

**ECONOMIC ANALYSIS OF SORGHUM-BASED CROPPING SYSTEMS IN
GARKO LOCAL GOVERNMENT AREA OF KANO STATE OF NIGERIA**

BY

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DECLARATION

I hereby declare that this thesis titled “**Economic Analysis of Sorghum-based Cropping Systems in Garko Local Government Area of Kano State of Nigeria**” has been written by me and it is a record of my research work. No part of this work has been presented in any previous application for another degree or diploma at any institution. All borrowed ideas have been acknowledged in the text and a list of references provided.

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CERTIFICATION

This thesis titled “**Economic Analysis of Sorghum-based Cropping Systems in Garko Local Government Area of Kano State of Nigeria**” by Seun Akinloye

OLADEJI meets the regulations governing the award of the degree of Masters of Science (Agricultural Economics) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to Almighty God and my daddy, The Very Reverend (Dr.) Dele Oladeji.

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ABSTRACT

The study examined the economic analysis of sorghum-based cropping systems in Garko Local Government Area of Kano State, Nigeria. A two-stage sampling technique was used to select 160 respondents. Primary data were collected using structured questionnaire. The data were analysed using descriptive statistics, gross margin analysis and stochastic frontier production analysis. The results showed that the six predominant sorghum-based enterprises in the study area in terms of percentage of farmers who were involved in these cropping systems were sole sorghum (S) (31.25%), sorghum/groundnut (S/G) (21.87%), sorghum/millet (S/M) (15.63%), sorghum/maize (S/Mz) (12.50%), sorghum/cowpea (S/C) (10%) and sorghum/millet/cowpea (S/M/C) (8.75%). The results of average levels of inputs used in the sorghum-based enterprises showed that for farmland, farmers cultivated more farmland for sole sorghum (29.06%) and the least land for S/M/C (8.75%). For seed, S/C had the highest seed rate (40 kg grain equivalent and sole sorghum had the least (12 kg grain equivalent/ha). For labour, S/M had the highest labour use per hectare (128 man-hours) and S/G had the least (70 man-hours). For fertilizer, sole sorghum had the highest quantity of fertilizer use per hectare (152 kg) and S/M/C the least (72.72 kg). For pesticide, S/G had the highest pesticide use per hectare (2 litres) and S/M/C the least (0.53 litres). In terms of output, sorghum/maize had the highest output per hectare of 749.55 kg grain equivalent and the least was sorghum/groundnut (469.70 kg grain equivalent). The results of stochastic frontier production function analysis showed that for sole sorghum, farm size, labour and fertilizer were positively and significantly related to output. For S/G enterprise, seed, fertilizer, and pesticides were positively and significantly related to output. For S/M enterprise, farm size, labour and seed were significantly related to output. For S/Mz enterprise, farm size, seed and fertilizer were significantly related to output. For S/C enterprise, farm size, labour and fertilizer were significantly related to output, and for S/M/C enterprise, farm size, labour, fertilizer, and pesticide were positively and significantly related to output. The results of the determinants of technical inefficiency in sorghum enterprises showed that for sole sorghum, farming experience, membership of cooperatives and amount of credit were significantly related with technical inefficiency. For S/G, age, household size and education were significantly related with technical inefficiency. For S/M, household size, membership of cooperatives and amount of credit were significantly related with technical inefficiency. For S/Mz, age, household size, and farming experience were significantly related with technical inefficiency. For S/C, farming experience, education and amount of credit were significantly related with technical inefficiency and for S/M/C, education, membership of cooperatives and amount of credit were significantly related with technical inefficiency. The results of the frequency distributions of technical efficiencies in sorghum enterprises showed that the mean technical efficiency for sole sorghum was 87%, for S/G 77%, for S/M 89%, for S/Mz 93%, for S/C 87% and for S/M/C 72%. The results of the gross margin analysis showed that S/G enterprise was the most profitable with a gross margin of ₦21,965 per hectare and an average rate of return of 2.00, and the least profitable was S/M enterprise with a gross margin of ₦13,950 per hectare and an average rate of return of 1.51. The most important constraints associated with sorghum-based cropping systems in the study area were; inadequate credit (28.90%), high cost of fertilizer (23.12%), high cost of hired labour (20.23%) and poor storage facilities (11.56%).

CHAPTER 1

INTRODUCTION

1.1 Background

The principal variations in agricultural production in Nigeria arise from climatic differences. Four major ecological areas with homogenous agricultural conditions can be identified: two savanna areas in the northern part of the country (Sudan savanna and Guinea savanna), the forest savanna in the middle belt, and the rain forest areas in the southern part of the country (ICRISAT, 1980).

The farming systems that have emerged over the years have been shaped by the interaction of factors such as (i) tradition, (ii) level of technology (hand labour, capital, use of oxen, etc.), resource availability (land, labour, capital, managerial skill, etc.), (iv) physical environment, (temperature, water availability, etc.) and (v) economic conditions (markets, storage facilities, transportation, etc.) (ICRISAT, 1980).

Sorghum is one of the most extensively grown cereal grains in the country (Aba *et al.*, 2004). About 50% of the total area devoted to cereal crops in Nigeria is occupied by sorghum (Aba *et al.*, 2004). The area, estimated at 6.86 million hectares, extends north – wards from latitude 8⁰N to latitude 14⁰N (Aba *et al.*, 2004). In 1978, the total sorghum production in Nigeria was estimated at 4.8 million tonnes but the figure has risen to about 7.0 million tonnes annually (Obilana, 2005).

Nigeria is the highest sorghum producer in the West African sub-region, accounting for 71% of the regional total sorghum output (USGRAIN, 2014). Globally also, the country rose from its fifth position in 1995 to be the third largest producer of sorghum in the world after the USA and India (Foraminifera, 2012). The crop is environmentally-friendly, requires little or no fertilizers or pesticides and is biodegradable (FAO, 1995).

In the savanna and semi – arid regions of Nigeria, millions of people consume sorghum in their daily diets as staple food (USAID, 2007). These foods are high in energy and are therefore recommended for infants, pregnant and lactating mothers, the elderly and the convalescent (Obilana, 2005).

Sorghum is adapted to a wide range of ecological conditions and can be grown under conditions which are unfavourable for most of the cereals (Onwueme and Sinha, 1991).

Sorghum-based cropping systems in which sorghum is the major crop are found predominantly in the sub- humid or savanna zones of West and Central Africa (Obilana, 2005).

1.2 Statement of the Problem

Available statistics have shown that while Nigeria's overall food demand has been growing at a rate of 3.5% per annum, food production has been growing at a rate of 2% per annum, thus creating a serious food gap (Shaib *et. al.*, 1999). At the national level, the main food problems are food supply deficits, poverty and uneven distribution of income in terms of ability to buy food (Ohajianya, 2004). Inadequate food production has resulted in reduced export earnings, large food imports, shortage of raw materials for industries, and increased inflationary pressure (CBN, 2011).

Sorghum is a source of staple food for most communities as well as a good source of income when sold. Though there is no official figure on the national demand and supply of sorghum in Nigeria, the local demand is more than the current local supply, owing to the increasing demand from local industries in Nigeria (Foraminifera Market Research, 2012). A lot of factors are responsible for this, some of which are the poor production systems adopted by farmers in growing sorghum, wrong combination of

resources, wrong tillage practices and wrong intercrop (Dixon *et al.*, 2001).

A poorly chosen intercrop may have the following effects: competition with sorghum, yield reduction, and contamination of the main crop (Elemo *et al.*,1990). This study investigated the economics of sorghum – based cropping systems in Garko Local Area of Kano State. The study addressed the following research questions:

- (i) What are the sorghum-based cropping systems in the study area?
- (ii) What are the input and output levels of these sorghum-based enterprises?
- (iii) What is the technical relationship between inputs and output for the different sorghum-based enterprises?
- (iv) What are the determinants of technical inefficiency in sorghum-based enterprises?
- (v) What are the levels of technical efficiency in the sorghum-based enterprises?
- (vi) What are the costs and returns for the sorghum-based enterprises?
- (vii) What are the constraints associated with the sorghum–based cropping systems in the study area?

1.3 Objectives of the Study

The broad objective of this study is to examine the economics of sorghum-based cropping systems in the study area. The specific objectives are to:

- (i) identify and describe the sorghum-based cropping systems in the study area.
- (ii) estimate the input and output levels for the sorghum-based enterprises.
- (iii) estimate the technical relationship between inputs and output for the sorghum-based cropping systems.
- (iv) estimate the determinants of technical inefficiency in sorghum-based cropping systems.
- (v) determine the technical efficiencies in the sorghum-based enterprises.

- (vi) evaluate the costs and returns for the sorghum-based enterprises.
- (vii) identify and describe the constraints associated with the sorghum-based cropping systems.

1.4 Justification of the Study

The general objective of farmers is sustainable production at reasonable levels and at minimal risk, to satisfy subsistence and commercial needs (Beets, 1990). According to Akinwunmi (2011), sorghum has greater untapped potentials than any other crop. The crop is also drought-tolerant with a high potential yield, which plays an important role in tropical Africa and elsewhere, especially as a source of food and fodder (Brink and Belay, 2006). In view of this, this study seeks to provide information on production efficiency in sorghum-based production systems and to identify the most profitable sorghum-based enterprises.

Farmers need to have a proper understanding of the sorghum-based enterprises that are most profitable because farmers with limited resources have limited capacity to tolerate failure in production (Alabi, 2012). The study will also provide insights for policymaker, non-governmental organizations and international organizations on the problems associated with sorghum-based production systems in the farmers' socio-economic environment.

1.5 Hypotheses.

The following hypotheses were tested:

- i. There is no technical relationship between inputs and output in sorghum-based production enterprises.
- ii. Sorghum-based enterprises are not profitable.

CHAPTER 2

LITERATURE REVIEW

2.1. World Production and International Trade in Sorghum

Sorghum grain is the fifth most important cereal in the world after wheat, rice, maize and barley (Brink and Belay, 2006). In Africa, it comes second after maize in terms of production. According to FAO estimates, the average world production of sorghum grain in 1999-2003 amounted to 57.7 million tonnes per year from 22.8 million hectares. The production in sub-Saharan Africa was 19.0 million tonnes/year from 42.6 million ha. The main producing countries are the United States (12.0 million t/year in 1999-2003 from 3.2 million ha), India (7.6 million t/year from 9.8million ha), Nigeria (7.6 million t/year from 9.8 million ha), India (7.6 million t/year from 9.8 million ha), Nigeria (7.6 million t/year from 6.9 million ha). Mexico (6.0 million t/year from 1.9 million ha), Sudan (3.4 million t/year from 5.3 million ha), Argentina (3.0 million t/year from 630,000 ha), China (3.0 million t/year from 690,000 ha), Ethiopia (1.4 million t/year from 1.1 million ha) and Burkina Faso (1.3 million t/year from 1.4 million ha) (Brink and Belay, 2006). In sub-Saharan Africa, annual production increased from around 10 million tonnes from 13 million ha in the early 1960s to about 20 million tonnes from 25 million ha in the early 2000s (Brink and Belay, 2006).

