. It has been argued that the failure to understand the process of agricultural change may result in the misinterpretation of technological patterns and environmental variables as well as the rules of labour and resource sharing. They concluded by stressing the need for more knowledge in this area.

In recent years the focus of soil fertility research has been shifted towards the combined application of organic matter and fertilizer as a way of arresting the ongoing soil fertility decline in northern guinea savannah of Nigeria (Vanlauwe et al., 2001). The organic sources can reduce the dependency on costly chemical fertilizers by providing nutrients that are either prevented from being lost (recycling) or are truly added to the system (biological N-fixation). When applied repeatedly, the organic manure leads to build-up of soil organic matter, thus providing a capital of nutrients that are slowly released, and at the same time increasing the soils buffering capacity for water cat-ions and acidity (Iwuafor et al., 2002.)

1.1 Problem statement

In the past, shifting cultivation or long-fallow cultivation and transhumant pastoralist were appropriate under conditions of slow population growth, abundant land, limited capital and limited technical know-how. The ecological and economic systems were in equilibrium, fostered by mobility. People shifted to a different location when soil fertility declined or forage was depleted. This allowed the fertility of the land to be reconstituted through natural vegetative growth and decay (Cleaver and Schreiber, 1992).

Rapid population growth without corresponding improvements in agricultural technology and in the absence of adequate increases in agricultural productivity to secure the livelihoods of the rural poor has intensified pressure on existing and potentially productive agricultural land. This has been reflected in reduction of arable land per farmer and in the scope for further expansion of cropland, shortened fallows with loss of soil nutrients and organic matter, resulting in declining yields; the extension of cultivation onto unsuitable or marginal lands; the conversion of large areas of forests, wetlands, river valley bottoms and the grassland savannah to farmland with loss of biodiversity; climate change and exposure of fragile soils; increased pressure on common property resources (woodlands and grazing areas), with breakdown of indigenous institutions that regulate and manage these resources, leading to open access regimes and resource degradation; declining resilience in ecosystems with reduced ability to rebound from stresses such as drought and reduced nutrition for poor farmers on depleted soils, amongst others (Cook and Grut, 1990; Cleaver and Schreiber, 1992; Scherr and Hazell, and Barbier, 1997).

The Balanced Nutrient Management Systems (BNMS) technologies was developed and tested in the northern guinea savannah of Nigeria to achieve a sustainable increase in farm productivity and profitability by improving the overall soil fertility in maize-based farming systems. The soil is continuously cropped resulting in serious depletion of the minerals needed for maize growth and yield.

The high demand for inorganic fertilizer has led to high cost of production. The BNMS technologies were packaged to address this problem of high inorganic fertilizer cost by providing alternatives. Three BNMS maize technologies have been tested since 1997. However, in 2003 cropping season the three BNMS maize technologies were compared to the farmers' own practice for maize cultivation. This comparison was necessary to determine which of the three BNMS technologies was the best in terms of gross margin.

The problems of intensive cultivation or continuous cropping is the lack of interest in the use of organic manure, which makes it imperative for researchers in the northern guinea savannah to come up with crop enterprise combinations that will utilize the available farm resources to give maximum farm income. Economic analysis was needed to proffer answers to the following research questions:

(i) Which of the three introduced BNMS technologies is the best in terms of earnings from farms?

(ii) What is the optimal farm plan for the maize farmers in the area?

(iii) What are the farmers' perceptions about the three BNMS technologies in terms of yield, soil fertility, suppression of weeds and striga, diffusion of the technologies to others and farmers' own use in future and affordability of inputs

1.2 Objectives of the study.

The broad objective of this study is to conduct an economic analysis of the BNMS maize-based technologies.

The specific objectives of this study are to:

1. determine the costs and returns to the tested BNMS technologies and farmer practice

2. determine the optimum farm plans for the technologies at farmers' level and

3. examine the farmers' perception of the BNMS technologies.

1.3 Justification for the study.

The problem at hand in agricultural development in most, if not all, developing countries is a contradiction: the contradiction between the imperative of intensifying production which inevitably increases the consumption of both renewable and un-renewable natural resources and the simultaneous need to stop and reverse environmental degradation (Cernea, 1991). The ray of renewable hope of finding a practical solution stands, therefore, not in stopping development, but in improving the use and management of natural resources such as land.

Land being an essential input in farming, the impact of the depletion of land resources has profound economic implications for a low income country like Nigeria and other poor regions of the World where economic development and poverty alleviation have taken centre stage. For instance, the degradation of land resources leads to losses in soil fertility and reduced crop productivity and by implication, threatens prospects for economic growth and future human welfare. Rough estimates suggest that in some countries, the losses in productive potential attributable to land depletion may amount to 0.5-1.5% of GDP annually (World Bank, 1992).

This study is justified by the improvement of soil fertility in the study villages, and agronomic successes recorded by the BNMS project in the region. Since the beginning of BNMS 1 in 1997, maize yield increases (increasing maize production to over three tons per hectare) have been recorded by farmers participating in the project. Economic analyses of the performance of these technologies are needed in order to determine their economic feasibility and the associated problems of adoption.

1.4 Hypotheses

The following hypotheses were tested:

(i) There is no difference between the returns from the introduced maize technologies and the farmers' practice of maize production.

(ii) There is no difference between the optimal farm plans of the introduced maize technologies and the farmers' practice of maize production.

(iii) There is no difference in the perception of the introduced maize technologies and the farmers' practice of maize production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cropping System of the Northern Guinea Savannah

Choosing an appropriate cropping system in agriculture is an important strategy for maximizing limited resources and ensuring higher crop yields. Any system adopted for a particular crop depends on the production objectives, availability of resources, and type of crop, perception of risk and farmers level of knowledge (Nweke et.al., 1999). While some systems such as shifting cultivation involves plenty of land and high labour requirements, others like mixed cropping and crop rotation allow for more efficient use of land, uniform utilization of soil nutrients, relatively lower cost as well as controlling pests and diseases (Onwueme, 1978). According to Rastogi (1980) the cropping system of any region is essentially determined by experiences gained over the years on a given soil and the climatic and environmental condition. For example, in dry land areas, rainfall considerations often tend to overshadow other considerations in the choice of crops and cropping patterns. Economic consideration on the other hand may be the determinant factor where cash crops have a major influence in the economy.

In the northern guinea savannah, the climate has been found to be well suited to a wide range of crops particularly cereals and legumes.

However, the emerging cropping pattern is influenced by the level of production technology, the tradition of the people, resource availability and time. Crops in general are either grown in single stand or in mixtures. Growing crops in mixtures has been described as the practice whereby two or more crops are grown on the same piece of land at the same time (Norman, 1972). Crop mixtures form a major cropping pattern in the zone. For instance, Norman (1972) reported that 75 percent of total land area under cultivation in Zaria area was in crop mixtures.

Maize is a major cereal crop in northern guinea savannah. In 1982 and 1982, IAR reported that, it accounted for 72 and 75 percent respectively of the total cereal production in Daudawa area of the zone. In 1983, a nation –wide survey by the federal office of statistics showed that maize was the second most popularly cultivated crop after sorghum in Nigeria (Federal office of statistics, 1983). The report further showed that maize was mainly produced in the savannah areas of northern Nigeria.

2.2 The Importance of Maize in the Farming System

Maize (Zea Mays L.) is a member of the grass family, graminacaea. The most probable theory about the origin is the one that said it originated from Mexico or Central America (FAO, 1984). Maize ranks second to wheat in world cereal production, with milled rice being third. As at 1997, the world production of maize stood at 580 million tonnes, with Nigeria producing about 6.2 million tonnes or a mere 1.1% of the world's output

(FAO, 1997). Maize is the most widely grown of the major crop species (on about 140 million hectares of land) with substantial quantities being cultivated on almost all corners of the world, attaining a world average of 4.13 tonnes per hectare, which is about 3 times the Nigeria's average yield (1.43 tonnes/ha).

Maize is one of the most important cereal crops grown in Nigeria, the area of its production stretching from the coast in the south to the savannah. It is a principal component of the different cropping systems in all the parts of the country. Production data of agricultural crops in Kaduna state as given by the state ADP (1999) recorded that, the total production figure of the maize crop in 1996 was 2.05 tonnes per hectare; 1997 was 2.97 tonnes per hectare whereas 1998 was 3.65 tonnes per hectare.

The use of maize as food crop and as cash crop was responsible for its growing importance. As food crop, it is prepared and eaten in form of *tuwo, pete, and akamu*. It is also eaten green by boiling or roasting while the dry grains are often fried and eaten. Maize also had commercial value in the industrial sector where it is used as a source of energy in livestock feed and as raw materials in brewing and confectionery industries (Ahmed, 1995).

Maize is not only a major food crop for many homes in Kaduna state, but also a major cash crop which became a replacement for earlier cash crops such as groundnut and cotton in the area (Ayuba, 1998).

2.3 Economic Analysis

One of the primary purposes of economic and financial analysis is to provide a basis for comparison of projects, for setting priorities and for ensuring that limited resources are invested in projects that will provide the best return (NAERLS, 1985). Viable and sustainable integrated rural development approach that would help in raising employment, purchasing power, rural income and increased productivity is by means of increasing the level of resources committed to farms with optimum efficiency in their allocation. Various kinds of studies on economic analysis have been carried out for different crops and activities. The main concern of all these studies has generally been to obtain farm level input-output data through field surveys in order to determine the relative financial costs and returns of the chosen farm enterprises or crop (Norman, 1972; Barau, 1979 and Idoko, 1996).

The production process is one whereby some goods and services called inputs are transformed into goods and services, called output. In agricultural production, the physical inputs which are utilized are land, labour capital, management and, of recent water resources. These resources can be organized into a farm-firm or a producing unit, whose ultimate objective may be profit maximization, output maximization, cost minimization or the maximization of satisfaction or a combination of all these motives (Olayide and Heady, 1982). In production, the product is that part of the output that is valuable to the producer while that which has no value is the waste or waste products. But as long as the production generates sufficient profit from the valuable part of the output, the investor is satisfied with the investment (Olukosi and Ogungbile, 1989).

Olayide and Heady (1982) defined agricultural productivity as the index of the value of total farm output to the value of total inputs used in farm production. It is important to note that one of the chief aims of any society is the attainment of an optimally high level of living, and this objective can be achieved by increasing the productivity of resources employed in production at the farm and off-farm level. In an agrarian economy like that of Nigeria, an increase in efficiency of resource use at farm level could suggest general economic advancement with a resultant improvement in the socio-economic status of the citizenry.

The input-output process of farm production is important in at least four major areas. These are the distribution of income, the allocation of resources, the relationship between stock and flows, and the measurement of efficiency or productivity (Olayide and Heady, 1982). The term productivity and efficiency are used interchangeably in the production literature. The concept of productivity or efficiency is instrumental in achieving an improved agricultural economy. There have been two concerns, first is that more efficient agriculture could reduce the amount of food which is imported or release resources which could be used for development in other sectors of the economy and second is that greater productivity would enable the incomes of farmers to be higher (Mijindadi, 1980).

The input-output study conducted in Zaria area by Norman (1972) indicated that apart from hired labour, most farms used all other resources in an efficient manner. Hired labour, as at that time, he said, was not efficiently used because it was particularly successful in mitigating the effect of peak demand period for labour. The study found that seasonal nature of farm work result in labour demand. The study also indicated that the number of family members is crucial in determining farm size. However, land size was found to be the most important determinants of farm productivity. Norman drew a general conclusion in which he asserts that under the existing technological and socio-economic conditions in the study area, farmers used their resources in a manner consistent with the goal of profit maximization. There is no thesis recently on testing of technologies. Most of the theses on Economic Analysis are on crop production.

2.4 Organic Manure Usage in Agriculture

The term 'manure' was originally used for describing materials such as cattle dung and other natural substances that were applied to the land with the object of increasing the production of crops. Later, chemical substance like ammonium sulphate was also used for such purposes. To distinguish between organic and inorganic substances and for such similar purposes, the organic manures are specifically called `manure' and the inorganic ones called 'fertilizers'. This usage is now commonly accepted although the term `manure' is often loosely used to refer to the organic ones specifically and both the organic and inorganic in a general way (Karikari and Yayock, 1987)

There is nothing new in the use of the products of our refuse dumps, dung or poultry dropping, compost or even the utilization of processed human faeces. The problem will always be its availability in the right quantity. That is to say, the teeming rural farming households face the challenge to generate, process and handle enough for their farm plots. The quantity that may be required per hectare will range between 5 and 15 tons (Okaiyeto, 1966).

The role of organic matter is to provide the soil with some plant nutrients and give the soil good structure, facilitate air circulation in the soil, enable the soil to absorb sufficient water to hold and retain essential nutrients. Some of the nutrients in the soil are held in organic matter. The nutrients comprise almost all the nitrogen, a large amount of phosphorus (25% to 60%) and a certain amount of sulphur. Therefore, the amount of organic matter in the soil determines the availability of these elements in the soil. The structure of organic matter also facilitates the growth and life of the microorganisms in the soil (Ngeze, 1998).