Almost all sorghum traded on international markets is for use as livestock feed. Average world exports of sorghum in 1998-2002 amounted to 6.3 million t/year, almost all from the United States (5.6 million t/year) (Brink and Belay, 2006). The main importers are Mexico and Japan. In tropical Africa, most sorghum is grown for home consumption (except for beer production). In southern and eastern Africa, malting sorghum for beer brewing has developed into a large-scale commercial industry, using about 150,000 tonnes of sorghum grain annually. In Uganda, commercial production of lager beer using

sorghum instead of barley is becoming a great success (annual requirement of sorghum is 3000 tonnes) and is very promising for other African countries (Brink and Belay, 2006).

In Nigeria, sorghum malting has become a major industry for lager and stout beer brewing and for malt beverages, using 15,000 tonnes of sorghum annually. In South Africa, an instant breakfast cereal is made from sorghum that is similar in quality but much cheaper than wheat or maize products. Annual production is 12,000 tonnes and is increasing steadily (Brink and Belay, 2006). In West Africa, small tied bundles of 4-6 leaf sheaths of sorghum dye cultivars are offered for sale on local markets (in the 1990s the price was about 150 CFA). In 1993 in Burkina Faso, the red pigment was successfully extracted chemically from sorghum leaf sheaths and offered for sale as dry powder on the world market (Brink and Belay, 2006).

2.2. Sorghum Area, Production and Yield in Nigeria

Table 1 shows the area planted, production and yield of sorghum in Nigeria from 1990 to 2010. There was an increase in the area planted from 1990 to 2008, but this decreased in 2009 and 2010. Also, production increased from 1990 to 2006, but declined between 2007 and 2010.

Table1: Area, Production and Productivity of Sorghum in Nigeria (1990-2010.)

Year	Area ('000 hectares)	Production ('000 tonnes)	Productivity (tone per hectare)
1990	4185	4185	1.000000
1991	5538	5367	0.969122
1992	5474	5909	1.079572
1993	5605	6051	1.079572
1994	5738	6197	1.079993
1995	6045	6997	1.157486
1996	6191	7514	1.207163
1997	6589	7954	1.273435
1998	6635	8401	1.266164
1999	6678	8504	1.273435
2000	6885	8824	1.2299581
2001	6437	8365.4	0.980012
2002	6849	6712.1	0.980012
2003	6935	9460.8	1.421476
2004	7031	9994.4	1.421476
2005	7284	10593.6	1.454366
2006	7308	11239.1	1.537917
2007	7812	9058	1.1599821
2008	7617	9318	1.2233162
2009	4737	5270	1.1125184
2010	4736	4784	1.0101351

Sources :Tanko and Olowogbaya (2010); FAOSTAT, 2010: www.fao.org

2.3 Sorghum Cropping Systems in the Nigerian Savanna

A cropping system refers to the crop production activity of a farm. It comprises all cropping patterns grown on the farm and their interaction with farm resources, other household enterprises and the physical, biological, technological, and socio-economic factors or environments (Elemo *et al.*, 1990).

The sorghum cropping systems in the Nigerian savanna, identified by Elemo *et al.* (1990) are:

(i) Sahel Savanna

Millet is the most important crop of the Sahel agro-ecological zone and it is the staple food crop. The most important crop mixture is millet/sorghum. Crops like rice, wheat and vegetables are grown on irrigation schemes. The soil is generally sandy and planting is on the flat with minimum land preparation.

(ii) Sudan Savanna

In this sub-zone, most predominant crop mixtures are sorghum/millet/cowpea, millet/cowpea, and sorghum/millet. Groundnut may or may not be included in each of these mixtures. The Gicci system of crop production is wide spread.

(iii) Northern Guinea Savanna

Although this area is dominated by sorghum, millet and cowpea, maize is now becoming important. The major sorghum crop mixtures in this zone are sorghum/millet, maize/sorghum and sorghum/cowpea.

(iv) Southern Guinea Savanna

The sorghum, maize and millet - based systems are predominant in the northern part of the Southern Guinea savanna. The major sorghum mixtures include sorghum /maize/groundnut, sorghum/millet, maize/sorghum and sorghum/groundnut.

(v) Derived Guinea Savanna

This sub-zone is dominated by yam/cassava based system. Other crops include sweet potatoes, sesame, pigeon peas, sorghum, groundnut and rice.

The important sorghum crop mixtures are maize/sorghum, and sorghum/groundnut.

2.4 Advantages of Mixed Cropping

The advantages of mixed cropping are as follows:

- (i) Mixed cropping gives higher total yields than sole cropping even if yields of individual components are reduced.
- (ii) Mixtures result in more efficient utilization of environmental resources (light, water, nutrients) by plants of different height, canopy structure, nutrient requirements and maturity. In addition, diseases and pests may not spread as rapidly in mixtures because of differential susceptibility to the pests and pathogens.
- (iii) Mixed cropping provides insurance against crop failure because if a component crop fails, the other may not.
- (iv) Effective coverage is provided for the soil by crop mixtures while erosion and exposure of soil to solar radiation is minimized.
- (v) It also provides a steady supply of a range of products for the family and helps to spread labour costs more evenly throughout the cropping season
- (vi) Mixed cropping may be used to suppress weeds, thereby reducing the cost of weed control and improving the quality of product (Elemo *et al.*,1990).

2.5 Uses of Sorghum

Sorghum is an important staple food, particularly in semi-arid tropical regions of Africa

and Asia, and an important feed grain and fodder crop in the Americas and Australia. In the simplest food preparations, the whole grain is boiled (to produce a food resembling rice), roasted (usually at the dough stage), or popped (like maize). More often the grain is ground or pounded into flour, often after hulling. Sorghum flour is used to make thick or thin porridge, pancake, dumplings or couscous, opaque and cloudy beers and non-alcoholic fermented beverages. In Africa, sorghum grain is germinated, dried and ground to form malt, which is used as a substratum for fermentation in local beer production. White grain is generally preferred for cooking, while red and brown grains are normally used for beer making (Brink and Belay, 2006).

In China, sorghum is extensively distilled to make a popular spirit and vinegar. Sorghum grain is a significant component of cattle, pig and chicken feeds in the United States, Central and South America, Australia and China, and is becoming important in chicken feed in India. It requires grinding, rolling, flaking, or steaming to maximize its nutritional value. Several non-edible sorghum cultivars are exclusively grown for the red dye present in the leaf sheaths and sometimes also in adjacent stem parts (Brink and Belay, 2006).

In Africa, this dye is used particularly for goat-skin leather (e.g. in Nigeria), but also for mats, textiles, strips of palm leaves and grasses used in basketry and weaving, ornamental calabashes, wool (e.g. in Sudan), as a body plant and to colour cheese and lick stones for cattle (e.g. in Benin). A similar dye can be extracted from the grain refuse (glumes and grain wall) of several red sorghum cultivars grown for food or for beer –making (Brink and Belay, 2006).

In Nigeria, the red sorghum dyes were traditionally used by the Bunu, Aworo, Igbira and Okpella people for a fabric called ‘abata’ used as a funeral hanging, decorated with

patterns made by thick threads added to the weft of the fabric. The fabrics in which the dominant colours were derived from sorghum were known as 'ifala'. Sorghum is also used to provide the violet colours decorating the masks worn during certain dances by Yoruba people in southern Benin and in South-western Nigeria (Brink and Belay,2006).

In Cote d'Ivoire, sorghum and other tannin-rich dyes are used in combination with mud to create the patterns of the painted cloths produced in the Korhogo region. The dye was formerly exported to Morocco where it was used in the leather industry (Brink and Belay, 2006).

In China, sorghum types with red panicles and leaf sheaths were also used for dyeing. In the 19th century red sorghums were exported to Europe where the dye was known as 'carmin de sorgho'. It was extracted by squeezing out the juice. Which was then fermented used with wool or silk mordanted with tin or chrome, the result was a colour fast red-brown that was once known as 'rouge badios'. 'Dura red' a similar product, was imported from India into the United Kingdom where the dye was known as 'Hansen brown' or 'Meyer Brown'. Recently the use of sorghum dye in hair dyeing products has been patented (Brink and Belay, 2006).

The stems of sweet sorghum types are chewed like sugar cane and, mainly in the United States, a sweet syrup is pressed from them. In North America and eastern Europe special types with very long, fibrous and few –seeded inflorescences known as 'broomcorn' are grown to make brooms. Sorghum plant residues are used extensively as material or roofing, fencing, weaving and as fuel. The stems can be used for the production of fibre board. Danish scientists have made good panelling using stem chips of sorghum. The stover remaining after harvesting the grain is cut and fed to cattle, sheep and goats, or

may be grazed. Some farmers grind harvested stover and mix it with sorghum bran or salt to feed livestock. Sorghum is also grown or forage, either for direct feeding to ruminants or for preservation as hay or silage. Sorghum flour is used to produce an adhesive in the manufacture of plywood. Sweet sorghum is suitable for the production of alcohol, while the bagasse is a suitable source of paper pulp for the production of kraft paper, newsprint and fibre board. (Brink and Belay, 2006).

Sorghum has various applications in African traditional medicine: seed extracts are drunk to treat hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are included in plant mixtures for decoctions against anaemia. The Salka people in northern Nigeria use sorghum in arrow –poisons, The red pigment is said to have antimicrobial and antifungal properties and is also used as a cure for anaemia in traditional medicine (Brink and Belay, 2006).

2.6 Resource Productivity and Efficiency in Agriculture

Agricultural productivity may be defined as the index of the ratio of the value of total farm output to the value of the total inputs used in farm production (Olayide and Heady,1982). Since one of the chief objectives of any society is the attainment of an optimally high level of living with a given amount of effort, any increase in the productivity of resources employed in farm production amounts to progress. Increases in agricultural productivity will contribute to the well being of the economy as a whole. Aggregate measures of productivity in production economics analyses will add to the sum of our knowledge by (a) serving as barometers of economic progress, (b) serving as guides to adjustment of resources, (c) providing a framework for formulating and evaluating policy and (d) indicating problem areas that need further research (Olayide and Heady,1982). The final objective of our interest in productivity should be to find

ways of increasing output per unit of input, and of attaining desirable inter-firm, intra-firm, and inter-sector transfers of production resources, thereby providing the means for raising our economic level of living.

The input-output process of farm production resources is important in at least four major problem areas. These are the distribution of income, the allocation of resources, the relation between stocks and flows, and the measurement of efficiency or productivity (Olayide and Heady,1982). In the productivity concept, a meaningful assessment will depend upon a clear and precise definition of input and output in such a way that their movements over time are not equal. It is also important to determine which inputs and outputs are consistent with the particular productivity concept in question. Thus, we are faced with separate and distinct conditions when we direct our efforts to, say, the measurement of labour or capital, or land, or water or management productivity. In other words, resource productivity is definable in terms of individual resource inputs or in terms of a combination of them. Using this definition as a bench-mark, change in productivity over time will depend upon changes in both the “included” and “excluded” components and maximum resource productivity will imply obtaining the maximum possible output from the minimum possible set of inputs. In this context, optimal productivity of resources implies an efficient utilization of resources in the production process. This means that productivity and efficiency are synonymous in this context (Olayide and Heady,1982).

An increase in farm output will result from one of three forces. First it will result from an increased quantity of inputs, with no change in output per unit of input. Second, it will result from an increased productivity of inputs with no change or decrease in quantity of inputs. Thirdly, it will result from a combination of changes in inputs and productivity.

This situation makes the concept of efficiency a central issue in production economics (Olayide and Heady,1982).

Several attempts have been made to define economic efficiency and to measure it in an empirical sense. Most of these definitions have foundered in one way or another. However, (Farrell, 1957) has defined economic efficiency in an admirably accepted form, but his definition defies precise measurement. His definition of efficiency is couched in three –related terms.

First, he defines “technical” efficiency as the measure of a firms’ success in producing maximum output from a given set of inputs. It indicates all those undisputed gains that can be obtained by simply gingering up the management. Second, he defines “price” efficiency as the measure of a firm’s success in choosing an optimal set of inputs. This is an indication of the gains that can be obtained by varying the input ratios on certain assumptions about future price structure. Third, he defines “overall” efficiency as the simple product of the technical and the price efficiencies (Olayide and Heady,1982).

Efficiency measure as the average productivity of say labour, capital, land, water, e.t.c. can only be a meaningful index of technical efficiency if any one of the resources is limiting in the production process. Index of efficiency, measured as the weighted average of all inputs compared with output is replete with index number problems and hence is not a dependably meaningful measure of technical efficiency. The use of cost comparisons in the production process as an index of technical efficiency has limited applicability where all farms or plants do not face the same factor prices. In situations where all farms of plants face the same factor prices, cost comparisons constitute a much better criterion than productivity, and are therefore equivalent to the best “efficiency

index” (Olayide and Heady,1982).

If we cannot obtain a universally acceptable yardstick for measuring technical efficiency, which is of interest in resource productivity, we can at least specify certain necessary conditions for the attainment of technical efficiency. Heady (1952) specifies eight technical conditions for attainment of economic efficiency. These are:

- (i) The marginal rate at which factor is transformed into product must be the same for any pair of farms using the same for any pair of farms using the same factors and producing the same product.
- (ii) The marginal rate of substitution between any pair of factors must be the same for any two farms using both factors to produce the same product.
- (iii) The marginal rate of substitution between two factors must be the same for every product in which they are used.
- (iv) The marginal rate of substitution between any two products must be the same for any two farms producing both products.
- (v) The marginal rate at which two crops substitute as products on one farm must be equal to the marginal rate at which they substitute as factors on another or the same farm.
- (vi) Marginal rate of substitution must be equal between (a) the income and direct utility (leisure) of a resource, in production, and (b) the income and direct utility of a resource in consumption for any single resource owner and between resource owners.
- (vii) Marginal rate of substitution of products in time or resources in time must be equal for all farms which produce or use both.

- (viii) Price ratios must equal substitution and transformation rates in all cases such that
- (a) the factor-product price ratios equal the marginal rate at which factor is transformed into product ,
 - (b) the product –product price ratio is equal to the marginal rate of substitution of any two commodities,
 - (c) the factor –factor price ratio is equal to the marginal rate of substitution between any pair of factors,
 - (d) the discounted price ratio is equal to the substitution ratio for one product produced at two points in time, and
 - (e) the compounded price ratio is equal to the substitution ratio for two resources extending into time.

Attainment of maximum efficiency is only possible if the eight conditions outlined above are simultaneously satisfied. A simultaneous attainment of these physical conditions will allow a maximum product from a given stock of resources, or conversely, a minimum input of resources for a given output of product (Olayide and Heady, 1982).

The eight conditions outlined above are necessary but not sufficient conditions for efficiency in resource use to be attained. This is due to the fact that eight conditions do not guarantee that a maximum product is forthcoming from a given stock of resources, or, otherwise, that a given output is being produced with a minimum of factor services. Maximum efficiency will be guaranteed if single products are produced under conditions of decreasing returns (or increasing costs) and if commodities produced in combination are never produced within ranges of complementary and supplementary relationships. In other words, the factor – product and the production possibility curves must be concave to the origin in the relevant area of equilibrium for each producing unit. Unless the eight necessary conditions and the sufficient conditions are all attained simultaneously, resources are not efficiently used, and this implies that they can always be arranged to allow (with given and limited resources) a greater total output of the products desired by

the consuming society.

If the goals of efficiency are specifically the reorganization of resources and the maximization farm income, then it is necessary to isolate the main causes of inefficiency in farm production process (Olayide and Heady, 1982).

Inefficiency may be due to endogenous and/or exogenous factors. These factors fall into three main categories. First, there are factors explaining why the resources of an individual farm are not organized to maximize the value of the product. Second, there are those which explain why the return on resources differs between agricultural areas. Third, there are those which seek to explain why the value of the product of agricultural resources is low relative to that of certain other occupations, and /or less than the maximum for the resources employed in the industry. These three categories when analysed in detail lead to an isolation of the specific causes of inefficiencies, we list these causes as (Olayide and Heady, 1982):

- (i) Lack of knowledge of alternative techniques and resource organizations.
- (ii) uncertainty and capital limitations coupled with net product of labour in relation to capital.
- (iii) The hypothesis that resource returns in primary or extractive industries, such as agriculture, are continually pressing below those of secondary industries, such as manufacturers.
- (iv) Institutions serving as adjustment base may precipitate inefficiency, e.g. creation of homesteads and pre-emption units in the southern Nigeria, the feudal structure of northern Nigeria, etc. Useful education directed precipitate inefficiency
- (v) The low income structure of family farms and the complexities of rural life and farm-household complex.

- (vi) The labour supply function in agriculture in relation to non-agriculture, and the level of investment in the human agent, coupled with tribal restraints as well as problems of migration.
- (vii) The degree of competitiveness or otherwise of markets for goods, services and products.
- (vii) The structure of costs and returns to society, due to regional differences in resources productivity, as well as the allusive structure of an efficient agriculture (Olayide and Heady, 1982).

Each of these specific causes constitutes broad areas of research, and discussion topics on modernizing peasant agriculture to enhance increased productivity. It is, however, necessary to outline some positive steps in reducing inefficiency in resource utilization in the production process. These steps will, among others, include the following (Olayide and Heady, 1982):

- (i) The minimization of risk and uncertainty in farming enterprise.
- (ii) Useful education directed at increasing productivity and adoption of new techniques on small-income farms.
- (iii) Provision of credit for acquisition of capital and expansion of farm size.
- (iv) Provision of employment outlook services, coupled with job training and transfer assistance.
- (v) Introduce steps that will try to successfully eliminate differences in costs and returns for the individual and the community.
- (vi) Integration of agriculture and industry in agribusiness framework and introduction of corporate and part-time farming.

2.7. Measurement of Profitability.

Costs and returns analysis is the basis for the measurement of profitability of farm enterprises. The procedure involves itemizing the various costs of inputs and returns from the production. More often, the values obtained are further tested statistically to verify differences between the values. Furthermore, monetary units should be used as the basis for measuring all inputs and outputs in cost and returns analysis for cropping systems (Olukosi and Erhabor, 2008).

2.7.1 Gross margin analysis

Gross margin analysis forms the basis for farm profitability analysis. It involves accurate collection of costs of variable inputs and the gross income obtained from a particular enterprise (Bernard, 2003). Essentially, gross margin is a budgeting tool used to estimate total variable costs of production and total revenue. Gross margin is the difference between gross income and total variable cost. It is a very useful planning tool in situations where fixed capital is a negligible portion of the farming enterprise as is the case in subsistence agriculture (Olukosi and Erhabor, 2008). Variable costs vary according to output and are incurred on variable inputs which can be attributed to specific enterprises. Costs incurred on variable inputs vary in proportion to the level of output, for example, cost of hired labour, maintenance costs, crop expenses and utilities. The variable cost is a major component in the derivation of gross margin. The gross farm income, also called total value of production, is the total physical product multiplied by the unit price of the product. The formula is:

$$\text{Gross Margin (GM)} = \text{GI} - \text{TVC}$$

Where:

GM = Gross margin (Naira/hectare)

GI = Gross Income (Naira /hectare)

TVC= Total Variable Cost (Naira/hectare)

2.7.2 Net farm income

The Net Farm Income (NFI) is determined by subtracting the total fixed cost (TFC) from the total gross margin (TGM) of the whole farm or all the enterprises (Olukosi and Erhabor, 2008). The total cost (TC) of production comprises two component parts – fixed costs (FC) and variable costs (VC), that is, $TC = FC + VC$. Fixed costs are those costs incurred on fixed inputs which cannot be used up during one production process such as depreciation on machinery and buildings, wages of permanent staff, interest on debt and property tax. Fixed cost is used to calculate the net farm income from the gross margin (Olukosi and Erhabor, 2008).

That is,

$$NFI = TGM - FC$$

Where:

NFI = Net farm Income (Naira /hectare)

TGM = Total Gross Margin (Naira/hectare)

FC = Fixed Cost (Naira /hectare)

2.8 Constraints to Increasing Agricultural Productivity in Nigeria

The major constraints to increasing agricultural productivity in Nigeria are as follows (Okigbo, 1994):

2.8.1 Physio-chemical

These are climatic or soil related.

2.8.1.1 *Climatic constraints*

- (i) unreliability of rainfall in onset, duration, cessation and intensity
- (ii) unpredictable periods of drought and flood/storms
- (iii) high temperatures which sometimes exceed 40⁰C and are detrimental to crops or biological, technological processes
- (iv) rapid rates of decomposition of organic matter
- (v) high rates of evapotranspiration and several months of moisture deficit
- (vi) inadequate water supplies for livestock and human use

2.8.1.2 *Soil-related constraints*

- (i) highly weathered soils of low inherent fertility
- (ii) low CEC and the presence of low activity clays in the colloidal complexes
- (iii) soils prone both to water and to wind erosion on removal of vegetation
- (iv) soil nutrient deficiencies especially related to phosphorus, nitrogen, sulphur, etc.
- (v) deficiency of calcium, magnesium, boron, molybdenum under increased cropping intensity
- (vi) poor physical structure under continuous cultivation
- (vii) high rates of leaching under intense rain
- (viii) structural management problems in general or specifically associated with vertisols in the region
- (ix) salinization problems may occur in drier parts of the region under irrigation.
- (x) poor drainage or water-logging in hydromorphic soils covering large areas
- (xi) presence of hardpan and laterite in some areas

2.8.2 Biological constraints

- (i) low productivity and adaptation potentialities in a large number of genetically unimproved crops and livestock
- (ii) susceptibility of crops and livestock to diseases and pests
- (iii) rapid losses of biodiversity in indigenous food crops and land races
- (iv) presence of several endemic parasitic diseases of livestock and man
- (v) problems of parasitic weeds such as striga in maize and cowpea
- (vi) problems of weeds and water borne diseases in irrigated areas
- (vii) environmental stresses and changes brought by human development activities and over-grazing
- (viii) activities, overgrazing which upset the dynamic ecological balance in the prevailing ecosystem
- (ix) parasitic diseases of ruminants such as East Coast fever and trypanosomiasis
- (x) unimproved forage of low nutritive value and low productivity

2.8.3 Technological constraints

- (i) inadequate human resources development and institutional capacity in research and development (R and D)
- (ii) lack of knowledge of , and neglect of traditional technologies as a basis for designing and testing new ones
- (iii) inappropriate technologies not sustainable in agriculture in the region
- (iv) limitations in basic knowledge about the environments necessary to ensure rapid progress in sustainable management of environmental resources
- (v) ineffective management of research and information required in research and development

- (vi) ineffective use and integration of tradition and existing/emerging technologies
- (vii) farming systems and technologies more adapted to uplands than to lowlands

2.8.4 Socio-economic constraints

- (i) rapid population growth and increasing pressures on the land
- (ii) unfavourable land tenure systems
- (iii) shortage of labour at peak periods of production
- (iv) lack of credit
- (v) high levels of illiteracy and superstition
- (vi) low income of farmers and the resultant lack of money to purchase inputs
- (vii) poor rural infrastructure including roads and transportation facilities
- (viii) inadequate prices and poor marketing services
- (ix) poor extension services
- (x) political instability
- (xi) inadequate policies for creating a favourable environment for Rand D
- (xii) low allocation of funds to research and development in agriculture
- (xiii) decline in commodity prices for over a decade.