The beneficial effects of organic manure, especially cattle dung in crop production have been emphasized by many workers (Lombin and Abdullahi, 1977; Klausner and Guest, 1981; Beauchamp, 1983; Motavalli et al, 1989). The results of work carried in West Africa savannah showed that organic manure is as effective as, and in some cases better than mineral fertilizers for sustainable crop production (Djokoto and Stephens, 1961; Pieri, 1971; Lombin and Abdullahi, 1977). Apart from their direct nutrient contribution, organic manure is known to improve soil physical properties (Aina, 1979; Von Wistinghausen and Peterson, 1979; Sharma et al., 1987) and soil fauna population.

The use of inorganic fertilizers by resource poor farmers is limited by high cost and scarcity of fertilizers. A combination of both organic and inorganic fertilizers may be a more cost effective approach. A field trial was conducted in Samaru, Nigeria to study the effect of supplementing inorganic fertilizers with organic manure on maize growth and yield. Treatments consisted of factorial combinations of five rates of organic manure (0, 2.5, 5.0, 7.5 and 10 tons/ha^{-1}) and five rates of NPK fertilizers ($N_0P_0K_0$, $N_{40}P_{20}K_{20}$, $N_{80}P_{40}K_{40}$, $N_{120}P_{60}K_{60}$, and $N_{160}P_{80}K_{80}$ kg/ha^{-1}). Results showed that organic manure alone significantly increased grain yield, 1000-grain weight, and cob length. Stover yield, number of kernels per cob and cob diameter were not significantly affected. Among the different rates of inorganic fertilizers applied, there were no significant differences in grain yield, 1000-grain weight and cob length. For all parameters, values generally increased with increasing levels of the inorganic fertilizer up to NPK: 120:60:60 kg/ha^{-1}. A combination of 40:20:20 kg/ha^{-1} of inorganic fertilizer and 2.5 tons/ha^{-1} of organic manure gave higher grain yield than when 120:60:60 kg/ha^{-1} fertilizers alone were applied (Yaro et al, 1997).

Most of the West African soils are low to very low in organic matter and plant nutrients especially N and P (Aina, 1979; Tian et al., 1993). The low activity clay Alfisols, Oxisols/Ultisols, Vertisols and weakly differentiated coarse textured Entisols and Inceptisols found within the region are low to very low in plant nutrients and low in effective cat-ion exchange capacity as kaolinite is the dominant clay minerals. The soils are susceptible to rapid nutrient depletion with intensive farming systems, which is fast becoming predominant in the area. Under this situation, high and sustainable crop production requires the use of inorganic and organic fertilizers. Although high crop yield can be obtained with judicious fertilizer use, the commodity is not always easily available to the resource poor farmers because of high cost and poor distribution systems. Continuous use of high rates of nitrogen fertilizer also results in acidification of the soils. The use of organic fertilizers is also limited by the huge quantities required to meet crop needs because of its low nutrient content. Such huge quantities are obviously not obtainable and even if they were, transportation and handling costs would constitute a major constraint. In view of this, an integrated management approach, which addresses a combination of low chemical inputs and organic manure, may be a cost effective economic strategy. This system may offer a good opportunity to the small-scale farmers to maintain yields at reasonable and sustainable cost levels (Yaro et al, 1997).

The complementary use of organic manure and inorganic fertilizers ensures the availability of nutrient throughout the growth period of crops. While the application of mineral fertilizer will provide the immediate nutrient requirement for the early growth stages of a crop, the supplementary organic manure, which supplies its nutrients by slow release, provides what is required during the later stages of growth (Yaro et al, 1997).

Management strategies for improved soil fertility and increased food production border mainly on improving the organic matter content of these soils. This is achieved through return to the soil of organic residues. In addition to improving the soil organic matter content, these increase the soil nutrient levels. Good crop mixtures and rotations also improve soil organic matter and nutrient status of these soils. Where residues are burnt the ash should be returned to the soil in view of its high nutrient content (Iwuafor, 1988).

Soil fertility must be managed more efficiently if Africa is to overcome its food-production problems. Mineral fertilizers and improved nutrient management strategies are crucial to such efficiency. So too are new nutrient sources and more responsive crop varieties. Maize combines widespread importance as a food staple with relatively high fertilizer responsiveness. As a result, maize production and fertilizer use are likely to become even more closely linked than they have been in the immediate past (Heisey and Mwangi, 1996).

On soils that are inherently poor, organic manures have given good results. Hartley and Greenwood (1933) found that in Northern Nigeria dressings of one ton per acre of pen manure gave a considerable increase in the yield of sorghum, although a comparative effect could not be obtained with inorganic fertilizers. In long-term trials in northern Nigeria, organic manure has given better results than equivalent amounts of inorganic nitrogen and phosphorus (Obi, 1959 and Goldsworthy, 1965). More recent data from this series of trials suggest that the reason for this is the reduction in pH which has occurred following the continuous use of ammonium sulphate on soils that have a low cat-ion exchange capacity (Goldsworthy, 1965). The reduction in pH where organic manure has been applied with the ammonium sulphate is less than where ammonium sulphate has been used on its own.

Organic manure is an excellent source of organic matter but relatively low in soil nutrients. For example, 100kg of NPK 10-10-10 inorganic fertilizer contains about the same amount of NPK as 2000kg of farm yard manure. Thus, organic manure needs to be applied at very high rates (about 20,000 to 40,000kg/ha per annum) to make up for their low nutrients content and to supply enough humus to improve the soil physical condition. Farmyard manure is scarce in many areas especially where livestock is not kept in large numbers. Organic manure is usually derived from plant or animal sources and may be classified as bulky organic manure and concentrated organic manure. Bulky organic manure consists of farmyard manure, compost, green manure, night soil and sewage. Concentrated organic manures contain higher percentage of nitrogen, phosphorus and potassium compared with bulky organic manure. The common concentrated organic manures are oil cakes, blood meal, fish manure, meat meal, and cotton and wood wastes (Karikari and Yayock, 1987).

In a series of experiments extending over three growing seasons, Hardley and Greenwood (1933) have shown that application of farmyard manure as small as 2.5t/ha gave considerable yield increases in guinea corn. Four rates were used (0, 2, 5, 5.0 and 7.5t/ha) and all the increases gave significant yields. The application of 5.0t/ha more than doubled the yield and 7.5t/ha almost trebled the yield.

The effect of organic manure in improving physical properties of soil has been reported generally. Organic matter applied to the soil will improve root penetration by preventing the close packing of soils and providing pores of suitable size for root to enter (Wiersum, 1957, quoted by Webber, 1972). Organic matter may also improve available water holding capacity, infiltration rate and aggregate stability. Webber, 1972 reported that heavy rates of farmyard manure applied to the soil could increase soil porosity by up to 3 percent by volume.

The use of organic fertilizer needs to be assessed as in several aspects organic fertilizers are better than inorganic fertilizers, for example in improving soil physical and biological properties (Hsieh and Hsieh, 1990). The other functions of soil organic matter include the improvement in plant nutrient availability, improvement in soil physical properties, reduction in soil erosion, as energy source for soil organisms, supply of organic substances for plant, increase in buffering and ionic exchange capacities, adsorption of pesticide and other organic compounds, and lower incidence of plant pathogens (Stevenson, 1982).

The use of inorganic combined with organic fertilizers will save a considerable amount of inorganic fertilizers and also maintains and improves soil productivity. Use of legumes can allow reduction of N fertilizer to subsequent cereals in a rotation. Grain legumes are likely to be adopted by farmers but their potential contribution may be low because of export of nutrients in the grain. There are few estimates of fertilizer replacement values from soybean in the mono-modal savannah zone of West Africa. The estimates for soybean range from 20 kg N ha^{-1} (Carsky et al., 1997) to 45 kg N ha^{-1} (Kaleem, 1993).

2.5 The Balanced Nutrient Management Technologies.

These technologies were developed through the BNMS project as follows:

BNMS 1

The collaborative project between IITA and the Katholieke Universiteit (K.U) Leuven on Balanced Nutrient Management Systems for maize-based systems in the Moist Savannah and Humid forest Zone of West Africa (BNMS) started in January 1997 and was for a duration of 4 years (until December 2000). The overall goal of the project was to curb the vicious cycle of plant nutrient depletion in maize-based farming systems in the moist savannah and humid forest zone of West Africa through integrated nutrient management systems geared to land use practices which are economically viable, ecologically sound and socially acceptable (Vanlauwe et al., 2002).

The objective was to develop and test management practices, which maintain and improve the soil nutrient balance by promoting utilization of locally available sources of plant nutrients, maximizing their nutrient use efficiency and thus reducing the need for external costly soluble fertilizers.

The BNMS used the strategy specifying different outputs that are required to achieve project goal. The postulated six outputs are shown below:

1. Diagnosis
2. Process Level
3. Management practices
4. Decision support
5. On-farm testing
6. NARS (National Agricultural Research Systems) capacity.

Amongst the soil fertility technology options tested by the BNMS project during the first phase of the project, two have emerged as break-through for sustainable agricultural systems in West Africa. These options are first, the combination of organic and inorganic inputs that allow a saving of about 50% on the cost of fertilizer N (Vanlauwe et al., 2001) and second, use of less available P or rock P by grain and/or herbaceous legumes that appear to have more efficient mechanisms for extracting P from the soil than other crops.

BNMS II

During the first phase of the BNMS project most of the goals were achieved, still, important knowledge gaps remained requiring further research. This led to a second phase of the BNMS project. The second phase was approved for a period of 4 years starting from January 2001 till December 2004. The main goal of the second phase was no longer to curb the vicious cycle of plant nutrient depletion in maize-based farming systems, but to improve food security and enhance income of the poor farming communities in the moist savannah zones without deleterious effects on biodiversity or environmental resources through the adoption of more environmentally friendly and profitable technologies. In partnership with farmers and their organizations, NARS and NGO's, the Scientists developed, tested and promulgated, balanced nutrient management system technologies specifically adapted to the local, biophysical and socio-economic environments of the savannah which enables a sustainable increase in farm productivity and profitability whilst, improving overall soil fertility in maize-based farming systems.

Just like in the first phase, there were six outputs, which include:

1. Increase biomass production to increase soil OM.
2. Publish recommendations of new knowledge of soil processes for efficient design of management practices that redress and increase soil productivity.
3. Validate and adapt BNMS technologies on-farm and promulgate them in benchmark areas.
4. Quantify and publish a socio-economic evaluation and impact assessment of best-bet BNMS technologies.
5. Develop guidelines for Balance Nutrient Management Systems and disseminate those to extension organizations.
6. Strengthen NARS capability for maintaining continuity of research effort after 2005.

2.6. Farmers' Perception of the BNMS Technology

Perception is the process and experience of gaining sensory information about the physical world (Lexicon Universal Encyclopaedia, 1989). Perception is a concept in philosophy and psychology with a family of meanings. The core meaning is immediate awareness. To perceive something is to become directly or immediately aware of it (The Encyclopaedia Americana, 1989). There are two reasons favouring the use of perceptions and opinions in research. First, perceptual data are easier and less costly to collect and secondly there is a positive correlation between perceptual data and objective facts (Akpoko, 2001). Thus perception scores can be used to show the correlation between recommended practices and adoption.

After having good knowledge of the farmers' goals and conducting an on-farm experiment, it will be important to do an adoption study. All too often on-farm testing ends with statistical and economical analysis showing the profitability or otherwise of an innovation. This kind of analysis does not, and probably cannot, account for all the criteria, which may be used by farmers when deciding whether or not to adopt an innovation. The farmers' own opinions and assessments may help to reinforce the conclusions, but, even then, these conclusions will remain tentative. The only real test is whether the farmers will continue to use the technology after being exposed to it during the trials. If, in spite of a positive evaluation, this is not the case, then the researchers should find out (Herdt, 1987).

2.7 Review of Analytical Techniques

2.7.1. Partial budgeting

One of the tools in economics used to compare the economic benefits of technologies is partial budget analysis. A budget is a farm management method that is intended to assist researchers, extension agents, and farmers in the decision-making process. It is a tool that aims at quantifying and comparing the effects of a proposed technology on crop production to those of other alternative technologies. Results from partial budget analysis assist agricultural scientists in identifying weaknesses (high cost and/or low income) of the technology being developed. Partial budget analysis aid scientists and extension agents in deciding which technology to recommend to farmers. Partial budget analysis shows the level of profitability and helps to decide whether to adopt a new technology or not. Budgeting forces management to think ahead, and aid sound decision-making. Partial budget analysis can apply to all crops and cropping systems (Alimi and Manyong, 2000). Partial budgeting is a planning method and involves the estimation of the likely cost and returns of planned changes in the organization of a business.

Partial budgeting does not consider the farm as a whole. For example it can be used to aid decisions such as: - the introduction of a particular machinery into a farm enterprise, the increase in size of an enterprise and the effect of introducing supplemental feeding into a field grazing livestock enterprise.