CHAPTER 3

METHODOLOGY

3.1 Description of the Study Area

The study was conducted in Garko Local Government Area of Kano State of Nigeria. Garko Local Government is located between latitudes $11^{\circ} 14'$ North of the equator and longitudes $8^{\circ} 24'$ East of the Greenwich meridian (Falola, 2002). It has its headquarters in Garko. Garko is in the southern part of Kano State, about 50 kilometres from Kano metropolis. It is one of the 44 Local Government Areas in Kano State. It has a total population of 161, 966, comprising 82,025 males, and 79,941 females (NPC, 2006). Garko LGA is surrounded by Wudil, Takai, Warawa, Gaya, and Sumaila Local Government Areas.

Garko has two seasons: the dry season and rainy season. The dry season starts from October to April and the rainy season from May to September. It is part of the Sudan Savanna zone of Nigeria with mean annual rainfall ranging from 780 mm to 1000 mm. Temperature varies sharply, depending on the season, reaching up to 38°C and 40°C when it is hot and as low as 25°C in the cold season.

Majority of people in Garko are farmers, traders and artisans. The crops cultivated in the area include sorghum, millet, maize, wheat, rice, groundnut and vegetables. Animals reared include cattle, goats, sheep and fowls.

3.2 Sampling Technique and Sample Size.

A two-stage sampling technique was used for the selection of respondents. The first stage involved purposive selection of six villages out of twelve villages from the Local Government, based on the predominance of sorghum-based cropping systems in the

villages. The villages selected were Garko, Gurjiya, Maida, Kafin-Malamai, Lamire and Buda. A reconnaissance survey conducted with village extension agents from Kano State Agricultural and Rural Development Authority (KNARDA) identified the farmers who grew sorghum as sole crop and in combination with other crops. From the population of farmers involved in sorghum-based enterprises in each selected village, proportional sampling method was used to select 160 respondents from the selected villages (Table 2).

Table 2: Distribution of sorghum-based farmers in the study area.

Local Government	Villages Selected	Sample Population*	Number of Farmers Selected
GARKO	Garko	262	26
	Gurjiya	215	22
	Maida	294	29
	Kafin Malamai	320	32
	Lamire	254	25
	Buda	260	26
	Total	1604	160

*Based on reconnaissance survey, 2011.

3.3 Method of Data Collection.

For the purpose of this study, only primary data were used, based on the 2011 cropping season. Primary data were collected using structured questionnaire. The data collected included the following:

- (i) land area cultivated in hectares for each sorghum – based cropping system (ha)
- (ii) quantity of seeds planted (kg) and the cost (₦)
- (iii) quantity of herbicides and pesticides (litres) and the cost (₦)
- (iv) quantity of fertilizer (kg) and the cost (₦).

- (v) labour used for different farm operations (man-hours) and the cost (₦)
- (vi) output (kg) realized from component crops in the sorghum – based cropping systems and their sales (₦).
- (viii) problems of sorghum-based production systems.

3.4 Analytical Techniques.

Data collected were analyzed using the following tools:

3.4.1 Descriptive statistics.

This involved the use of percentages, means and standard deviations. These were used to achieve objectives (i), (ii), and (vi).

3.4.2 The Stochastic frontier production function.

This was used to achieve objectives (iii) and (iv). The explicit form of the empirical stochastic frontier production model was specified as follows (Tanko and Opara, 2010) :

$$L_n Y = \beta_0 + \beta_1 L_n X_1 + \beta_2 L_n X_2 + \beta_3 L_n X_3 + \beta_4 L_n X_4 + \beta_5 L_n X_5 + (V_i - U_i) \text{-----(1)}$$

Where:

Y = Output of sorghum (Kilogramme for sole sorghum and Kilogramme grain equivalent for sorghum mixtures).

X₁ = Farm size (hectares)

X₂ = Seed (Kilogramme/Kilogramme grain equivalent)

X₃ = Labour (man-hours)

X₄ = Fertilizers (Kilogramme)

X₅ = Pesticides (litres)

β₀- β₅ = Co-efficients to be estimated

L_n = Natural logarithm

V_i's = are assumed to be independent and identically distributed normal random errors, having zero mean and unknown variance.

V² and U_i's are the technical inefficiency effects which are assumed to be independent of V_i's such that U_i is the non – negative truncation (at zero) of the normal

distribution with mean U_i and variance U^2 . Where U_i defined by :

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} \text{ -----(2)}$$

Where:

U_i = Technical efficiency of the i^{th} farmer

Z_1 = Age of the farmer (years)

Z_2 = Household size (number)

Z_3 = Farming experience (number of years)

Z_4 = Level of education (number of years spent in school)

Z_5 = Membership of cooperatives (years)

Z_6 = Amount of credit (Naira)

δ_0 = Constant

δ_1, δ_6 = Co-efficients to be estimated

3.4.4 Gross margin analysis.

This was used to achieve objective v, that is, to estimate the costs and returns, hence the profit or loss in sorghum-based enterprises. Gross margin is expressed as:

$$GM = TR - TVC$$

Where: GM = Gross Margin (₦/hectare)

TR = Total revenue (₦/hectare)

TVC = Total Variable Cost (₦/hectare).

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Sorghum Cropping Systems in the Study Area

The sorghum cropping systems found in the area in terms of the number and percentage of farmers who were involved in these cropping systems are shown in Table 3. The most popular was sole sorghum (31.25%), followed by sorghum/groundnut (21.87%) and sorghum/millet (15.63%). The least popular was sorghum/millet/cowpea (8.75%).

The popularity of sole sorghum as the preferred cropping system may be due to the fact that faced with limited supply of inorganic nitrogen fertilizers, sorghum as a sole crop is given priority by farmers (Ogungbile et al.,1999). These findings agree with those of Ogungbile et al. (1999) who found that the most important cropping systems in terms of occurrence on farmers' fields in Kano State were sole sorghum (30.7%), groundnut (16.7%), cowpea (14.3%) and millet (14%).

Table 3. Sorghum cropping systems by percentage of farmers in the study area.

Sorghum-cropping systems	Frequency	Percentage
S	50	31.25
S/G	35	21.87
S/M	25	15.63
S/MZ	20	12.50
S/C	16	10.00
S/M/C	14	8.75
Total	160	100.00

Key: S = sole sorghum, S/G = sorghum/groundnut, S/M = sorghum/millet, S/MZ = sorghum/maize, S/C = sorghum/cowpea and S/M/C = sorghum/millet/cowpea.

The results also showed that there were more farmers who grew sorghum in mixture with other crops (68.75%) than those who grew sorghum sole (31.25%). Those who intercropped sorghum with other crops could have done so because of the advantages of

intercropping which include higher total yields than sole cropping, more efficient utilization of environmental resources (light, water and nutrients), insurance against crop failure, and reduced spread of diseases and pests (Elemo *et al.*, 1990).

4.2. Input and Output levels of Sorghum-based Cropping Systems in the Study Area.

4.2.1 Average input levels per hectare

4.2.1.1 *Sizes of farmland cultivated for sorghum cropping systems.*

Table 4 shows the sizes of farmland cultivated for the different sorghum cropping systems in the study area. The results showed that farmers cultivated more farmland for sole sorghum (29.06%), followed by sorghum/maize (19.51%), sorghum/groundnut (17.74%) and sorghum/millet (16.78%). The least land was cultivated for sorghum/millet/cowpea (8.75%). These findings agree with those of Ogungbile *et al.* (1999), who found that some of the most important cropping systems in Kano State in terms of land occupancy were sole sorghum (14%), sorghum/cowpea (10.7%), sorghum/rice (10.3%) and sorghum/millet (9%).

Table 4. The total sizes of farmland cultivated for various sorghum cropping systems.

Sorghum-based cropping systems	Total farm size (hectares)	Percentage
S	213	29.06
S/G	130	17.74
S/M	123	16.78
S/MZ	143	19.51
S/C	68	9.28
S/M/C	56	7.64
Total	733	100.00

4.2.1.2 Seed

Table 5 shows the average quantity of seed input used per hectare in the study area. Sorghum/cowpea enterprise had the highest average seedrate (40 kg grain equivalent/ha), followed by sorghum/millet/cowpea enterprise (28 kg grain equivalent/ha) and sorghum/millet (27 kg grain equivalent). Sole sorghum had the least average seed rate of (12 kg grain equivalent/ha).

Table 5. Average quantities of seed per hectare for sorghum cropping systems in the study area.

Sorghum enterprises	Sorghum (kg)	Groundnut (Kg)	Millet (Kg)	Maize (Kg)	Cowpea (Kg)	Kilogramme grain-equivalent
S	20.00					12.00
S/G	11.70	6.00				13.62
S/M	28.33		14.71			27.00
S/MZ	16.67			8.00		16.00
S/C	50.00				8.93	40.00
S/M/C	19.10		10.29		8.53	28.00
Total						136.62

*Conversion indices of crop combinations from kg to kg grain equivalent are in Appendix 2, P. 85.

4.2.1.3 Labour

Table 6 shows that the highest average labour input was used for sorghum/millet (128 man-hours/ha), followed by sorghum/cowpea (102 man-hours/ha), and by both sole sorghum (100man-hours/ha) and sorghum/millet/cowpea (100 man-hours). The least labour input was used for sorghum/groundnut (70 man- hours/ha).

Table 6. Average labour levels of sorghum-based cropping systems in the study area.

Sorghum enterprises	Labour (man-hours/ha)	Percentage
S	100.0	17.92
S/G	70.0	8.96
S/M	128.0	22.44
S/MZ	78.0	13.98
S/C	102.0	18.28
S/M/C	100.0	17.92
Total	578.0	100

4.2.1.4 Fertilizer

Table 7 shows that the largest quantity of fertilizer was used in sole sorghum (152kg/ha), followed by sorghum/millet (100kg/ha), sorghum/maize (98.57kg/ha) and sorghum/cowpea (97.05kg/ha). The least quantity of fertilizer was used in sorghum/millet/cowpea (72.72kg/ha).

Table 7. Average fertilizer levels of sorghum-based cropping systems in the study area.

Sorghum enterprises	Fertilizer (kg/ha)	Percentage
S	152.0	24.80
S/G	92.3	15.06
S/M	100.0	16.31
S/MZ	98.57	16.08
S/C	97.05	15.84
S/M/C	72.72	11.86
Total	612.97	100.00

4.2.1.5 Pesticides

Table 8 shows that the highest average pesticide use was in sorghum/groundnut (2.20 litres), followed by both sole sorghum (2.0 litres) and sorghum/cowpea (2.0 litres). The least pesticide use was in sorghum/millet/cowpea (0.53 litres).

Table 8. Average pesticides levels of sorghum-based cropping systems.

Sorghum-based enterprises	Pesticides (litres/ha)	Percentage
S	2.00	22.91
S/G	2.20	25.20
S/M	1.00	11.45
S/MZ	1.00	11.45
S/C	2.00	22.91
S/M/C	0.53	6.07
Total	8.73	100.00

4.2.2 Output per hectare in sorghum cropping systems.

Table 9 shows the output per hectare for the sorghum-based cropping systems in the study area. Sorghum/maize enterprise had the highest yield (750 kg grain equivalent/ha), followed by sole sorghum enterprise (600kg grain equivalent/ha), sorghum/millet/cowpea (599.60kg grain equivalent/ha) and sorghum/millet (550.24 kg grain equivalent/ha). The least output per hectare was obtained for sorghum/groundnut enterprise (469.70 kg grain equivalent/ha).

Table 9. Output levels per hectare of sorghum-based cropping systems.

Sorghum enterprises	Kilogramme grain equivalent
S	600.00
S/G	469.70
S/M	550.24
S/MZ	749.55
S/C	505.28
S/M/C	599.60

4.3 Estimates of the Stochastic Frontier Production Function in Sorghum-Based Enterprises

The results of the Cobb–Douglas stochastic frontier production function used to estimate the input-output relationship in sorghum-based cropping systems are presented in Tables 10, 11, 12, 13, 14 and 15.

4.3.1 Sole sorghum enterprise

The results in Table 10 show that the sigma square (σ^2) value was 0.179 and significant at 5%, signifying a good fit and the correctness of the specified distributional assumption for the composite error term. The gamma (γ) with value of 0.55 was significant at 5%, implying that 55% of the variation in output of sole sorghum in the study area was due to differences in technical efficiency. The estimated coefficients of farm size, labour and fertilizer were positive and significantly related with sole sorghum output at 1% and 5% levels of probability respectively. This result is in agreement with that of Rahman *et al.* (2005) who found farm size, labour and fertilizer to be significantly related with sole sorghum output at 5% level of probability in their study on the technical efficiency in sorghum-based cropping systems in Soba area of Kaduna State, Nigeria.

Table10. Estimates of the stochastic production function for sole sorghum enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	0.1232	0.6438	0.1914
Farm size (X ₁)	0.2649***	0.0091	2.9321
Labour (X ₂)	0.5750**	0.2690	2.1320
Seed (X ₃)	-0.6328	0.311	-0.2035
Fertilizer (X ₄)	0.14295**	0.054	2.6470
Pesticide (X ₅)	0.1555	0.2376	0.6544
σ^2	0.179**	0.071	2.5338
γ	0.650**	0.2772	2.345

*, **, *** = p < 0.1, p < 0.05 and p < 0.01 respectively.

4.3.2 Sorghum/Groundnut enterprise

The results in Table 11 show that the σ^2 value of 0.05 is significant at 5% level of probability, indicating goodness of fit and correctness of the specified distributional assumption of the composite error term. The γ (0.75) implies that 75 % of the variation in total output is due to the inputs included in the model. The estimated coefficients of seed, fertilizer and pesticides were positively and significantly related with sorghum/groundnut output.

Table 11. Estimates of the stochastic production function for sorghum/groundnut enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	3.191***	0.6142	5.196
Farm size (X ₁)	-0.04732	0.3429	-0.138
Labour (X ₂)	0.665	0.5195	1.280
Seed (X ₃)	0.5193*	0.3105	1.672
Fertilizer(X ₄)	0.2949**	0.1247	2.265
Pesticide(X ₅)	1.0106***	0.2719	3.7130
σ^2	0.051***	0.0172	2.964
γ	0.750**	0.3132	2.395

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.3.3 Sorghum/Millet enterprise

The results in Table 12 show that the value of σ^2 is 0.0275 and significant at 1 % level of probability. It shows goodness of fit and correctness of the specified distributional assumptions for the composite error term. The γ has value of 0.78, indicating that 78% of the variation in output is due to differences in farmers' technical efficiency. The coefficient of farm size, labour and seed were significantly related with sorghum/millet output. Labour and seed were positively related to output, while farm size was negatively related.

Table 12. Estimates of the stochastic production function for sorghum/millet enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	0.1393	0.8954	0.1556
Farm size (X ₁)	-0.3606**	0.1417	-2.5448
Labour (X ₂)	0.3272*	0.2031	1.6110
Seed (X ₃)	0.8427**	0.3980	2.1298
Fertilizer (X ₄)	0.4509	0.4638	0.9720
Pesticide (X ₅)	0.0532	0.4873	0.1091
σ^2	0.0275***	0.0104	2.6623
γ	0.250**	0.1066	2.345

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.3.4 Sorghum/Maize enterprise

The results in Table 13 show that σ^2 (0.014) is significant at 5% level of probability, indicating goodness of fit and correctness of the specified distributional assumptions for the composite error term. The γ was 0.99, implying that 99% of the variation in total output is due to differences in technical inefficiency. The estimated coefficients of farm size, seed and fertilizer were positive and significantly related with sorghum/maize output.

Table 13. Estimates of the stochastic production function for sorghum/maize enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	2.9723***	0.556	5.346
Farm size (X ₁)	-0.3597**	0.2054	-1.7511
Labour (X ₂)	-0.1657	0.1718	-0.9646
Seed(X ₃)	0.3698**	0.1644	2.2498
Fertilizer(X ₄)	1.1535***	0.1863	6.1895
Pesticide(X ₅)	-0.2657	0.1261	-0.2105
σ^2	0.0145**	5.5284	2.6227
γ	0.99***	0.1807	5.4801

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.3.5 Sorghum/cowpea enterprise

The results in Table 14 show that σ^2 was 0.0428 and significant at 5% level of probability, indicating goodness of fit and correctness of the specified distributional assumption for the composite error term. The γ was 0.99, implying that 99% of the variation in total output was due to differences in farmers' technical efficiencies. The estimated coefficient of farm size was positively and significantly related with sorghum/cowpea output, while labour and fertilizer were negatively related to output. This result is in agreement with that of Rahman *et al.* (2005) who found farm size and labour to be significantly related with sorghum/cowpea output in their study on the technical efficiency in sorghum-based cropping systems in Soba area of Kaduna State of Nigeria.

Table 14. Estimates of the stochastic production function for sorghum/cowpea enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	0.3612***	0.1113	3.242
Farm size (X_1)	1.6027**	0.9069	1.7672
Labour (X_2)	-0.5686***	0.2024	-2.8090
Seed(X_3)	0.1095	0.4732	0.2314
Fertilizer(X_4)	-0.1069*	0.0604	-1.7697
Pesticide(X_5)	-0.0839	0.2857	-0.2937
σ^2	0.0428**	0.0189	2.2655
γ	0.9676***	0.1089	8.8794

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.3.6 Sorghum/millet/cowpea enterprise

The results in Table 15 show that σ^2 was 0.054 and significant at 5% level of probability, indicating goodness of fit and correctness of the specified distributional assumption for the composite error term. The γ (0.99) implies that 99% of the variation in total output was due to differences in farmers' technical efficiencies. The estimated coefficients of farm size, labour, seed, fertilizer and pesticides were positively and significantly related with sorghum/millet/cowpea output.

Table 15. Estimates of the stochastic production function for sorghum/millet/cowpea enterprise

Variable	Coefficient	Standard Error	T-ratio
Constant	1.8261	0.9178	1.900
Farm size (X_1)	0.2680**	0.0915	2.2978
Labour (X_2)	0.5725*	0.0806	1.7098
Seed(X_3)	0.4201*	0.0532	1.7892
Fertilizer(X_4)	0.9748***	0.2209	4.4122
Pesticide(X_5)	0.3871**	0.1703	2.2722
σ^2	0.054***	0.0080	6.6816
γ	0.999***	0.1912	5.224

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

Based on the result of stochastic frontier production function, the null hypothesis that there is no significant technical relationship between inputs and output in sorghum-based crop enterprises is rejected and the alternative accepted.

4.4 Determinants of Technical Inefficiency in Sorghum Enterprises

4.4.1 Sole Sorghum

The determinants of technical inefficiency in sole sorghum enterprise as presented in Table 16 show that the coefficients of farming experience, membership of cooperative societies and amount of credit were negatively and significantly related with technical inefficiency. The negative sign for farming experience means that an increase in farming experience will result in reduced technical inefficiency. Increase in years of membership of cooperatives tends to reduce technical inefficiency of farmers. The reason is that increased membership of cooperative societies afford the farmers the opportunity of sharing information on modern practices and gaining access to improved

technologies and credit for the purchase of inputs and payment of hired labour which reduces technical inefficiency of the farmers (Njoku, 1991). The negative coefficient of amount of credit suggests that greater access to credit reduces technical inefficiency. The reason is that the availability of credit enhances the farmers' ability to purchase the inputs embodied in new technologies and to pay for hired labour needed for the use of these inputs and improved management practices (Njoku,1991).

Table 16. Estimates of determinants of technical inefficiency for sole sorghum enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	0.0099	0.0066	1.5000
Household size (Z ₂)	0.2193	0.1801	1.2177
Farming Experience(Z ₃)	-0.9380**	0.4462	-2.101
Educational Level(Z ₄)	0.0407	0.0933	0.4284
Membership of Cooperatives (Z ₅)	-0.0143***	0.0026	-5.500
Amount of Credit (Z ₆)	-0.0788*	0.0439	-1.7919

*, **, *** = p < 0.1, p < 0.05 and p < 0.01 respectively.

4.4.2 Sorghum/Groundnut enterprise

The results of the determinants of technical inefficiency show that household size, educational level and access to credit were negatively and significantly related with technical inefficiency. The negative sign for household size, education and amount of credit means that increases in household size, education and amount of credit will result in reduced technical inefficiency. The reason for the negative relation between household size and technical inefficiency is that as the number of people in a household increases, a pool of family labour becomes available and this leads to specialization and reduced technical inefficiency. Household size could reduce labour constraints, thereby

leading to increase in productivity and income (Tanko *et al.*, 2010). Education showed a negative relationship with technical inefficiency. This could be due to the fact that educated farmers are able to understand and use information from research and extension more easily than illiterate farmers which reduces technical inefficiency. Moreover, educated farmers are likely to be less risk-averse and therefore more willing to use modern technologies. Khalirajan and Shard (1985) observed that education sharpens managerial input and leads to a better assessment of the importance and complexities of good decisions in farming. The reason for the negative coefficient of amount of credit is that the availability of credit enhances the farmers' ability to purchase the inputs embodied in new technologies and to pay for hired labour needed for the use of these inputs and improved management practices which reduces technical inefficiency (Njoku, 1991).