In the preparation of a partial budget, the farmer should find answers to questions such as:

a. What added costs will be incurred?

b. What revenue will be lost?

c. What costs will be reduced as a result of the change?

d. What extra revenue will be gained?

2.7.2 Linear programming

Another analytical technique in economics is linear programming (LP). LP is a planning method that is often helpful in taking decision requiring a choice among a large number of alternatives. The theoretical concepts on which the method depends have been known for many years. However, it was during World War II and immediately after that its application to planning problems first was stressed. Since then LP and similar techniques have been applied increasingly to management decisions in industry. Where should production facilities and warehouses be located in respect to sources of raw materials and markets for the finished product? What mix of ingredients will minimize the cost of producing feed, gasoline, or fertilizer? How can production be scheduled to achieve the greatest output of product from plant and equipment? These are a few of the questions linear programming techniques can help answer (Beneke and Winterboer, 1973).

According to Bajpai et-al (1978) the linear programming model is specified as follows:

Maximise

$$Z = \sum_{j=1}^{n} C_j X_j \quad (j=1,2\ldots n)$$

Subject to

$$\sum_{j=1}^{m} a_{ij} x_j \leq b_i \quad i = 1, 2\ldots m$$

Where $x_j \geq 0$

$$j=1,2\ldots n$$

He stated that we have n variables and m constraints, which mean that there are m slack variables and (n-m) original basic variables.

Lucey (1996) stated that LP could be used to solve problems, which conform to the following:

(a) The problem must be capable of being stated in numeric terms.

(b) All factors involved in the problem must have linear relationships.

(c) The problem must permit a choice or choices between alternative courses of action.

(d) There must be one or more restrictions on the factors involved.

Vazsonyi and Spirer (1987) stated that linear programming is one of the most powerful mathematic techniques of optimization used to solve problems of the optimal allocation of limited resources among various competing enterprises. It is quite efficient in handling a large number linear constraints and activities at the same time. It uses a global objective function in finding optimal farm plan or strategy by putting together the best combination of activities or objectives (Thampapillai, 1978). The method is based on the premise that peasant farmers tend to behave in a way that optimizes their objectives given the constraints within which they operate. The programming procedure provides a computational method of determining the best plan among alternatives that are characterized by a specific objective, limited resources and competing means of using resources provided these three requirements can be quantified.

Seven fundamental assumptions of a static linear programming model identified by Agrawal and Heady (1972) are:

(i) The objective function and constraints equation must be linear

(ii) Activities and resources are assumed additive, implying the absence of any interaction among the activities or resources.

(iii) Activities and resources are assumed to be infinitely divisible.

(iv) The activities and decision variables must be non-negative.

(v) The number of activities and quantities of resources are assumed finite to permit realistic programming.

(vi) Activities and resources have linear relationship implying constant resource productivity and constant resource productivity and constant return to scale.

(vii) Resource supplies, input-output coefficients, and prices of resources and products are known with certainty.

Mbonda (1983) stated that analysis of linear programming problems usually provide the following information:

(i) The optimal total farm net revenue or total farm gross margin with profit derived by deducting the fixed costs.

(ii) The optimum combination of activities on enterprises consistent with available resources, input-output coefficients and some level of desired objective function.

(iii) The optimum resource mix based on the prevailing input-output coefficient that will give the optimum objective function.

(iv) Marginal value product (shadow prices) of resources or constraints fully utilized in the solution assuming all other coefficients is unchanged.

(v) Effect of varying product and resources price ratio on the magnitude of the gross margin.

The advantages of using the linear programming model can be seen from the wide and diversified areas it has been applied to variety of problems. Some of the problems are:

(i) Diet problems: To determine the minimum requirement of nutrients, subject to availability of food and their prices.

(ii) Purchasing problems: To have the least cost objective in, say processing of goods purchased from outside and varying in quantity, quality and prices.

(iii) Transportation problems: To decide the routes, number of units, the choice of factories so that the cost of operation is a minimum.

(iv) Manufacturing problem: To find the number of items of each type that should be made so as to maximise profits.

(v) Production problems: Subject to sales fluctuations. To decide the production schedule to satisfy demand and minimise cost in face of fluctuating rates and storage expenses.

(vi) Job assigning problems: To assign jobs to workers for maximum effectiveness and optimum results subject to restrictions of wages and costs.

The works of Heady and Candler (1958) and Beneke and Winterboer (1973) among others were fundamental in the application of linear programming in the field of agriculture. The tool is in particular well suited to solving the problems of optimum selection and the combination of crop and livestock enterprises through much of Europe and Japan (Baker, 1963).

The linear programming model has been widely used to examine efficiency of resources use in agriculture. Linear programming is also widely applied in African countries. Clayton and Heyer are regarded as pioneers in this breakthrough. It is only since the early 1970s that this technique has been used in other African countries. It is, nonetheless, limited to countries like Nigeria, Kenya, Tanzania; Uganda, Malawi, Cameroon, Mali and Burkina Faso, Kenya and Nigeria being on the top list (Eicher and Baker, 1982 quoted by Sanni, 2000). Most of the contributions deal with the identification of constraints and the evaluation of the profitability of new technologies on smallholder farming systems with special emphasis on annual crops, livestock, and recently on optimizing crop-livestock combinations (Sanni, 2000). Many studies in Africa (e.g Clayton, 1961, Ogunfowora, 1970, Olayide and Olowude 1992, Shapiro, 1973, Abalu, 1975, Belete, et. al. 1993,) have successfully used the technique to analyse a variety of farm management problems. Ahmed (1995) used linear programming method to develop the optimum farm plan for maize farmers in the Northern Guinea Savannah zone of Nigeria. Sanni (2000) used linear/mixed integer programming techniques to solve the problem of optimum selection and combination of crop and livestock activities based on the existing farm-household resources in integrated crop-livestock farming systems in Katsina State, Nigeria.

CHAPTER THREE

METHODOLOGY

3.1 The Study Area.

The study was conducted in three of the four extension zones of Kaduna state ADP namely: Maigana , Lere and Birnin Gwari. They are located in the Northern Guinea Savannah (NGS). Kaduna State covers about 46,016 square kilometres and representing about 5% of the total land area of Nigeria, which has been put to be 923,768 square kilometres. It lies between latitudes $11^{0}32'$ and $09^{0}02'$ N and longitudes $08^{0}50'$ and $06^{0}15'$ E. Kaduna state is one of the 36 states in Nigeria and has 23 local government areas ($L.G.A,_{S}$) by 1996. The longest distance from North to south is about 290 kilometres while from East to West is about 286 kilometres (Kaduna State, 1996). Kaduna state is located in a pen plain consisting of various kinds of rocks such as older granite, schist and quartzite's in variable composition. The land gradually slopes down towards the west and southwest and is drained by the two most dominant rivers, Kaduna and Gurara Rivers.

There is less distinction in terms of average monthly maximum temperatures especially in the southern areas of Kaduna State. The hottest months in the north are March-April, while the coldest are December and January. Rainfall is heaviest in the south and east and decreases northwards. The rainy season varies from March to October with the wettest being in the southern part. Kaduna (the state capital) falls within the wetter areas with an average monthly rainfall of 361mm while Ikara in the drier north has an average of 146 mm over the past five years. The duration of rainy days varies from about 65 in Ikara to about 165 in Kaduna. The pattern of temperature and rainfall determine the types of crops, planning of farm operations, food and animal production and assessment of drought and erosion hazards on different parts of the state. After the wet season when the bulk of the food crops are grown, there follows the dry harmattan season during which the days are cool and the nights chilly. This period lasts from around November to February and coincided with the harvest season (Kaduna State, 1996).

The vegetation in Kaduna state is the Guinea Savannah. In the southern parts where rainfall is heavier, savannah woodland, with trees like shea butter, locust bean and tamarind predominate. In the drier areas of the north and northwest, the vegetation is made up of shade trees like baobab, silk cotton, shea butter, and date and deleb palm. The less fertile laterite soil found in the drier area is suited to millet and groundnut production, while the black soil of the more southerly river valleys favours cotton, maize and root crops.

3.2 The Project Villages and the Farmers.

The research trials from which this study were done were located in eight villages in three out of the four extension zones of Kaduna state ADP. There were three villages in the Maigana zone, three in the Lere zone and two in the Brinin Gwari zone. All the villages were located in the NGS benchmark or very close to it. The zones and villages were as follows:

* Maigana zone: Kaya, Danayamaka and Fatika.
* Lere zone: Krosha, Kayarda and Kadiri Garun
* Birnin Gwari zone: Kufana and Buruku.

The participating villages were selected in consultation with the extension services of IAR and SG 2000. There were two types of trials: demonstration and adaptation trials. In 2003, eight villages were involved in the demonstration trials and four in the adaptation trials. These project villages are in Kaduna state in the Northern Guinea Savannah (NGS) of Nigeria. The landscape of the NGS is strongly influenced by man. Trees were cut for firewood and building materials and to meet the high pressure on land for agriculture and cattle rearing. The landscape became a large plain, with fields dotted with sporadic trees and inselbergs.

The selection of farmers was done in a group meeting organized by the extension agents from IAR and SG 2000, which was attended by the local chiefs. The selection criteria were willingness of farmers to cooperate and the ability of spreading the technologies within the villages. In the

2003 trials, there were 50 farmers made up of 20 demonstration and 30 adaptation farmers (Table 3.1).

Table 3.1**:** The participating villages and number of farmers involved in the demonstration and adaptation trials.

Village	Demonstration trials	Adaptation trials	Total
Kaya	2	14	16
Fatika	5	4	9
Danayamaka	1	11	12
Buruku	2	-	2
Kufana	2	-	2
Krosha	2	1	3
Kayarda	2	-	2
Garo	4	-	4
Total	20	30	50

3.3 Sources and Methods of Data Collection

The study relied on both primary and secondary data. The primary data were collected by interviewing the participating farmers, and by means of questionnaires. The data generated include material inputs (seed, manure and inorganic fertilizer), and labour inputs (hours worked on the field by the farmer and his/her family or by hired labourers). During the season, there were several operations done that required material and labour inputs. The "Economic Analysis Questionnaire" was used to solicit information on the different operations carried out. The different operations were: Land preparation, manure application, planting, first fertilizer application, first weeding, second fertilizer application, second weeding, and third weeding. The secondary data were mainly on types and rates of fertilizers to be applied (Table 3.2), seed rates and type to be planted and data on other vital areas of the introduced technology gotten from the BNMS programme manual.

Table 3.2: Treatment structure of the demonstration trials

Treatment	Year 1 crop	Year 1 inputs (/ha)	Year 2 crop	Year 2 inputs (/ha)
Farmers practice	Maize-hybrid	Farmers' choice	Maize-hybrid	Farmers' choice
SG 2000	Maize- hybrid	450 kg NPK 20-10-10 at emergence; 100kg Urea at knee high	Maize-hybrid	450 kg 20-10-10 at emergence; 100kg at knee high
BNMS-manure	Maize hybrid	6000kg/ha animal manure at ridging, 200kg NPK 20-10-10 at emergence and 100 kg Urea at knee high	Maize-hybrid	6000kg/ha animal manure at ridging, 200 kg NPK 20-10-10 at emergence and 100 kg Urea at knee high
BNMS-soybean/maize rotation	Soybean TGx-1448-2E	No fertilizer	Maize-hybrid	200 kg 20-10-10 at emergence, 100 kg Urea at knee-high

The treatment structure of adaptation trials was the same as those of the demonstration trials. It was only their plot sizes that differ. The adaptation farmers' were supposed to watch the demonstration plots and select the best two maize treatments that appealed to them and compare with their own farmer's maize.

3.3.1 Variable costs.

The variable costs in the four maize treatments and soybean include costs of purchased inputs and costs of labour.

The following costs were not included in the partial budget analysis because they don't generate varying costs between the treatments, as they are the same. The costs were: land clearing costs and land preparation or ridging costs. Farmers could not differentiate these costs between the various crop treatments.

The variable costs used in this partial budget analysis were:

(i) **Manure cost:** This cost pertains only to the BNMS-manure treatment. It has three components namely: the input cost of manure, the labour cost of manure application and the transportation cost of manure to the field. The recommended quantity of manure was applied to the old furrows immediately after clearing the land but before land preparation.

(ii) **Planting cost**: This has two components namely: the cost of the seed and the cost of planting.

(iii) **Fertilizer application cost:** This like the manure cost has three components namely: the cost of the fertilizer, the cost of its application and the transportation cost to the field.

(iv) The harvest cost: Four steps are involved in the harvesting of maize. Harvesting start with the cutting and gathering of the maize plants in one place mostly in a standing position because of the wetness of the soil which affects the cobs. The second operation is dehusking or removal of the cobs from the maize plants. Threshing of the cobs and bagging of the grains are the concluding operations. The harvest of soybean also involves four steps. Cutting and gathering of the soybean plants is the first step. The second step is threshing which is done by beating the soybean plants and the haulms together with wooden sticks. Winnowing, an operation, which separates the grains from haulms with the help of the wind, is the next operation. This operation is aided with the prevalence of strong harmattan wind in the study area at this time of the year. Bagging of the grains is the last operation.

The actual costs of the various inputs (seed, manure and inorganic fertilizers) the farmers used were estimated. Where a farmer used own stock of seed, the prevailing local price in the village market was taken. In case of organic manure the actual and transportation costs to the farmers' fields was used. For the inorganic fertilizers the actual and the transportation costs were also used.

3.3.2 Determination of the labour cost.

Labour costs for planting, manure application, fertilizer applications and harvest were of two types: hired labour and family labour. The actual costs paid to the hired labourers were used, while in the case of family labour the opportunity cost was used. No female labour was involved in all labour operations except for threshing (shelling) and bagging which were costed on per kilogram of seed harvested. An eight-hour man-day was used for all labour operations. Two hundred and fifty naira (₦250) and eighty naira (₦80) respectively were used as the cost of adult and child man-day. These are average figures arrived at from the responses of the participating farmers in the trials.

3.3.3 General remarks about the calculations.

All the data on yields and the variable costs that appear in the partial budget analysis are the average of the pooled data of all the participating farmers in the demonstration and adaptation trials of 2003. The yield was scaled down by 5% on the assumption that though the trials were on- farm farmer managed trials, they still do not represent perfectly the farmers' environment and the farmers' practices because of the inherent competitions due to the awareness of farmers that they were participating in a trial thereby putting in their best.

The plot size of 0.125 hectare and 0.04 hectare recommended for the demonstration and adaptation plots was not adhered to by the participating farmers. Most of the 50 participating farmers did not adhere strictly to expert recommendations on manure and inorganic fertilizer application. All the fifty participating farmers in the trials were supposed to have the farmers own practice plots in their trials (for comparison with the three improved maize based BNMS technologies), but two and six farmers respectively in the demonstration and adaptation trials of 2003 did not have it.

3.4 Analytical Techniques.

The analytical tools used for the data were:

(i) Partial budget analysis to achieve Objective 1

(ii) Linear programming technique to achieve Objective 2

(iii)Scoring technique to achieve Objective 3

3.4.1 Partial budget analysis

Gross margin as a tool of analysis is essential where partial budgeting is conducted and fixed cost is not included in the analysis. Gross margin represents the most relevant economic indicator, which can be used to draw the attention of the farmer to the problems of his farm and offer possible solutions to them. According to Olukosi and Erhabor (1988), Gross Margin is given by:

GM = GR-TVC

Where; GM = Gross Margin (₦ per hectare)

GR = Gross Return (Quantity x Price) (₦ per hectare)

TVC = Total Variable Cost (Cost of material inputs + labour cost for all operations (₦ per hectare).

In calculating the "Gross Return (GR)", the crop yields (quantity) were scaled down by 5% because it was assumed that the trials had tremendous inputs from visiting scientists and so not totally on-farm trials.

3.4.2 Linear Programming.

The linear programming model was used to obtain the optimum farm plan for the introduced maize technologies.

Model Specification.

For maximizing profit, the linear programming was specified as follows below:

Maximize

$$Z = \sum_{j=1}^{n} C_j X_j \ (j=1,2\ldots n)$$

Subject to

$$\sum_{j=1}^{m} a_{ij} x_j \leq b_i \ (i = 1, 2\ldots m) \text{ and}$$

$$X_j \geq 0 \text{ for the } j\text{s}$$

Where:

Z = Objective function (Gross margin)

X_j = the activities: crop (maize) production, labour hiring, manure buying, fertilizer buying, seed buying and use of owned seed, selling and consumption activities.

C_j = Gross margin

b_i = Total amount of resource available (constraints)

a_{ij} = Resource requirement per unit of activity.

n = Number of activities

m = Number of resources

Activities in the initial LP model

The following activities were identified and included in the initial LP model:

(a) Crop production activities: The four maize production activities were included in the initial LP model (Appendix 1). These were:

(i) The farmers' practice of maize cultivation ($x1$ column).

(ii) Sasakawa Global 2000 maize cultivation practice ($x2$ column).

(iii) BNMS maize-manure practice ($x3$ column) and

(iv) BNMS maize-soybean practice ($x4$ column). This is maize planted in plots where soybean variety TGX 1448 E was planted the previous year to nitrify the soil.

The unit of production for each activity was one hectare.

(b) Labour hiring activities: This was shown in column $x5$ of the initial LP model. Their coefficients in the family labour row were negative meaning that an increase by one unit relaxes labour constraint by one unit. The activity unit was one man-day, which is equivalent to eight hours. The objective function column showed the wage rate per man-day (md). This was negative because it decreases the return by its value.

(c) Organic manure buying activities: The calculation of N supply from manure was based on the assumption that manure, on the average, contains 0.64% N per kilogramme (Diels et al., 2002). Price per kilogramme is the coefficient on the objective function while the coefficient in the row showed the N value present in the manure. Organic manure buying activity is in column x6 of the initial LP model.

(d) Fertilizer buying activities: Three brands of inorganic fertilizers were used in maize production in the study area. They are: NPK 20-10-10, Urea and Single Super Phosphate (SSP). According to Enwezor et al (1989), NPK 20-10-10, contains 20% N, 10% P_2O_5 and 10% K_2O. Urea contains 46% N while SSP contains 18% P_2O_5. The activity was included in the model to allow the farmer purchase from these different brands of fertilizers available in the market in order to meet its N, P and K nutrient requirements.

The coefficients in the objective function columns show the price per kilogramme of each fertilizer while the coefficients in the rows show the amount of each nutrient present in the fertilizer brand used. The fertilizer buying activities were shown in columns x7, x8 and x9 of the initial LP model.

(e) Seed buying and use of owned seed activities: Seeds from the farmers' farm (previous year's harvest) and direct purchases from the local markets were allowed in the optimum farm model. Columns x_{10} to x_{13} of the initial LP model showed the seed buying activities while the use of owned seed activities were shown in the model as columns x_{14} to x_{17}. For the seed buying activities the objective function has the value of the unit purchase price, which was negative and equal in value for all the four maize production activities. The negative values of the seed buying activities in the rows showed that it took from the resources available in the farm. For the use of owned seed, their objective function values were zeros since they have already been accounted for in the individual crop balance rows. Their values were also negative in the balance row meaning that the resources have been used up.

(f) Selling activities: Farmers sold their maize crop in the model. Crop selling activities were shown in columns x_{18} to x_{21} of the initial LP model. Sales were allowed after meeting the minimum consumption requirement of the family. The objective function values of each activity represent the unit selling price of the crop at their harvest time. Their values were positive on the maize production row meaning that resources had been added.

(g) Consumption activities: The initial LP model was restricted to maize consumption (columns x_{22} to x_{25}) from the farmer's farm only (excluding purchases from the markets). The objective function values for these were zero. The row values of consumption activities for maize crops produced on the farm were positive in both the maize production and home consumption rows. Most of the BNMS demonstration farmers were self sufficient in maize consumption and does not need to purchase.

Resource constraints in the model

Certain limiting factors often constrained farmers' in their production activities. In the model, the constraints identified were specified at some levels using maximum (≥), minimum (≤) and equality (=) signs depending on the circumstances. The resource constraints in the initial LP model were:

(i) Land constraint/restriction.

The upland farm was used mainly for the cultivation of maize and soybean crops in the project area. The limit of land available for cultivation in the study area was taken as the maximum farm size, which were 4.5 ha. The land constraint was row Y1 in the model.

(ii) Labour constraint.

Both family and hired labour were used for production activities in the project area. The amount of labour restriction was determined by adopting the method used by Ahmed (1995). The family labour was determined by the composition and size of the farm household. An average household was found to be made up of eight man equivalent (Table 3.3). Each man was assumed to be capable of working on the farm each day for eight hours for 30 days in a month. The available monthly man-hour was 1920 hours. The available monthly man-day was 240 man-days.

Due to fatigue, illness, traditional festivities and other incidentals, only 70% efficiency was assumed for available family labour in a month i.e. 168 man-days. The maize production activities last for 6 months (July-December). The restriction for family labour therefore was 1008 man-days. Family labour constraint is in row Y2 of the model.

(iii) Operating capital constraint

This was the amount used to buy the necessary production inputs (inorganic fertilizers, organic manure, and seeds) plus payment for hired labour. Operating capital used in this model was the total variable cost. This was so because for most of the farmers' in the zone, the fixed costs were little or nothing as they used mainly hand hoes, cutlasses and oxen for which depreciation charges were small. Moreover, the aim of this study was to compare introduced cropping technologies, which the total variable cost satisfies. The operating capital was in row Y3 in the model. The restriction level was ≤ 50,000, which was the average of resources available to farmers' in the study (average income from all sources available to the farmers).

(iv) Organic manure constraint.

Kilogramme (kg) was the unit of measurement of organic manure (row Y4 in the model). The quantity of O.M used was 5198 kg/ha containing 33 kg of N/ha. The restriction was therefore ≤ 149 N/4.5 ha.

(v) Inorganic fertilizer constraint.

SSP, NPK and Urea fertilizers were used. They occupy rows Y5 to Y7 in the model. The N, P and K in the various fertilizer brands were calculated. The farmers' practice used 129 kilogramme (kg) of N, 29 kg of P and 19 kg of K. The SG2000 used 147 kg of N, 35 kg of P and 25 kg of K. The BNMS-manure used 118kg of N; 28 kg of P and 19 kg of K. BNMS-maize/soybean used 88 kg of N, 30 kg of P, and 20 kg of K. Their restriction level was ≥zero (0).

(vi) Seed constraint.

The total quantity of maize seed used in kilogramme was entered into the model as row Y8. Their restriction level was ≥ 0.

(vii) Maize production constraint.

This restriction was introduced into the model to account for the total quantities of each of the maize practices. The restriction level was zero implying that all that was produced was sold after deducting the quantities consumed at home. The row coefficients showed the yield per hectare of the four maize practices. This was shown in row Y9 of the model.

(viii) Food consumption constraint

Hazel and Norton (1986) quoted by Ahmed (1995) stated two ways of representing food consumption in a linear programming model. One of the ways is to add lower bound constraint on the production of the required food crops. The family consumption of each crop is assumed to be fixed. The second way allows the amount of each food crop to be consumed to change with the change in the income of the farmer. This relationship is given by:

C: ∞ + By

Where

C: Annual consumption of each crop (kg)

∞= A constant representing the subsistent requirement for each crop (kg).

B= A constant representing marginal propensity to consume each crop (kg/₦)

y= Annual income of the household.

This second method though more realistic was found to be more difficult to use as it involves determining the value of consumption through the consumption function. The first method was therefore used in the model.

Information from the Food and Agricultural Organisation (FAO) and World Health Organisation (WHO) reports were used to determine the minimum requirement for each food crop. The report contained data on the minimum energy requirements for different categories of people and also the protein and energy contents of different food crops.

According to the report, an average adult of about 65kg body weight requires a minimum energy of 2,925 kilocalories daily or 1,070,550 kilocalories annually. The report showed further that a subsistence consumption of 1kg each of sorghum, maize and cowpea will supply 3,420, 3,610, and 3,470 kilocalories respectively to the body (FAO & WHO, 1973). Table 3.4 show the average consumption unit in a household.

Table 3.3: The average consumption unit in a household**.**

Age/Sex	No. in household	Consumption unit	Total consumption unit
Male adult	2	1.00	2
Male working youth	2	1.00	2
Female adult	3	0.75	2.25
Female working youth	1	0.75	0.75
Male child	1	0.50	0.50
Female child	1	0.50	0.50
Total	10		8

Source: survey data.

The following assumptions were made before arriving at the total consumption unit:

(i) That the male adult and male working youth consume equal amount of food.

(ii) That female adult and female working youth consume the same quantity of food but this amount is only about 75% of the male consumption.

(iii)That the male and female children consume the same quantity, which was assumed to be 50% of the male adult consumption.

(iv) Ahmed (1995) from a crop choice interview he conducted stated that the preference given to the consumption of sorghum, maize and cowpea were in the ratio of 50: 40: 10.

Based on these assumptions, the minimum quantity of maize needed per annum per household was estimated as bellow:

Maize (kg) = $1070550 \times 0.40 \times 8/3610 = 949$kg. This value was used as food consumption restriction (rowY10 in the model).

(viii) Balance row.

This row (Y11) was introduced to make sure that the total quantities of maize from the four maize cropping systems produced were accounted for in the model. The restriction level is zero.

3.4.3 The scoring technique

Through open-ended questions posed at the middle of the season, the farmers were asked to compare their own farmers' practice with the three improved maize technologies. At the end of the 2003 cropping season, the participating farmers were asked to assess each improved technology against eight criteria on a five point scale as follows: (0) completely disagree, (1) disagree, (2) indifferent, (3) agree, and (4) completely agree. A satisfactory score on a particular criterion was considered if the rating was greater or equal to 3. A score greater than 50% of the total mark attainable (32 points) corresponded to an overall positive appreciation of the technology.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. General characteristics of the participating farmers

4.1.1 Age distribution of farmers.

All the participating farmers in demonstration and adaptation were males. This was because of the Islamic tradition which restricts women from farm activities. Women were however involved in post harvest activities. The age of farmers in the demonstration trials was given in Table 4.1. The Table showed that 60% of the demonstration farmers were of the age range of 31-50 years. 35% of the demonstration farmers were above 50 years, while 5% were below 31 years. This means that most of the demonstration farmers were in the middle age category (60%).