Table 17. Estimates of determinants of technical inefficiency for sorghum/groundnut enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	0.680	0.4151	1.6380
Household size (Z ₂)	-0.0385***	0.01040	-3.706
Farming Experience(Z ₃)	0.0088	0.4616	0.0191
Educational Level(Z ₄)	-0.2927***	0.0787	-3.717
Membership of Cooperatives (Z ₅)	0.0836	0.2656	0.3147
Amount of Credit (Z ₆)	-0.0164***	5.5331	-2.964

*, **, *** = p < 0.1, p < 0.05 and p < 0.01 respectively.

4.4.3 Sorghum/Millet enterprise

The results of the determinants of technical inefficiency in sorghum/millet enterprise as presented in Table 18 shows that the coefficients of household size, membership of cooperative societies and amount of credit were negatively and significantly related with technical inefficiency. The negative sign for household size may be due to the fact that a household with many productive members possibly contributes the extra labour requirements of the new technology which reduces technical inefficiency (Obeta and Nwagba, 1991).

The coefficient for membership of associations was negative, implying that membership of association reduces technical inefficiency. Membership of cooperatives and farmers' associations is expected to increase the farmer's interactions with his fellow farmers and other entrepreneurs which would in turn increase his capacity to access information and credit which would reduce technical inefficiency (Nwaru *et al.*, 2006). The negative coefficient obtained for the amount of credit suggests that farmers who have greater access to credit have reduced technical inefficiency. The reason is that the availability of credit enhances farmers' ability to purchase the inputs embodied in new technologies and also pay for hired labour needed for the use of these inputs and improved management practices which, in turn, will lead to increased rice output (Njoku, 1991).

Table 18. Estimates of determinants of technical inefficiency for sorghum/millet enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	0.0264	0.5883	0.0449
Household size (Z ₂)	-0.0287***	0.0066	-4.3484
Farming Experience(Z ₃)	0.2128	0.0557	0.3820
Educational Level(Z ₄)	0.9288	0.0727	0.1276
Membership of Cooperatives (Z ₅)	-0.0247**	0.0111	-2.2221
Amount of Credit (Z ₆)	-0.4880***	0.00912	-5.351

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.4.4 Sorghum/maize enterprise

The results of the determinants of technical inefficiency show that age, household size and farming experience were the significant factors that influenced technical inefficiency in sorghum/maize enterprise. The coefficient obtained for age was negative and significant, implying that an increase in age would reduce technical inefficiency. The reason is that age, in correlation with farming experience, has a significant influence on the decision- making process of farmers with respect to risk aversion, adoption of improved agricultural technologies, and other production-related decisions which could reduce farmers' technical inefficiency (Adubi, 1992). Household size showed a negative relation with technical inefficiency and was significant at 1% level. This implies that farmers who have large household sizes have lower technical inefficiency. The reason for this relationship is that as the number of people in a household increases, a pool of family labour becomes available for farm operation which could enhance specialization and reduce technical inefficiency. The reason for the negative coefficient of household size is that large household size eases labour constraints thereby leading to increase in

productivity and income (Njoku, 1991). Farming experience was also negative and significant, implying that, increased farming experience reduces technical inefficiency. Experience in sorghum/maize enterprise could improve farmers' skills in farm operations, thereby reducing technical inefficiency of the farmers.

Table 19. Estimates of determinants of technical inefficiency for sorghum/maize enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	-0.8288**	0.3800	-2.1784
Household size (Z ₂)	-0.0513***	0.0182	-2.8019
Farming Experience(Z ₃)	-0.0088*	0.0048	-1.6667
Educational Level(Z ₄)	0.0437	0.0556	0.794
Membership of Cooperatives (Z ₅)	0.0460	0.0724	0.6353
Amount of Credit (Z ₆)	0.0650	0.0478	0.1359

*, **, *** = $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

4.4.5 Sorghum/cowpea enterprise

The results of the determinants of technical inefficiency in sorghum/cowpea enterprise as presented in Table 20 show that coefficients of farming experience, education and amount of credit were negatively and significantly related with technical inefficiency. Farming experience was negative, implying that increase in farming experience would reduce technical inefficiency. The reason is that farmers with longer farming experience are more likely to accept any useful innovations for the expansion of production which will reduce technical inefficiency. The negative coefficient of education reveals that a higher level of education results in a reduction in technical inefficiency of sorghum/cowpea farmers. Education could propel farmers to adopt innovations and technologies that are vital for enhancing productivity and also enhance managerial

capacity in agricultural production which reduces technical inefficiency (Ezeh, 2006). Education raises the technical competence of an entrepreneur and enables him or her cope with the complexities associated with adoption of improved technology (Tanko, *et al.*, 2010). Credit can improve the productivity, incomes and welfare of rural people. Short- term credit may alleviate seasonal needs for working capital and help in the purchase of improved inputs and payment of hired labour required for additional farm operations thereby reducing technical inefficiency (Obeta and Nwagba, 1991).

Table 20. Estimates of determinants of technical inefficiency for sorghum/cowpea enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	0.054	2.7980	0.0193
Household size (Z ₂)	0.0173	0.0234	0.7393
Farming Experience(Z ₃)	-0.0244*	0.0150	-1.6193
Educational Level(Z ₄)	-0.4633*	0.2857	-1.6216
Membership of Cooperatives (Z ₅)	0.045	0.0519	0.8671
Amount of Credit (Z ₆)	-0.1892**	0.0855	-2.2120

*, **, *** = p < 0.1, p < 0.05 and p < 0.01 respectively.

4.4.6 Sorghum/millet/cowpea enterprise

The results of the determinants of technical inefficiency in sorghum/millet/cowpea enterprise as presented in the Table 21 show that the coefficients of education, membership of cooperatives and amount of credit were negatively and significantly related with technical inefficiency. Ogundari (2006) noted that education enhances productivity among farming households and educated farmers may better understand and process information provided by different sources regarding new investments thereby reducing their technical inefficiency. The reason for negative relationship between

membership of cooperative and technical inefficiency could be due to the fact that membership of cooperative can serve as a medium for exchange of ideas that can improve farm operations. It has also been reported that membership of cooperative can serve as an avenue through which innovations diffuse among farmers thereby reducing technical inefficiency. (Adeola *et al.*, 2011). The availability of credit enhances farmers' ability to purchase the inputs embodied in new technologies and also pay for hired labour needed for the use of these inputs and improved management practices which, in turn, will lead to reduced technical inefficiency (Njoku, 1991).

Table 21. Estimates of determinants of technical inefficiency for sorghum/cowpea enterprise

Variable	Coefficient	Standard Error	T-ratio
Age (Z ₁)	0.0316	0.0075	0.4179
Household size (Z ₂)	0.0482	0.0364	0.1323
Farming Experience(Z ₃)	0.0157	0.0161	0.9780
Educational Level(Z ₄)	-0.2802***	0.0869	-3.2297
Membership of Cooperatives (Z ₅)	-0.0183***	0.0018	-9.7176
Amount of Credit (Z ₆)	-0.0343***	0.0063	-5.4340

*, **, *** = p < 0.1, p < 0.05 and p < 0.01.

4.5 Frequency Distribution of Technical Efficiency in Sorghum-Based Cropping Systems.

The frequency distributions of technical efficiencies of farmers in sorghum-based cropping systems are presented in Tables 22, 23, 24, 25 and 26.

4.5.1. Sole Sorghum enterprise

The results in Table 22 show that technical efficiency indices for sole sorghum ranged between 30% and 98%, with a mean of 87%. The estimates show that for the

average farmer to achieve technical efficiency of the most efficient farmer, he needs 11% [(1 - 0.89) x 100] cost savings while the least technically efficient farmer needs 69% [(1 - 0.31) x 100] cost savings to become the most technically efficient farmer.

Table 22. Distribution of farmers according to their technical efficiency in sole sorghum enterprise

Technical Efficiency Index	Frequency	Percentages
0.30-0.39	4	8
0.40-0.49	3	6
0.50-0.59	10	20
0.60-0.69	8	16
0.70-0.79	5	10
0.80-0.89	10	20
0.90-1.00	10	20
Total	50	100
Minimum	30	
Maximum	98	
Mean	87	

4.5.2. Sorghum/groundnut enterprise

The results in Table 23 show that technical efficiency indices for sorghum/groundnut ranged between 50% and 99%, with a mean of 77%. The estimates show that for the average farmer to achieve technical efficiency of the most efficient farmer, he needs 22% [(1 - 0.78) x 100] cost savings while the least technically efficient farmer needs 49% [(1 - 0.51) x 100] cost savings to become the most technically efficient farmer.

Table 23. Distribution of farmers according to their technical efficiency in sorghum/groundnut enterprise

Technical Efficiency Index	Frequency	Percentages
0.50-0.59	7	20
0.60-0.69	4	11.43
0.70-0.79	8	22.86
0.80-0.89	9	25.70
0.90-1.00	7	20
Total	35	100
Minimum	50	
Maximum	99	
Mean	77	

4.5.3. Sorghum/Millet enterprise

The results in Table 24 show that technical efficiency indices for sorghum/millet ranged between 53% and 99%, with a mean of 89%. The estimates show that for the average farmer to achieve technical efficiency of the most efficient farmer, he needs 10% $[(1 - \text{---}) \times 100]$ cost savings while the least technically efficient farmer needs 46% $[(1 - \text{---}) \times 100]$ cost savings to become the most technically efficient farmer.

Table 24. Distribution of farmers according to their technical efficiency in sorghum/millet enterprise

Technical Efficiency Index	Frequency	Percentages
0.50-0.59	1	5
0.60-0.69	1	5
0.70-0.79	2	10
0.80-0.89	6	30
0.90-1.00	10	50
Total	20	100
Minimum	53	
Maximum	99	
Mean	89	

4.5.4. Sorghum/Maize enterprise

The results in Table 25 show that technical efficiency indices for sorghum/maize ranged between 45% and 99%, with a mean of 93%. The estimates show that for the average farmer to achieve technical efficiency of the most efficient farmer, he needs 6% $[(1 - \frac{45}{99}) \times 100]$ savings while the least technically efficient farmer needs 54% $[(1 - \frac{99}{45}) \times 100]$ cost savings to become the most technically efficient farmer.

Table 25. Distribution of farmers according to their technical efficiency in sorghum/maize enterprise

Technical Efficiency Index	Frequency	Percentages
0.40-0.49	2	8
0.50-0.59	1	4
0.60-0.69	3	12
0.70-0.79	3	12
0.80-0.89	6	24
0.90-1.00	10	60
Total	25	
Minimum	45	
Maximum	99	
Mean	93	

4.5.5 Sorghum/Cowpea enterprise

The results in Table 26 show that technical efficiency indices for sorghum/cowpea ranged between 43% and 98%, with a mean of 87%. The estimates show that for the average farmer to achieve technical efficiency of the most efficient farmer, he needs 11% $[(1 - \text{---}) \times 100]$ cost savings while the least technically efficient farmer needs 56% $[(1 - \text{---}) \times 100]$ cost savings to become the most technically efficient farmer.

Table 26. Distribution of farmers according to their technical efficiency in sorghum/cowpea enterprise

Technical Efficiency Index	Frequency	Percentages
0.40-0.49	1	6.25
0.50-0.59	1	6.25
0.60-0.69	1	6.25
0.70-0.79	1	6.25
0.80-0.89	3	18.75
0.90-1.00	9	56.25
Total	16	100
Minimum	43	
Maximum	98	
Mean	87	

4.5.6. Sorghum/Millet/Cowpea enterprise

The results in Table 27 show that technical efficiency indices for sole sorghum ranged between 42% and 99%, with a mean of 72%. The estimates show that for the average farmer to achieve technical efficiency of the most efficient farmer, he needs 27% $[(1 - \frac{72}{99}) \times 100]$ cost savings while the least technically efficient farmer needs 58% $[(1 - \frac{42}{99}) \times 100]$ cost savings to become the most technically efficient farmer.

Table 27. Distribution of farmers according to their technical efficiency in sorghum/millet/cowpea enterprise

Technical Efficiency Index	Frequency	Percentages
0.40-0.49	2	14.29
0.50-0.59	2	14.29
0.60-0.69	1	7.14
0.70-0.79	2	14.29
0.80-0.89	3	21.43
0.90-1.00	4	28.57
Total	14	100
Minimum	42	
Maximum	99	
Mean	72	

4.5.7 Comparative Technical Efficiency of Sorghum-Based Enterprises

Table 28 shows the comparative technical efficiency of farmers in sorghum –based enterprise. The results show that sorghum/maize farmers were most technically efficient, with mean technical efficiency of 93%, followed by sorghum/millet farmers with mean technical efficiency of 89%. The least technically efficient farmers were sorghum/millet/cowpea farmers with mean technical efficiency of 72%.

Table 28. Comparative Technical Efficiency of Sorghum-Based Enterprises

Enterprise	Minimum TE (%)	Maximum TE (%)	Mean TE (%)
S/MZ	45	99	93
S/M	53	99	89
S	30	98	87
S/C	43	98	87
S/G	50	99	77
S/M/C	42	99	72

4.6. Costs and Returns of Sorghum-Based Enterprises in the study area

The costs and returns for the sorghum-based enterprises are presented in Tables 29, 30, 31, 32, 33 and 34.

4.6.1 Sole sorghum enterprise.

The results in Table 29 indicate that the total variable cost for sole sorghum was ₦31,100/ha and the total revenue was ₦55,000/ha. The gross margin was, therefore, ₦23,900/ha. Average rate of return obtained was 1.77, implying that for every ₦1 invested, there was a return of 77 kobo. This result is in agreement with that of Jongur (2006) who found sole masakwa sorghum production to be profitable in Yola South with gross margin of ₦22,728/ha and an average rate of return of 3.01.

Table 29. Costs and returns of sole sorghum enterprise.

Cost and Return Items	Quantity/ha	Unit price(₦)	Value (₦)/ha
(A) Variable Costs(₦)			
Seeds (kg)	20	55	1100
Labour (Man-hour)	100	100	10000
Fertilizer (kg)	150	120	18000
Pesticides (litre)	2	1000	2000
(B) Total Variable Costs			31,100
Output (kg)	1000	55	55,000
(D) Total Revenue (₦)			55,000
(E) Gross Margin (D-B)			23,900
Average rate of return D/B			1.77

4.6.2 Sorghum/groundnut enterprise.

The study revealed that the total variable costs for sorghum/groundnut was ₦21,535/ha while the total revenue was ₦43,500/ha (Table 30). The gross margin was calculated to be ₦21,965/ha. The average rate of return was 2.00, meaning that for every one naira invested, there was a return of ₦2.00. This result is in agreement with that of Hassan (2008) who found sorghum/groundnut to be profitable in Giwa Local Government Area with gross margin of ₦30,701.94/ha and an average rate of return of 1.85.

Table 30. Costs and returns of sorghum/groundnut enterprise in the study area.

Cost and Return Items	Quantity/ha	Unit price(₦)	Value (₦)/ha
(A) Variable Costs (₦)			
Seeds (kg) :			
(i) Sorghum	7	55	385
(ii) Groundnut	11	150	165 0
Labour (Man-hour)	50	200	1500
Fertilizer (kg)	100	120	12000
Pesticides (litre)	2.5	1000	2500
(B) Total Variable Costs			21,535
Output (kg)			
i. Sorghum	350	50	17,500
ii. Groundnut	200	130	26,000
(D) Total Revenue (₦)			43,500
(E) Gross Margin (D-B)			21,965
Average rate of return D/B			2.00

4.6.3 Sorghum/Millet enterprise in the study area.

The results in Table 31 indicate that the total variable costs incurred in sorghum/millet enterprise was ₦27,550/ha, while the total revenue was ₦41,500/ha. The gross margin was ₦13,950/ha. The average rate of return was 1.51, implying that for every ₦1 invested, there was a return of 51kobo. This result is in agreement with that of Yakubu (2001) in her study of sorghum production under alternative cropping systems in Giwa Local Government Area of Kaduna State where sorghum/millet enterprise was found to be profitable with a gross margin of ₦21,335/ha and an average rate of return of 1.62.

Table 31. Costs and returns of sorghum/millet enterprise

Cost and Return Items	Quantity/ha	Unit price (₦)	Value (₦)/ha
(A) Variable Costs (₦)			
Seeds (kg)			
(i) Sorghum	17	50	850
(ii) Millet	10	70	700
Labour (Man-hour)	128	100	12800
Fertilizer (kg)	100	120	12000
Pesticides (litre)	1	1200	1200
(B) Total Variable Costs			27,550
Output (kg)			
(i) Sorghum	300	55	16,500
(ii) Millet	250	100	25,000
(D) Total Revenue (₦)			41,500
(E) Gross Margin (D-B)			13,950
Average rate of return D/B			1.51

4.6.4 Sorghum/Maize enterprise in the study area.

The results in Table 32 indicate that the total variable cost incurred in sorghum/maize enterprise was ₦21,650/ha and the total revenue was ₦36,250/ha. The gross margin was ₦14,600/ha. The average rate of return was 1.67, implying that, for every ₦1 invested, there was a return of 67 kobo. This result is in line with that of Abu (2005) in her study of economic analysis of prevalent cropping systems in Sabon-Gari Local Government Area of Kaduna State where sorghum/maize enterprise was found to be profitable with a gross

margin of ₦28,700/ha and an average rate of return of 1.60.

Table 32. Costs and returns of sorghum/maize enterprise in the study area.

Cost and Return Items	Quantity/ha	Unit price(₦)	Value (₦)/ha
(A) Variable Costs (₦)			
Seeds (kg) :			
(i) Sorghum	10	55	550
(ii) Maize	6	50	300
Labour (Man-hour)	78	100	78000
Fertilizer (kg)	100	120	12000
Pesticides (litre)	1	1000	1000
(B) Total Variable Costs			21,650
Output (kg)			
(i) Sorghum	500	50	25000
(ii) Maize	250	45	11250
(D) Total Revenue (₦)			36,250
(E) Gross Margin (D-B)			14,600
Average rate of return D/B			1.67

4.6.5. Sorghum/Cowpea Enterprise in the study area.

The results in Table 33 indicate that the total variable costs obtained for sorghum/cowpea was ₦27,150/ha, while the total revenue was ₦44,775/ha. The gross margin was calculated to be ₦17,625/ha. The average rate of return of 1.65 means that for every one naira invested, there was a return of 65 kobo. This result agrees with that of Yakubu (2001) where sorghum/cowpea enterprise was found to be profitable with a gross margin of ₦24,291.25/ha and an average rate of return of 1.68.

Table 33. Costs and returns of sorghum/cowpea enterprise in the study area.

Cost and Return Items	Quantity/ha	Unit price(₦)	Value (₦)/ha
(A) Variable Costs (₦)			
Seeds (kg) :			
(i) Sorghum	30	55	1650
(ii) Cowpea	10	150	1500
Labour (man-hour)	100	100	10000
Fertilizer (kg)	100	120	12000
Pesticides (litre)	2	1000	2,000
(B) Total Variable Costs			27,150
Output (kg)			
(i) Sorghum	305	55	16,775
(ii) Cowpea	200	140	28,000
(D) Total Revenue (₦)			44,775
(E) Gross Margin (D-B)			17,625
Average rate of return D/B			1.65

4.6.6. Sorghum/Millet/Cowpea enterprise in the study area.

The results in Table 34 indicate that the total variable costs incurred in S/M/C enterprise was ₦22,355/ha, while the total revenue was ₦44,500/ha. The gross margin was ₦22,145/ha. The average rate of return was 1.99, implying that for every ₦1 invested, there was a return of 99 kobo. This result is in agreement with the findings of Abu (2005) who found sorghum/millet/cowpea enterprise to be profitable with a gross margin of ₦34,500/ha and an average rate of return of 1.55

Table 34. Costs and returns of Sorghum/Millet/Cowpea enterprise in the study area.

Cost and Return Items	Quantity/ha	Unit price(₦)	Value (₦)/ha
(A) Variable Costs (₦)			
Seeds (Kg)			
(i) Sorghum	11	55	605
(ii) Millet	07	70	490
(iii) Cowpea	10	150	1500
Labour (man-hour)	100	100	10000
Fertilizer (kg)	75	120	9000
Pesticides (litre)	1.6	1100	1760
(B) Total Variable Costs			22,355
Output (kg)			
(i) Sorghum	300	55	16,500
(ii) Millet	200	70	14000
(iii) Cowpea	100	140	14,000
(D) Total Revenue (₦)			44500
(E) Gross Margin (D-B)			22145
Average rate of return D/B			1.99

Based on the results of the costs and returns analysis and of the average rates of return for the different sorghum-based cropping systems, the null hypothesis that sorghum-based enterprises are not profitable is, therefore, rejected and the alternative hypothesis that sorghum-based enterprises are profitable is accepted.

4.6.7 Comparative Profitability of Sorghum-Based Enterprises.

The comparative profitability of the sorghum-based enterprises presented in Table 35 show that sorghum/groundnut was the most profitable with a gross margin of ₦21,965 and an average rate of return of 2.00, while the least profitable was sorghum/millet with a gross margin of ₦13,950 and an average rate of return of 1.51.

Table 35. Comparative Profitability of Sorghum-Based Enterprises

Enterprises	Gross Margin (₦)	Rate of return
S/G	21,965	2.00
S/M/C	22,145	1.99
S	23,900	1.77
S/MZ	14,600	1.67
S/C	17,625	1.65
S/M	13,950	1.51

4.7. Constraints Associated with Sorghum-Based Cropping systems in the Study Area.

The constraints associated with the sorghum-based cropping systems were:

4.7.1 Inadequate credit

Inadequate credit ranked first (34.68%) among the constraints faced by the farmers involved in sorghum-based cropping systems. The lack of credit makes it difficult to finance technological and capital improvements for raising productivity (Saito *et al.*, 1994). This limits farmers' scale of operations and eventually reduces their income.