Table 4.1: The age of Farmers in Demonstration and Adaptation trials.

	Demonstration trials		Adaptation trials	
Age range (years)	Number of farmers	Percentage	Number of farmers	Percentage
20-30	1	5	3	10
31-40	6	30	4	13
41-50	6	30	8	27
> 50	7	35	15	50

In the adaptation trials (Table 4.1), 40% of the farmers were of the age range of 31-50 years. Fifty percent of the adaptation farmers were above 50 years. Half of the adaptation farmers were above 50 years of age indicating that they are highly experienced in farming.

4.1.2 Average household size in the study area.

Table 3.4 shows the average household size as 10. This was broken down into male adult (two), male working youth (two), female adult (three), female working youth (1), male child (1) and female child (1). This shows that family labour may not likely be a limiting factor in production in the area as a high percentage of the household members were available for farm work.

4.1.3 Level of education of the participating farmers

Sixty percent of the demonstration farmers had western education, while only about one third (23%) of the adaptation farmers attained such a level of education. All the participating farmers were knowledgeable in the usage of local units of measures like “tiyas” and “mudus”.

Table 4.2: Level of education of participating farmers

Educational	Demonstration trials		Adaptation trials	
level	Frequency	%	Frequency	%
Koranic	6	30	23	76.67
GCE O’level & above	12	60	7	23.33
Nil	2	10	0	0

4.1.4 Land Holdings and Income of Farmers

The participating farmers on the average have four and half hectares to commit to their farming activities. The farmers also have ₦50, 000 on the average to invest in their maize farming activities with a maximum value of ₦85, 000 and a minimum value of ₦43, 000 leaving the standard deviation of the distribution at 9113. The monies come mainly from the sale of their previous year's crops.

4.2 Input use levels and yields in the trials.

The major inputs used in the trials were:

(1) Fertilizer and manure

(2) Seed

(3) Family and hired labour

4.2.1 Fertilizer and manure use levels:

The applied and recommended rates of fertilizer on demonstration trials are shown in Table 4.3. In the first fertilizer application the recommended rate of 450kg of NPK 20-10-10 was not complied with in the SG2000 treatments. Farmers on the average applied below 200kg of NPK 20-10-10 on their plots. One farmer used NPK 15-15-15. Urea and SSP fertilizers were used to augment the NPK 20-10-10 deficiency. The farmers' behaviour may be as a result of the high cost of fertilizers during the season.

The 123 and 128 kilograms of NPK 20-10-10 per hectare applied in the BNMS-manure and BNMS-maize plots respectively though not adequate are closer to the recommended rate of 200 kilograms of NPK 20-10-10 per hectare. Urea and SSP fertilizers were also used to augment the NPK 20-10-10 deficiency.

In the second fertilizer application the farmers surpassed the recommended application rate of 100 kilograms of Urea per hectare in all the three improved treatments of SG2000, BNMS-manure and BNMS-maize. Some farmers, in addition, applied NPK 20-10-10 and Urea. In the adaptation trials (Table 4.3), the quantities of NPK 20-10-10 applied during the first fertilizer application were so low compared to the recommended rates in the three improved treatments of SG2000, BNMS-manure and BNMS-maize. Urea was used at higher rates in both the BNMS-manure and BNMS-maize treatments may be due to high cost. It should be noted that three farmers used NPK 15-15-15 which is a different formulation from the recommended NPK 20-10-10.

In the second fertilizer application all the maize treatments (including the farmers' own practice) received more than the recommended rate of 100 kilograms of Urea per hectare. In addition the farmers' augmented with NPK and SSP fertilizers.

The average quantity of manure applied in the demonstration trials (5,198 kilograms per hectare) was below the recommended quantity of

6000 kilograms per hectare. Over 50% of the demonstration farmers fall within this group.

Table 4.3: Applied and recommended rates of fertilizer (kg/ha) in the trials

Treatment	Fertilizer type	Demonstration trials: fertilizer applications.		Adaptation trials: fertilizer applications.		Recommended Rates (kg/ha)
		1st	2nd	1st	2nd	
Farmers' practice	NPK 20-10-10	116 (91)	69 (39)	81 (61)	72 (56)	Farmers' choice
	Urea	78 (31)	123 (56)	78 (33)	102 (67)	Farmers' choice
	SSP	20 (9)	41 (0)	31 (0)	31 (0)	Farmers' choice
SG 2000	NPK 20-10-10	172 (149)	82 (37)	141 (120)	0 (0)	450
	Urea	88 (36)	121 (50)	56 (12)	131 (79)	100
	SSP	14 (0)	41 (0)	31 (0)	31 (0)	0
BNMS-manure	NPK 20-10-10	123 (112)	62 (41)	76 (58)	48 (25)	200
	Urea	71 (33)	106 (47)	78 (32)	112 (59)	100
	SSP	14 (0)	41 (0)	30 (1)	29 (1)	0
BNMS-maize/	NPK 20-10-10	128 (101)	76 (39)	44 (19)	71 (89)	200
	Urea	75 (33)	107 (49)	96 (40)	120 (47)	100
	SSP	14 (0)	41 (0)	29 (1)	29 (1)	0

Note: The figures in the brackets are the standard deviations

The average quantity of manure applied in the demonstration trials (Table 4.4: 5198 kilograms per hectare) was below the recommended quantity of 6000 kilograms per hectare. Over 50% of the demonstration farmers fall within this group. Adaptation farmers applied on the average 10,151 kilograms of manure per hectare in the trials. This was far more than the recommended rate of 6000 kilograms per hectare. The corresponding N supply is shown in Table 4.4.

Table 4.4: Quantity of manure applied per hectare in the trials.

Demonstration trials			**Adaptation trials**		
Average manure quantity (kg/ha) (Standard deviation)	Target quantity (kg/ha)	N-quantity (kg/ha) (min-max)	Average manure quantity (kg/ha) (Standard deviation)	Target quantity (kg/ha)	N-quantity (kg/ha) (min-max)
5198	6000	33	10,151	6000	65
(2874)		(6-81)	(1848)		44-110

4.2.2 Seed.

There was no significant difference in the quantity of maize seed planted in the demonstration trials (23kg, 21kg, 20kg and 19kg for the farmers practice, SG 2000 practice, BNMS-manure practice and BNMS-soybean/maize practice respectively). The quantity of seed planted in the adaptation trials ranged from 47 kilograms (SG2000 treatment), 42 kilograms (BNMS- soybean/maize treatment) to 36 kilograms per hectare in both BNMS-manure and farmers' own treatments. The farmers were supposed to follow the planting rates of SG 2000 practice, which is 17kg/ha.

4.2.3 Family and hired labour.

The actual amount paid by farmers to the hired labourers was taken as the hired labour cost in respect of the various labour operations in the different crop treatments. The family labour cost was calculated for the different labour operations using ₦250 per adult man-day and ₦80 per child-day. These were the average labour rates in the eight villages of both the demonstration and adaptation trials of 2003 cropping season. Labour charges for threshing and bagging of both the maize and soybean grains was by grain weight per bag.

4.3 Yield and Resource Use Levels for Each Technology

The three improved BNMS introduced technologies (SG2000, BNMS-manure and BNMS-soybean) all gave higher yield figures than the farmers' own practice of maize cultivation in the demonstration trials. This was expected. However, the BNMS-soybean production was incidental to the BNMS project. This treatment was added because soybean provides good income to the farm families in the study area.

The three improved technologies introduced (SG2000, BNMS–manure and BNMS-maize) gave higher yield than the farmers' own practice of maize cultivation in the adaptation trials also. It must be noted that the BNMS-soybean/maize technology was consistent in having the highest yield in both the demonstration and adaptation trials (Table 4.5).

Table 4.5 Yield data in the trials.

Technology	**Demonstration trials**		**Adaptation trials**	
	Average-yield (kg/ha)	Standard Deviation	Average-yield (kg/ha)	Standard Deviation
Farmers' practice	2111 (18)	984	2310 (24)	1287
SG 2000 practice	2635 (20)	1108	3300 (6)	1714
BNMS-manure practice	2963 (20)	1121	2955 (23)	1385
BNMS-maize/soybean practice	3166 (17)	1160	3412 (11)	1146
BNMS-soybean practice	1592 (5)	411	1674 (18)	462

Note: The figures in brackets are the number of farmers

Information on the productivity (yield and resource use levels) of the technologies is shown in Table 4.6 for the demonstration trials and 4.7 for the adaptation trials.

Table 4.6: Yields and resource use levels in the demonstration trials

Description	Treatments				
	Farmers practice	SG2000	BNMS-manure	BNMS-maize	BNMS-soybean
Average crop yield(kg/ha)	**2111(18)**	**2635(20)**	**2963(20)**	**3166(17)**	**1592(5)**
Family labour for planting (man-day/ha)	3(13)	4(12)	3(13)	3(9)	6(5)
Hired labour for planting(man-day/ha)	4(9)	4(10)	3(10)	3(9)	
Quantity of seed(kg/ha)	**23(18)**	**21(20)**	**20(20)**	**19(17)**	**58(5)**
Family labour for manure application(man-day/ha)			1(19)		
Hired labour for manure application(man-day/ha)			1(1)		
Quantity of manure(kg/ha)			**5198(20)**		
Family labour-1st fertilizer application(man-day/ha)	3(14)	4(16)	3(14)	2(12)	
Hired labour –1st fertilizer application(man-day/ha)	4(5)	3(6)	3(6)	3(6)	
Quantity of fertilizer-1st application(kg NPK/ha)	**116(16)**	**172(19)**	**123(19)**	**128(16)**	
Quantity of fertilizer-1st application(kg Urea/ha)	**78(5)**	**88(7)**	**71(7)**	**75(6)**	
Quantity of fertilizer-1st application(kg SSP/ha)	**20(2)**	**14(1)**	**14(1)**	**14(1)**	
Family labour-2nd fertilizer application(man-day/ha)	4(13)	2(13)	3(15)	3(11)	
Hired labour-2nd fertilizer application(man-day/ha)	2(6)	2(7)	2(6)	2(6)	
Quantity of fertilizer-2nd application(kg NPK/ha)	**69(7)**	**82(7)**	**62(7)**	**76(5)**	
Quantity of fertilizer-2nd application(kg Urea/ha)	**123(17)**	**121(19)**	**106(19)**	**107(17)**	
Quantity of fertilizer-2nd application(kg SSP/ha)	**41(1)**	**41(1)**	**41(1)**	**41(1)**	
Family labour-1st weeding (man-day/ha)	4(7)	6(11)	6(11)	6(10)	7(3)
Hired labour-1 weeding (man-day/ha)	6(11)	6(12)	6(12)	6(10)	5(3)
Family labour-2nd weeding (man-day/ha)	13(3)	16(2)	13(3)	13(3)	
Hired labour-2nd weeding (man-day/ha)	7(7)	7(6)	7(8)	7(6)	7(3)
Family labour-3rd weeding (man-day/ha)	6(9)	6(10)	5(10)	5(8)	5(3)
Hired labour- 3rd weeding (man-day/ha)	5(11)	4(12)	4(12)	4(10)	2(2)
Family labour for harvesting(man-day/ha)	5(8)	5(12)	4(12)	5(8)	8(5)
Hired labour for harvesting(man-day/ha)	9(15)	8(16)	7(16)	7(14)	12(1)
Average plot size (ha)	0.1112	0.1177	0.1195	0.1210	0.1153

Note: the figures in the brackets are number of farmers.

Table 4.7: Yields and resource use levels in the adaptation trials

Description	Treatments				
	Farmers' practice	SG2000	BNMS-manure	BNMS-maize/ Soybean	BNMS-Soybean
Average crop yield(kg/ha)	2310(24)	3300(6)	2955(23)	3412 (11)	1674 (18)
Family labour for planting(man-day/ha)	2(22)	5(5)	4(19)	6(11)	14(12)
Hired labour for planting(man-day/ha)	6(9)	5(2)	6(8)	7(6)	10(60)
Quantity of seed(kg/ha)	36(24)	47(6)	36(23)	42(11)	55(18)
Family labour for manure application(man-day/ha)			1(23**)**		
Hired labour for manure application(man-day/ha)			**-**		
Quantity of manure(kg/ha)			**10151(23)**		
Family labour-1st fertilizer application(man-day/ha)	2(21)	2(5)	3(23)	3(10)	
Hired labour-1st fertilizer application(man-day/ha)	3(4)	6(1)	1(2)	1(2)	
Quantity of fertilizer-1st application (kg NPK/ha)	**81(23)**	**141(6)**	**76(23)**	**44(11)**	
Quantity of fertilizer-1st application (kg Urea/ha)	**78(17)**	**56(3)**	**78(19)**	**96(11)**	
Quantity of fertilizer-1st application (kg SSP/ha)	**31(1)**	**31(1)**	**30(3)**	**29(2)**	
Family labour-2nd fertilizer application (man-day/ha)	2(14)	2(6)	3(13)	3(6)	
Hired labour-2nd fertilizer application (man-day/ha)	2(1)		2(1)	2(1)	
Quantity of fertilizer-2nd application (kg NPK/ha)	72(13)		48(14)	71(8)	
Quantity of fertilizer-2nd application (kg Urea/ha)	102(16)	128(5)	112(19)	120(9)	
Quantity of fertilizer-2nd application (kg SSP/ha)	31(1)	31(1)	29(2)	29(1)	
Family labour-1st weeding(man-day/ha)	14(15)	21(2)	11(12)	15(3)	14(10)
Hired labour-1st weeding(man-day/ha)	9(10)	12(4)	9(12)	7(8)	8(9)
Family labour-2nd weeding(man-day/ha)	10(13)	2(1)	11(10)	10(4)	10(7)
Hired labour-2nd weeding (man-day/ha)	10(8)	13(3)	9(11)	7(7)	8(7)
Family labour-3rd weeding(man-day/ha)	1(17)	3(4)	1(14)	1(6)	2(12)
Hired labour-3rd weeding(man-day/ha)	2(5)	1(2)	2(8)	2(5)	1(5)
Family labour for harvesting (man-day/ha)	6(23)	12(6)	7(20)	12(7)	11(14)
Hired labour for harvesting (man-day/ha)	11(7)		12(9)	10(7)	12(14)
Average plot size(ha)	**0.0420**	**0.0400**	**0.0418**	**0.**0440	**0.0403**

Note: The figures in brackets are the number of farmers.

4.4 Test of significance between the maize yields in the treatments

Results of the ANOVA analysis showed that there was enough variability in yields in the four maize treatments and soybean at one percent level of significance in the demonstration trials (Tables: 4.8). The establishment of significant variability in yields is necessary in order to establish if there are differences in the yields from the different treatments.

Table 4.8: Test of significance between maize yields in the demonstration trials

Source	DF (degrees of freedom)	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	17322130	4330532.5	3.78	0.0074
Error	75	85853937.4	1144719.2		
Corrected	79	103176067.4			

In the Duncan grouping, means with the same letter are not significantly different. The difference may be due to chance. Table 4.9 show that yields of BNMS-soybean/maize, BNMS-manure and SG 2000 maize treatments were not statistically (significantly) different from each other because they have a common letter A. In the same vein, yields of BNMS-manure, SG 2000 and the farmers' practice maize treatments on one hand and farmers' maize and BNMS-soybean were not statistically different from each other because of common letters B and C respectively. Yield of BNMS-soybean/maize was statistically different from yields of farmers' practice maize and BNMS-soybean. BNMS-manure's yield was also statistically different from BNMS-soybean.

Table 4.9: Duncan's Multiple Range Test for Values of maize yield on demonstration trials.

Treatment	N= Number of Farmers	Mean Yield (kg/ha)	Duncan Grouping
BNMS-maize/soybean (d)	17	3166.40	A
BNMS-manure (c)	20	2962.80	BA
SG 2000 (b)	20	2634.80	BA
Farmers' practice (a)	18	2110.70	BC
BNMS-soybean (e)	5	1592.30	C

There was enough variability in yields of the four maize treatments and soybean in the adaptation trials also at one percent level of significance as shown by the results of the ANOVA analysis and the Duncan's Multiple Range Test for values in Tables 4.10 and 4.11:

Table 4.10: Test of significance between maize yields in the adaptation trials

Source	DF (degrees of freedom)	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	30471565	7617891	5.25	0.0009
Error	77	111715623.40	14508552		
Corrected	81	142187188.30			

In the Duncan grouping, means with the same letter are not significantly different. Results in Table 4.11 shows that yields of BNMS-maize/soybean, SG 2000 and BNMS-manure maize treatments were not significantly different from each other because they have a common letter A. Like wise, yields of SG 2000, BNMS-manure and the farmers' practice maize treatments on one hand and farmers' maize and BNMS-soybean were not statistically different from each other because of common letters B and C respectively. Yield of BNMS-maize/soybean was statistically different from yields of farmers' practice maize and BNMS-soybean. SG 2000's yield was also statistically different from BNMS-soybean.

Table 4.11: Duncan's Multiple Range Test for values of maize yield on adaptation trials**.**

Treatment	N= Number of Farmers	Mean Yield (kg/ha)	Duncan Grouping
BNMS-maize/soybean (d)	11	3411.50	A
SG 2000 (b)	6	3300.30	BA
BNMS-manure (c)	23	2954.70	BA
Farmers' practice (a)	24	2310.30	BC
BNMS-soybean (e)	18	1673.70	C

4.5 Farm Gate Prices

Farm gate price for maize was calculated separately for the demonstration and adaptation farmers in the trials. This was because of the differences in the price of a 100-kilogram bag of maize in the eight villages of the BNMS trials at harvest. Twenty nine (29) of the thirty (30) adaptation farmers were in the three villages of Kaya, Fatika and Danayamaka where two thousand naira (₦2000) was the price paid for a

100kg bag of maize at the beginning of the season. One thousand six hundred naira (₦1600) was the price taken by the remaining adaptation farmers in the fourth adaptation village of Krosha.

Table 4.12 gives the prevailing prices of 100kg bag of maize at harvest during 2003 in the BNMS villages:

Table 4.12: Maize price at harvest in the study villages.

Village	₦/bag of 100kg	**Demonstration trials**		**Adaptation trials**	
		No. of farmers	Total Value ₦	No. of farmers	Total Value ₦
Kaya	2000	2	4000	14	28000
Fatika	2000	5	10000	4	8000
Danayamaka	2000	1	2000	11	22000
Buruku	2000	2	4000	-	-
Kufana	2000	2	4000	-	-
Krosha	1600	2	3200	1	1600
Kayarda	1600	2	3200	-	-
Garo	1500	4	6000	-	-
Total		20	36400	30	59600
Average			1820		1987

Table 4.13 shows the farm gate price of maize (demonstration and adaptation trials) and soybean. Soybean attracted a uniform price of ₦4000 per 100kg bag in all the eight villages. A uniform farm gate price was thus used for both the demonstration and adaptation farmers.

Table 4.13: Farm gate price of maize and soybean in the trials (naira)

Subject	Maize-demonstration trials	Maize-adaptation trials	Soybean-demonstration and adaptation trials
Market price of one 100 kg bag	1820	1987	4000
Cost of 1 jute bag	45	45	45
Cost of transporting 1 bag to the market	60	60	60
Farm gate price of one bag of maize	1715	1882	3895
Farm gate price/kg of	17.15	18.82	38.95

maize

4.6. Partial Budget Analysis.

The gross margin per hectare from the partial budget analysis for the demonstration trials (paid manure) were as follows: BNMS-soybean (₦41335), BNMS- soybean/maize (₦18462), SG 2000 (₦6834), BNMS-manure (₦5513) and the farmer's maize (₦-256) as shown in Table 4.14.

BNMS- soybean/maize with the highest gross margin of ₦18462 came out as the best of the introduced maize technologies in the demonstration trials of 2003. The SG2000, BNMS-manure and the farmers' own maize followed respectively in order of performance. The BNMS-manure though superior to SG 2000 in terms of gross return, has the highest variable cost of ₦42759 per hectare causing it to lag behind in terms of gross margin. The cost of fertilizer represented the bulk of variable cost, which accounted for more than 50% of the total variable cost.

Due to the fact that 75% of the demonstration farmers in 2003 got their manure free, a partial budget analysis assuming manure to be free was carried out. The result still shows BNMS-soybean/maize with the highest gross margin followed by BNMS –manure, SG 2000 and the farmer's maize in that order. The three introduced technologies proved their superiority over the farmer's maize practice.

Table 4.14: Partial budget analysis for the demonstration trials paid manure

	Farmers practice	SG 2000	BNMS-manure	BNMS-soybean/ maize	BNMS-soybean
Average yield (kg/ha)	**2110.74**	**2634.79**	**2962.80**	**3166.43**	**1592.35**
Adjusted yield (kg/ha)	2005.20	2503.05	2814.66	3008.11	1512.73
Farm gate price (₦/kg)	17.15	17.15	17.15	17.15	39.95
Gross return (₦/ha)	**34389.19**	**42927.31**	**48271.42**	**51589.04**	**58920.83**
Cost of seed (₦/ha)	1689.49	1647.53	1672.23	1660.16	7005.81
Cost of labour-planting (₦/ha)	1677.88	1531.62	1523.00	1664.19	2463.45
Costof labour-manure appl. (₦/ha)			275.28		
Cost of manure (₦/ha)			8292.65		
Transportation cost-manure (₦/ha)			2071.61		
Cost of fert-1st appl. (₦/ha)	9132.70	11284.46	7931.88	9169.47	
Cost of labour-1st fert. appl. (₦/ha)	1366.63	1278.70	1262.28	1343.09	
Cost of fert-2nd appl. (₦/ha)	9015.07	8615.23	7697.41	6852.83	
Cost of labour-2nd fert. Appl (₦/ha)	1042.13	900.68	875.43	948.17	
Cost of labour-weeding (₦/ha)	6544.90	5844.23	5922.07	5952.79	4782.69
Cost of labour-harvesting (₦/ha)	4176.00	4991.00	5235.00	5536.00	3331.00
Total variable cost(₦/ha)	**34644.81**	**36093.45**	**42758.82**	**33126.71**	**17585.95**
Gross margin (₦/ha)	**-255.62**	**6833.86**	**5512.59**	**18462.33**	**41334.88**

₦ = Naira

Table 4.15:Partial budget analysis for the demonstration trials free manure

	Farmers practice	SG 2000	BNMS-manure	BNMS-soybean/maize	BNMS-soybean
Average yield (kg/ha)	**2110.74**	**2634.79**	**2962.80**	**3166.43**	**1592.35**
Adjusted yield (kg/ha)	2005.20	2503.05	2814.66	3008.11	1512.73
Farm gate price (₦/kg)	17.15	17.15	17.15	17.15	39.95
Gross return (₦/ha)	**34389.19**	**42927.31**	**48271.42**	**51589.04**	**58920.83**
Cost of seed (₦/ha)	1689.49	1647.53	1672.23	1660.16	7005.81
Cost of labour-planting (₦/ha)	1677.88	1531.62	1523.00	1664.19	2463.45
Cost of labour manure appl. (₦/ha)			275.28		
Cost of manure (₦/ha)					
Transportation cost manure (₦/ha)					
Cost of fert-1st appl. (₦/ha)	9132.70	11284.46	7931.88	9169.47	
Costoflabour-1stfert.appl. (₦/ha)	1366.63	1278.70	1262.28	1343.09	
Cost of fert-2nd appl.(₦/ha)	9015.07	8615.23	7697.41	6852.83	
Costoflabour2ndfert.appl.(₦/ha)	1042.13	900.68	875.43	948.17	
Cost of labour-weeding (₦/ha)	6544.90	5844.23	5922.07	5952.79	4782.69
Cost of labour-harvesting (₦/ha)	4176.00	4991.00	5235.00	5536.00	3331.00
Total variable cost (₦/ha)	**34644.81**	**36093.45**	**32394.56**	**33126.71**	**17585.95**
Gross margin (₦/ha)	**-255.62**	**6833.86**	**15876.86**	**18462.33**	**41334.88**

₦ = Naira

Among the four maize based treatments in the adaptation trials (Table 4.16), BNMS- soybean/maize treatment confirmed its supremacy as the best from the partial budget analysis with a gross margin of

₦19784.59, followed by SG 2000 (gross margin ₦19614.51), Farmers' practice (gross margin ₦3730.15) and BNMS-maize manure (gross margin of - ₦7807.35). The poor performance of the BNMS-manure in the adaptation trials compared to the demonstration trials was partly due to the high cost of the over-applied manure. Two of the six farmers' in the SG2000 recorded extremely good yields (of over eight tons collectively).

Table 4.16: Partial budget analysis for the adaptation trials, paid manure.

	Farmers practice	SG 2000	BNMS-manure	BNMS-soybean/maize	BNMS-soybean
Average yield(kg/ha)	**2310.35**	**3300.29**	**2954.67**	**3411.51**	**1673.68**
Adjusted yield(kg/ha) 5%	2194.83	3135.28	2806.93	3240.93	**1590.00**
Farm gate price(₦/kg)	18.82	18.82	18.82	18.82	**38.95**
Gross return (₦/ha)	**41306.71**	**59005.97**	**52826.50**	**60994.34**	**61930.44**
Cost of seed(₦/ha)	2243.31	30500.00	2318.56	2031.38	**6308.82**
Cost of labour-planting(₦/ha)	1774.36	2362.85	2146.45	2082.68	**2926.00**
Costof labour- manure appl.(₦/ha)			647.27		
Cost of manure(₦/ha)			13896.93		
Transportation cost-manure(₦/ha)			5194.08		
Cost of fert-1st appl.(₦/ha)	10117.79	9270.83	9837.05	9015.02	
Cost of labour-1st fert.appl.(₦/ha)	916.13	1396.25	822.17	945.70	
Cost of fert-2nd appl.(₦/ha)	10356.73	8775	11440.26	12224.95	
Cost of labour-2nd fert.appl.(₦/ha)	490.22	383.05	542.79	701.81	
Cost of labour for weeding (₦/ha)	6638.03	7707.48	8098.29	8734.22	**7367.16**

Cost of labour-harvesting(₦/ha)	5040.00	5996.00	5690.00	5474.00	**3329.00**
Total variable cost(₦/ha)	**37576.57**	**39391.46**	**60633.85**	**41209.76**	**19930.98**
Gross margin(₦/ha)	**3730.15**	**19614.51**	**-7807.35**	**19784.59**	**41999.46**

The partial budget analysis assuming free manure in the adaptation trials was conducted because 20 out of the 23 adaptation farmers' representing 87% of the farmers that adopted the BNMS-manure practice used free manure. The result from this analysis gives the following gross margins: ₦41999, ₦19785, ₦19615, ₦11284, and ₦3730 in respect of BNMS-soybean BNMS- soybean/maize, SG 2000, BNMS-manure and farmers' own practice respectively (Table 4.17).

Table 4.17: Partial budget analysis for the adaptation trials free manure

	Farmers practice	SG 2000	BNMS-manure	BNMS-soybean/maize	BNMS-soybean
Average yield(kg/ha)	**2310.35**	**3300.29**	**2954.67**	**3411.51**	**1673.68**
Adjusted yield(kg/ha) 5%	2194.83	3135.28	2806.93	3240.93	**1590.00**
Farm gate price(₦/kg)	18.82	18.82	18.82	18.82	39.95
Gross return (₦/ha)	**41306.71**	**59005.97**	**52826.50**	**60994.34**	**61930.44**
Cost of seed(₦/ha)	2243.31	30500.00	2318.56	2031.38	6308.82
Cost of labour-planting(₦/ha)	1774.36	2362.85	2146.45	2082.68	2926.00
Cost of labour- manure appl.(₦/ha)			647.27		
Cost of manure(₦/ha)					
Transportation cost-manure(₦/ha)					
Cost of fert-1st appl.(₦/ha)	10117.79	9270.83	9837.05	9015.02	
Cost of labour-1st fert.appl.(₦/ha)	916.13	1396.25	822.17	945.70	
Cost of fert-2nd appl.(₦/ha)	10356.73	8775	11440.26	12224.95	
Cost of labour-2nd	490.22	383.05	542.79	701.81	

fert.appl.(₦/ha)					
Cost of labour for weeding (₦/ha)	6638.03	7707.48	8098.29	8734.22	7367.16
Cost of labour-harvesting(₦/ha)	5040.00	5996.00	5690.00	5474.00	3329.00
Total variable cost(₦/ha)	**37576.57**	**39391.46**	**41542.83**	**41209.76**	**19930.98**
Gross margin (₦/ha)	**3730.15**	**19614.51**	**11283.67**	**19784.59**	**41999.46**

4.7. Dominance analysis.

Results of the dominance analysis showed that BNMS-soybean/maize was superior to all the other three technologies in the demonstration trials because it has the least variable cost and the highest gross margin. The SG 2000 technology in the same vein was superior to the BNMS-manure (Table 4.18).

Table 4.18: Dominance analysis for demonstration trials, paid manure.

Treatments	Total variable cost (₦/ha)	Gross margin (₦/ha)
BNMS-soybean/maize	33127	18462
Farmers practice	34645	-256 D
SG 2000	36093	6834 D
BNMS-manure	42759	5513 D

Note: D = Dominated

The same dominance analysis was done, assuming free manure. In the free manure, BNMS-manure and BNMS- soybean/maize treatments proved more superior to the other two treatments of Farmers' practice and the SG 2000.

Table 4.19: Dominance analysis for the demonstration trials, free manure

Treatments	Total variable cost (₦/ha)	Gross margin (₦/ha)
BNMS-manure	32395	15877
BNMS-soybean/maize	33127	18462
Farmers treatment	34645	-256D
SG 2000	36093	6834D

Note: D = Dominated

BNMS-paid manure was inferior to all the other treatments in the adaptation trials. A marginal analysis was required to make a final recommendation on the remaining three systems (Table 4.20).

Table 4.20: Dominance analysis for adaptation trials, paid manure

Treatments	Total variable cost (₦/ha)	Gross margin (₦/ha)
Farmers practice	37577	3730

SG 2000	39391	19615
BNMS-soybean/maize	41210	19785
BNMS-manure	60634	-7807D

D = Dominated.

With free manure, BNMS-manure was still inferior to the BNMS-soybean/maize and SG 2000 practices. The farmers' practice was inferior to the BNMS-free manure practice (Table 4.21).

Table 4.21: Dominance analysis for the adaptation trials, free manure

Treatments	Total variable cost (₦/ha)	Gross margin (₦/ha)
Farmers' practice	37577	3730
SG 2000	39391	19615
BNMS-soybean/maize	41210	19785
BNMS-manure	41543	11284D

D = Dominated

4.8 Marginal rates of returns to each technology.

Results from the dominance analysis in the demonstration trials using paid manure showed that the BNMS-soybean/maize should be recommended because it proved superior to the other systems. Removing the BNMS- soybean/maize out of the analysis showed that SG 2000 treatment still dominated the BNMS-manure treatment. Therefore a marginal analysis was further conducted leaving out the dominated BNMS-manure treatment.

The marginal rate (MRR) of changing from farmers' practice to BNMS-maize/soybean is 1233%. This means for every ₦1 invested in changing from Farmers' practice to BNMS- soybean/maize, an additional 11.33 was gained. The calculation is shown below (Refer to item 13 Table 3.3 for formula for the calculation):

MRR: Farmers' practice- BNMS- soybean/maize = Gross margin BNMS-maize soybean-Gross margin Farmers' practice/ Total variable cost BNMS-maize soybean-Total variable cost Farmers' practice x 100.

$$= \frac{₦18462-(-256)}{(₦33127-₦34645)}$$

$$= \frac{₦18718}{₦1518}$$

= 12.33 0r 1233%.

The result from the dominance analysis showed that BNMS-free manure is the second best choice after the BNMS- soybean/maize. The results also show that moving from current farmers' practice to SG 2000 is still being very profitable.

Changing from the farmers' practice to the BNMS free manure gave a marginal return of 7.17 or 717% which also mean, for every ₦1 invested ₦6.17 was gained.

Changing from farmers' practice to SG2000 gives a marginal rate of return of 490% (a gain of ₦3.90 on every ₦1 invested in fertilizer and its procurement).

Results from the marginal rate of return in the adaptation trials showed the following:

Farmers' practice to BNMS-free manure............................190%

For every ₦1 invested in changing ₦0.90 is gained.

Farmers' practice to SG 2000...876%

For every ₦1 invested in purchasing and applying more fertilizer ₦7.76 is gained.

Farmers' practice to BNMS- soybean/maize 442%

For every ₦1 invested in the change ₦3.42 is gained.

4.9 Analysis of the linear programming model

The optimum farm model (LP model) provide information on the value of the objective function (gross margin in this case), optimum enterprise combinations, the resources used, the non-optimal activities with the cost of forcing each of such resources into the solution and the range of values over which the optimum plan holds.

4.9.1 Optimum farm plan of the maize practices

Table 4.22 shows the features of the optimum farm plan. The value of the objective function was ₦77,861 as against ₦18,462 in the unplanned farm. This represents the gross margin. Out of the four maize practices specified in the model, BNMS-soybean/maize practice was the only one accepted (feasible) in the optimum farm plan at 1.51ha land resource usage. All the other practices did not enter the optimum farm plan. Farm planning results in improved net income from the practices. Human labour hiring activity level was zero in the optimum farm plan because the family labour available was enough for maize production. The optimum farm derived its N, P and K nutrients by purchasing six bags of NPK 20-10-10 compound fertilizer, three bags of Urea and one and a half bag of single super phosphate at a total cost of ₦26,564. This cost excludes transportation and other handling charges.

The maize seed buying activity entered the optimum farm plan at zero level. This means that the farmers used their owned seeds from the previous year harvest. The total quantity of seed used was 29kg/ha with an estimated cost of ₦3,770. Of the four maize cropping activities in the optimum farm plan, only BNMS-soybean/maize was sold after the minimum family consumption allowed. A total of 4,540kg of maize was sold yielding net revenue of ₦77,861. The household consumption requirement specified for maize (949kg) was satisfied before the sale. If a farmer obtains the optimum farm plan, he would have satisfied both the food security and cash security goals.

The optimum production plan (Table 4.23) shows that 1.51 ha of BNMS- soybean/maize could be produced profitably with the restrictions imposed. Land use in the optimum farm plan was not a limiting factor because the total land available (4.5ha) was not completely used up in producing the feasible maize enterprise. The resources required for the enterprise were: 1.51 hectare of land, 24 man-days of family labour, ₦50, 000 operating capital, 133 kg of N, 45 kg of P, 30 kg of K and 29 kg of seed. Operating capital was a limiting factor as available capital (₦50, 000) was used up. Injection of more capital into the plan will generate more returns to the farmers.

Table 4.22: Optimum farm organization of the farm and the existing activity level.

Objective function/Real activity	**Existing Activity Level**
Objective function (Gross margin (₦/ha))	77,861
Real activities – maize/ha	
Farmers' practice	0.00
SG 2000 practice	0.00
BNMS-manure practice	0.00
BNMS-soybean/maize practice	1.51

Human labour hiring activity (man-day)	0.00
Fertilizer purchases (kg/ha)	
NPK 20-10-10	300
Urea	154
SSP	83
Seed buying (kg) – maize seed	0.00
Use of farmer's owned seed (kg/ha) – maize seed	29
Maize selling activity (kg)	
Farmers' practice	0.00
SG 2000 practice	0.00
BNMS-manure practice	0.00
BNMS-soybean/maize practice	4540
Maize consumption (kg)	949

The ₦50,000 capital is the average available money from all sources available to the farmers, which they were willing to put to maize production. The organic manure as a source of N and for stabilising the soil was zero. This means it did not enter the optimum plan. Organic manure use level in the BNMS-manure practice in the unplanned farm was 5,198kg/ha (33kg of N).

Table 4.23: Resource use levels in the optimum farm plan

ROW ID	RESOURCE	USED	SLACK
Y1	Land (ha)	1.51	2.99
Y2	Family Labour (md/ha)	24.15	980.85
Y3	Operati- ng capital (₦/ha)	50,000	0
Y5	N (kg/ha)	132.82	132.82
Y6	P (kg/ha)	45.28	45.28
Y7	K (kg/ha)	30.18	30.18
Y8	Seed (kg/ha)	28.68	21.34

Table 4.24 show the penalties for forcing into the optimum plan the excluded maize practices. If farmers' practice (X1), SG 2000 practice (X2), and BNMS-manure practice (X3) were forced in respectively, the return would be reduced by ₦39129, N26561 and ₦36626. Forcing hired labour into the optimum farm plan will result in ₦250 loss per man-day (₦31.25/hour) in income. The usage of organic manure in the optimum farm plan will reduce the farmer's income by three naira per kilogram (kg). Purchases of more NPK 20-10-10, Urea and super phosphate fertilizers will reduce the farmer's income by ₦56, ₦44 and ₦36 per kg respectively. Planting more maize seed in the optimum farm plan will reduce the farmers' income by ₦130/kg. Consumption of more maize seed in the optimum farm plan will reduce the farmers' income by ₦17.15/kg.

Table 4.24: Marginal Analysis of the unused resources/ activities

Activities	Returns/ha
X1(Farmers practice)	-39129
X2 (SG 2000)	-26561
X3 (BNMS-manure)	-36626
X5 (Labour hiring activity)	-250
X6 (Organic manure buying activity)	-3
X7 (Fertilizer buying activity-:NPK 20-10-10)	-56
X8 (Fertilizer buying activity-Urea)	-44
X9 (Fertilizer buying activity-SSP)	-36
X10-X13 (Maize seed buying activities)	-130
X22-x25 (maize consumption activities)	-17.15

4.9.2 Resource use efficiencies

The efficiencies of the farm resources were evaluated by comparing their marginal value products with their unit costs where possible as shown in Table 4.25. The marginal value products of resources are also the dual values of the solution are the same as the shadow prices of the linear programming model. The shadow prices of the disposal activities show the resources that could best be expanded in order to increase the income from the farm. The shadow prices show the productivity of each resource and thus, how the total income can be expanded by utilizing an additional unit of the resource. The values were zero for excess (slack) resources and positive for the limiting or constraining resources (Ahmed, 1995). Etuk (1979) stated that the more limiting a resource is, the higher is the marginal value product.

The resources with zero MVP values (land, family labour, organic manure, N, P, K and seed did not limit production in the optimum farm plan. They are all in excess. Operating capital was a limiting resource in the optimum farm plan. The MVP for capital in the area was ₦2.11. This means, increasing the operating capital will increase the net farm income to the farmers' by ₦2.11 per naira invested. The farmers' can go for borrowed capital with the commercial bank interest rates ranging between 20 and 30%. Public banks like the Nigerian Agricultural and Rural Development Bank (NARDB) lend at a rate below 10% of interest. Increasing maize production by one kilogram will increase the farm income of farmers in the study area by ₦17.15. The unit cost of production in the area is estimated to be ₦10.22, so the farmer should be advised to increase production.

Table 4.25: Marginal Value Products (MVP) and unit cost of the resources in the optimum farm plan.

Row	Resource	Unit	Marginal value product (₦)	Unit cost (₦)
Y1	Land	Ha	0.00	0.00
Y2	Family labour	Man-day	0.00	250
Y3	Operating capital	₦	2.11	0.22
Y4	Organic manure	kg	0.00	3
Y5	N	kg	0.00	56
Y6	P	kg	0.00	44
Y7	K	kg	0.00	36
Y8	Seed	kg	0.00	130
Y9	Maize production	kg	17.15	10.22

4.9.3 Sensitivity analysis

Due to the over 400% increase in the price of maize in 2003 and 2004 cropping seasons (price went up from ₦1,715 to as high as ₦9,000/100kg bag of maize), sensitivity analysis was carried out at two levels:

(i) Maize price was increased by 100%, and the operating capital restricted at ₦50000 was increased by 50% to ₦75000. This means that more money was available to the farmers to invest in production inputs like fertilizer and pay for labour. The result shows that BNMS-soybean/maize was accepted in the optimum farm. The net profit increased to ₦233,583 (6810kg of maize multiplied by ₦34.30). In the model, 43kg of owned was used. The cost of the owned seed used was ₦5,590/ha. The resource use level is shown on Table 4.26.

Table 4.26: Resource use levels in the optimum farm plan when maize price increased by 100% and operating capital by 50%

ROW ID	RESOURCE	USED	SLACK
Y1	Land (ha)	2.26	2.24
Y2	Family Labour (md/ha)	36.22	971.78
Y3	Operati-ng capital (₦/ha)	75000	0
Y5	N (kg/ha)	199.23	199.23
Y6	P (kg/ha)	67.92	67.92
Y7	K (kg/ha)	45.28	45.28
Y8	Seed (kg/ha)	43.02	43.02

The MVP (Table4.27) showed a return of ₦3.18 per naira (operating capital) invested in maize production (318%). There was a return of ₦34.30 per kilogram of maize sold.

Table 4.27: Marginal Value Products (MVP) and unit cost of the resources in the optimum farm plan when maize price increased by 100% and operating capital by 50%.

Row	Resource	Unit	Marginal value product (₦)	Unit cost (₦)
Y1	Land	Ha	0.00	0.00
Y2	Family labour	Man-day	0.00	250
Y3	Operating capital	₦	3.18	0.22
Y4	Organic manure	kg	0.00	3
Y5	N	kg	0.00	56
Y6	P	kg	0.00	44
Y7	K	kg	0.00	36
Y8	Seed	kg	0.00	130
Y9	Maize production	kg	34.30	10.22

(ii) Maize price was increased from ₦17.15 by 150% to ₦42.88/kg of maize. Operating capital was still restricted to ₦75000. The result still shows that BNMS-soybean/maize was accepted in the optimum farm. The net profit increased to N292,013. The model used 43kg of owned seed. The cost of the owned seed used was ₦5,590. The resource use level at this price and operating cost remains same as in Table 4.26.

However, the MVP for operating capital and maize were 4.45 and 42.88 respectively. This means that increasing the operating capital will increase net returns by ₦4.5 per naira invested while selling a kilogram of maize yield additional ₦42.88.

4.10 Farmers' Perception

During the mid-season interviews, the average response from the demonstration farmers was that the introduced technologies were superior to the farmers' practice in terms of crop yield. The problem of the high cost of inorganic fertilizers in the season made the SG 2000 maize practice to be less appealing to the farmers. This perception was confirmed at the end of the season when none of the farmers agreed with the statement that the fertilizer input in the SG2000 technology was affordable (Table 4.28). It is significant to note that 95% of the farmers indicated that they would use the soybean/maize and maize-manure technologies again, while only 50% of the farmers would use the SG2000 system again. A similar contrast was found on the auto-diffusion (automatic diffusion of the technologies). While both the maize-manure and soybean/maize technologies received an overall good appreciation by all farmers, some weaknesses of the maize-manure technology clearly came out. Many felt that it does not suppress weeds (whereas the soybean/maize rotation does), and a few felt that the manure input is not available and affordable. Most farmers indicated that the maize-manure technology suppresses *Striga hermontica*, unlike the SG2000 system. It is possible because maize grows faster under organic manure and since fast growth suppresses weed, the striga may have no effect on the crop even where they are present.

The BNMS-soybean/maize rotation was perceived to be a very good technology because of the high price of soybean grains throughout the season and also, it has low input cost since fertilizer was not used.

Table 4.28: Overall appreciation of the technology in the demonstration trials (% score).

Criterion	**SG 2000 (n=20)**	**BNMS-manure (n=20)**	**BNMS-maize/soybean (n=20)**
Yield of maize/ha	75	90	90
Soil fertility: Current season	20	95	100
Soil fertility: Next season	15	95	100
Suppression of weeds	20	35	90
Suppression of striga	5	80	85
Diffusion to others	50	95	95
Own use in future	50	95	95
Affordability of inputs	0	75	95

Input concerned is	(fertilizer)	(manure)	(soybean seed)

n= number of farmers who participated in the scoring.

The adaptation farmers like the demonstration farmers during the mid-season interviews, acknowledged the superiority of the three introduced technologies their own practice in terms of crop yield as their general response. The high cost of inorganic fertilizers during the 2003 cropping season made the SG 2000 maize practice to be less appealing to them. This perception was confirmed at the end of the season when none of the farmers agreed with the statement that the fertilizer input in the SG2000 technology was affordable (Table4.29). All the farmers in the adaptation trials indicated that they would use the soybean/maize and maize-manure technologies again, while only 33% said they would use the SG2000 technology.

Perception on automatic diffusion of the introduced technologies was the same for the use. All the farmers agreed that they would tell their family members, friends and neighbours about both the BNMS-maize/soybean and BNMS- manure technologies, while 33% will tell about SG 2000 technology. This was in spite of the obvious inability of the BNMS-manure practice to suppress weeds.

About 17% and 27% of the farmers felt that SG 2000 and BNMS-manure practices respectively suppress weeds, while 83% felt BNMS-maize/soybean practice suppress weeds. That the availability and affordability of inorganic fertilizer and manure got very low appreciation (zero and 36%) among adaptation farmers should be of great concern to the change organization (BNMS).

Table 4.29: Overall appreciation of the technology in the adaptation trials (% score)

Criterion	**SG2000 (n=5)**	**BNMS-manure (n=23)**	**BNMS-maize/ soybean (n=29)**
Yield of maize/ha	50	96	100
Soil fertility: Current season	0	95	96
Soil fertility: Next season	0	91	92
Suppression of weeds	17	27	83
Suppression of striga	29	77	92
Diffusion to others	33	100	100
Own use in future	33	100	100
Affordability of inputs	0	36	72
Input concerned is	(fertilizer)	(manure)	(soybean seed)

n= number of farmers who participated in the scoring.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

That BNMS-soybean came out as the best technology in terms of gross margin. Among the four maize based technologies, BNMS-soybean/maize treatment came out as the best with the highest gross margin of ₦18,462 and dominated all the three other treatments in the paid manure trials.

BNMS-manure came out as the second best technology based on the partial budget analysis in the free manure scenario. The Duncan test confirmed that there was a significant difference between the yields of BNMS-soybean/maize and the farmers' practice.

Inorganic fertilizer costs accounted for more than 50% of the total variable cost of inputs used for maize production during the 2003 maize cropping because of its very high prices.

The optimum farm utilised 1.51 ha to produce BNMS-soybean/maize and with a net return of ₦111,760. The farmers' practice was the least profitable of the four maize technologies. The optimum production plan also used 24.15 man-days (193.2 man hours) of family labour, ₦50000 operating capital, 132.82kg of N, 45.28kg of P, 30.18kg of K and 28.68kg of maize seed.

The marginal value product (MVP) showed that the operating capital was a limiting factor in maize production in the area, and that about 4,892kg of maize should be sold to get the optimum return.

Majority of the demonstration farmers perceive the yield of maize in the introduced technologies as satisfactory. A very high percentage of the farmers perceive both the BNMS-soybean and the BNMS-manure to have positive short and long term desirable effect on soil fertility. The farmers believed that the nitrifying effect of the previous crop of soybean and the organic manure added value to the soil in both the long-run and the short-run.

Ninety and 85% of the farmers believed that BNMS-soybean suppresses weed and striga growth respectively. This means that growing soybean on the plot of land and applying organic manure reduce the striga and weeds prevalence.

Automatic diffusion of both the BNMS-soybean/maize and the BNMS-manure technologies were observed among the farmers. There was an overall acceptance of both the BNMS-soybean/maize and BNMS-manure technologies and a near rejection of the SG 2000 technology.

About 64% of the adaptation farmers disagreed with the notion that manure is available. Similarly, none agreed that fertilizer is available and affordable.

5.2 Conclusion

The three introduced maize technologies proved to be better than the farmers' practice of maize cultivation in terms of yield. The BNMS-soybean/maize technology was chosen in the optimum farm plan as it has the best yield out of the three maize technologies.

The combined information from the farmers' perception in the demonstration and the adaptation trials illustrates clearly the positive interest of farmers in both the BNMS-soybean/maize treatment and BNMS-manure treatment over SG 2000 treatment. Furthermore, the farmers' perception indicates the most important constraints and weaknesses of each treatment, from the farmers' point of view.

5.3 Recommendations

The following are the recommendations based on the empirical findings from the study:

(i) The farmers should be enlightened to adopt the maize after soybean practice because of its productivity and profitability.

(ii) The existence of a soybean seed industry and favourable policy would boost the adoption of the new cultivars and would complement agricultural research efforts in developing a sustainable soybean-based economy in Nigeria.

(iii) Government should provide the enabling environment for investors to establish fertilizer-blending plants to bring down the price of inorganic fertilizers and production of fertilizer types that are targeted at some specific areas.

(iv) Extension agents should liaise with farmers to ensure that the organic manure used by the farmers' are of high quality. Organic manure should not be stored in open fields till the rainy season is about to set in before it is taken and spread on the field.

(v) Farmers should be enlightened on how to go about obtaining easy and timely loans from Nigerian Agricultural and Rural Development Bank to enhance their operating capital base.

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Appendices

Appendix 1: Crop production, labour hiring and organic manure buying activities in the initial LP model.

		Farmers' practice $x1$	SG 2000 $x2$	BNMS-manure $x3$	BNMS maize/ soybean $x4$	Labour hiring activity $x5$	Organic Manure Buying $x6$	Sign	RHS
Constraint/Objective		-256	6834	5513	18462	-250	-3	=	0
Row	Unit								
Y1	Ha	1	1	1	1			≤	4.5
Y2	Md	16	16	16	16	-1		≤	1008
Y3	₦	34645	36093	42759	33127			≤	50000
Y4	kg			33			-0.0064	≤	149
Y5	kg	129	147	118	88			≥	0

Y6	kg	29	35	28	30	≥	0
Y7	kg	19	25	19	20	≥	0
Y8	kg	23	21	20	19	≥	0
Y9	kg	-2005	-2503	-2815	-3008	=	0
Y10	kg					≤	949
Y11	kg	1	1	1	1	≥	0

Appendix 2 explain the rows.

Appendix 1 continue:

			Fertilizer buying activities			Seed buying activities				Use of owned seed activities				Sign	RHS
			x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17		
Objective function			-56	-44	-36	-130	-130	-130	-130	0	0	0	0	=	0
Function	Row	Unit													
N	Y5	kg	-0.20	-0.46										≥	0
P	Y6	kg	-0.10		-0.18									≥	0
K	Y7	kg	-0.10											≥	0
Seed	Y8	kg				-1	-1	-1	-1	-1	-1	-1	-1	≥	0

Appendix 1 continue:

			Selling activities				Consumption activities				Sign	RHS
			x18	x19	x20	x21	x22	x23	x24	x25		
Objective function			17.15	17.15	17.15	17.15	0	0	0	0	=	0
Function	Row	Unit										
Maize production	Y9	kg	1	1	1	1	1	1	1	1	≥	0
Home consumption	Y10	kg					1	1	1	1	≤	949

Appendix 2

Rows in the initial LP model (Appendix 1)

Y1 – Land

Y2 – Family labor

Y3 – Operating capital

Y4 – N in organic manure

Y5 – N

Y6 – P

Y7 – K

Y8 – Maize seed

Y9 – Maize production

Y10- Home consumption