4.7.2 High cost of chemical fertilizer

High cost of chemical fertilizers was the second most important constraint in sorghum-based cropping systems (23.12%). Majority of the farmers said they did not use the

required quantities of chemical fertilizer due to its high cost and supplemented the little they could afford with organic manures.

4.7.3 High cost of hired labour

High cost of hired labour ranked third (20.23%) among the constraints limiting sorghum-based enterprises. The farmers said this increased their cost of production, thereby reducing their profit.

4.7.4 Poor storage facilities

Poor storage facilities (11.56%) ranked fourth among the constraints faced by the farmers. The lack of adequate and efficient storage facilities predisposes the excess crop that is produced to deterioration and waste (Ohiagu, 1986). The farmers are, therefore, forced to sell their produce immediately after harvest when prices are low.

4.7.5 Fluctuating market prices

Fluctuations in market prices for crops (6.35%) was the fifth most important constraint which faced the farmers. This happens during the season when there is a glut in the market.

4.7.6 Disease and pest attack

Disease and pest attack was the sixth most important constraint (5.20%). It is estimated that, worldwide, up to 30% of total agricultural production is lost to animal pests, weeds and diseases each year (Kiss and Meeran, 1991). This may be connected with the use of local seed varieties that are susceptible to disease and pest attack and poor farm cultural practices by farmers.

4.7.7 Lack of tractor- hiring services

Lack of tractor-hiring services was the seventh most important constraint reported by the farmers (4.6%). According to the farmers, tractors were not available and accessible to them for their farming operations. This limits the farmers' scale of production and compels them to use their primitive tools and implements and sometimes draught animals for their farming operations. They, therefore, produce little or no surplus output for the market (Saito *et al.*,1994).

Table 36. Constraints associated with sorghum-based production systems in the study area.

Constraints	Frequency*	Percentage	Ranking
Inadequate Credit	50.00	28.90	1 st
High cost of fertilizer	40.00	23.12	2 nd
High cost of hired labour	35.00	20.23	3 rd
Poor storage facilities	20.00	11.56	4 th
Fluctuating market prices	11.00	6.36	5 th
Disease and pest attack	9.00	5.20	6 th
Lack of tractor -hiring services	8.00	4.62	7 th
Total	173	100	

*Multiple responses allowed.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study examined the economics of sorghum-based crop mixtures in Garko Local Government Area of Kano State. The specific objectives were to: identify and describe the predominant sorghum-based enterprises in the study area, determine the input and output levels for the sorghum-based enterprises, estimate the technical relationship between inputs and output of the sorghum-based cropping systems, estimate the technical efficiencies of the sorghum-based cropping systems, determine the socio-economic characteristics of farmers which influence their technical inefficiency, evaluate the costs and returns of the sorghum-based enterprises, and identify and describe the constraints associated with the sorghum-based cropping systems. The instrument used for data collection was a structured questionnaire. A two-stage sampling technique was used to select the respondents for the study. The first was the purposive selection of six villages from Garko LGA and the second was the proportional selection of farmers who grew sorghum either sole or in combination with other crops from each village. Data were analyzed using descriptive statistics, gross margin analysis and stochastic frontier production function analysis.

The results of the study showed six predominant sorghum-based enterprises in the study area in terms of the number and percentage of farmers. These were sole sorghum (31.25%), sorghum/groundnut (21.87%), sorghum/millet (15.63%), sorghum/maize (12.50%), sorghum/cowpea (10%) and sorghum/millet/cowpea (8.75%). The average levels of inputs used in the sorghum-based enterprises showed that farmers cultivated more farmland for sole sorghum (29.06%) and least land for sorghum/millet/cowpea

(8.75%). For seed input, sorghum/cowpea had the highest seed rate (40 kg grain equivalent /ha) and sole sorghum the lowest seed rate (12 kg grain equivalent/ha). For labour, sorghum/millet had the highest labour use per hectare (128 man-hours) and sorghum/groundnut the least (70 man-hours). For fertilizer, the largest fertilizer use per hectare was in sole sorghum (152 kg) and the least was in sorghum/millet/cowpea (72.72 kg). For pesticides, the largest pesticide use per hectare was in sorghum/groundnut (2.20 litres) and the least was in sorghum/millet/cowpea (0.53 litres).

In terms of output, sorghum/maize had the highest yield per hectare of 750 kg grain equivalent, and the least was sorghum/groundnut (470 kg grain equivalent). The results of the stochastic frontier production function analysis showed that in sole sorghum enterprise, farm size, labour and fertilizer were positively and significantly related to output. For sorghum/groundnut enterprise, seed, fertilizer, and pesticides were positively and significantly related to output. For sorghum/millet enterprise, farm size, labour and seed were significantly related to output. For sorghum/maize enterprise, farm size, seed and fertilizer were significantly related to output. For sorghum/cowpea enterprise, farm size, labour and fertilizer were significantly related to output, and for sorghum/millet/cowpea enterprise, farm size, labour, fertilizer and pesticide were positively and significantly related to output.

The results of the estimates of technical efficiency in the sorghum-based crop enterprises showed the mean technical efficient for sole sorghum was 0.87, for sorghum/groundnut 0.77, for sorghum/millet 0.89, for sorghum/maize 0.93, for sorghum/cowpea 0.87 and for sorghum/millet/cowpea 0.72.

The results of the determinants of technical inefficiency showed that for sole sorghum, farming experience, membership of cooperatives and amount of credit were significantly related with technical inefficiency. For sorghum/groundnut, age, household size and education were significantly related with technical inefficiency. For sorghum/millet, household size, membership of cooperatives and amount of credit were significantly related with technical inefficiency. For sorghum/maize, age, household size, and farming experience were significantly related with technical inefficiency. For sorghum/cowpea, farming experience, education and amount of credit were significantly related with technical inefficiency. For sorghum/millet/cowpea, education, membership of cooperatives and amount of credit were significantly related with technical inefficiency.

Gross margin analysis results for the sorghum-based enterprises in the study area showed that sorghum/groundnut enterprise was the most profitable with a gross margin of ₦21,965/ha and an average rate of return of 2.00, followed by sorghum/millet/cowpea with a gross margin of ₦22,145/ha and an average rate of return of 1.99. The least profitable was sorghum/millet enterprise with a gross margin of ₦13,950/ha and an average rate of return of 1.51.

The constraints associated with the sorghum-based cropping systems in the study area were inadequate credit (34.68%), high cost of fertilizer (23.12%), high cost of hired labour (20.23%), poor storage facilities (11.56%), fluctuating market prices (6.35%), disease and pest attack (5.20%) and lack of tractor- hiring services (4.62%).

5.2 Conclusion

Sorghum-based crop enterprises are an important component of the food production system in the study area and were found to be profitable. This means that sorghum-based

enterprises should be promoted as a way of alleviating poverty and increasing the food security of the farmers.

The mean technical efficiencies in the different sorghum-based cropping systems varied from 0.72 in sorghum/millet/cowpea to 0.93 for sorghum/maize. This means that, in the short run, there is a scope for increasing production in the sorghum-based cropping systems by between 18% and 7% by adopting the best technologies and techniques in sorghum-based cropping systems.

5.3 Recommendations

The following recommendations are made based on the findings of the study:

- (i) In view of the importance of sorghum-based cropping systems in the study area, cropping systems research should, to a significant level, focus on developing sorghum-based cropping systems that are productive, stable and acceptable to farmers and which also perform well in the agro-ecological conditions of the study area. This will help to minimize farmers' risk, increase their output and enhance their income.
- (ii) The mean technical efficiencies of sole sorghum (87%), sorghum/groundnut (77%), sorghum/millet (89%), sorghum/maize (93%), sorghum/cowpea (87%) and sorghum/millet/cowpea (72%), is an indication that there is a great opportunity for farmers to increase their level of efficiency in sorghum-based cropping systems by adopting the best technologies and techniques.
- (iii) Given the problem of high cost of fertilizer and lack of tractor –hiring services, there is the need for provision of fertilizers and tractor–hiring services at affordable prices and at the right time to the farmers. This will help to increase farmers' output.

- (iv) Given the problem of inadequate credit, farmers should form cooperatives or associations to make it easier for them to source loans from banks. This will help in the procurement of farm inputs in a timely manner.
- (v) Given the problem of disease and pest attack, crop improvement research should not only aim at increasing yields, but also at increasing resistance to diseases and pests as well as tolerance to adverse environmental conditions.
- (vi) Since poor storage facilities was a problem, there is need for adequate and efficient storage facilities to save the excess crop produced from deterioration and waste and ensure steady availability and stable market prices for farm produce.

5.4 Contributions of the Study to knowledge

The study has contributed the following to knowledge:

- (i) Six sorghum-based cropping systems were identified to be the most popular in the study area. These were sole sorghum (31.25%), sorghum/groundnut (21.87%), sorghum/millet (15.63%), sorghum/maize (12.50%), sorghum/cowpea (10%) and sorghum/millet/cowpea (8.75%).
- (ii) The study revealed that the sorghum-based enterprises in the study area were profitable. These included the sorghum/groundnut enterprise with gross margin of ₦21,965/ha and an average rate of return of 2.00, followed by sorghum/millet/cowpea with a gross margin of ₦22,145/ha and an average rate of return of 1.99, and sole sorghum enterprise with a gross margin of ₦13,950/ha and an average rate of return of 1.77.
- (iii) The mean technical efficiencies for the different sorghum-based crop enterprises were 0.72 for sorghum/millet/cowpea, 0.77 for sorghum/groundnut, 0.87 for both sole sorghum and sorghum/cowpea 0.89 for sorghum/millet and 0.93 for

sorghum/maize.

- (iv) The determinants of technical inefficiency among the farmers were found to include age, household size, farming experience, level of education, membership of cooperatives and amount of credit.
- (v) The constraints associated with the production of the sorghum-based cropping systems included inadequate credit (34.68%), high cost of fertilizer (23.12%), high cost of hired labour (20.23%) and poor storage facilities (11.56%).

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APPENDIX 1: QUESTIONNAIRE

SECTION A. (GENERAL INFORMATION)

Name of farmer

Village Date.....

1. Age of farmer(Years)
2. Sex : a). Male () b. Female ()
3. Material Status: Single () Married ()
4. Household Size (Number)
5. Farming experience(Month/Years)
6. Educational status: a). No formal education ()....years b.) Primary education ()
.....years c.) Secondary education ().....years d). Tertiary education
()....years e). Others (specify)years
7. Occupation : a). Major..... others
8. a. Are you a member of cooperative or farmers' society ? b. If yes, how long have
you been a member (years)
c. Benefit demand 1= No benefit, 2= fairly benefit, 3 =
benefit, 4= very bad if no give reasons.....
9. What was the source of Capital for farming last season (2011)
a. Own () b. off- farm income () c .friends () d. money lenders
() e. from farms ()f. Others (specify).....
b. What was the interest rate?.....
10. Do you have access to extension services ?a Yes () b. No ()
If yes, how many times were you visited in the last one year..... times
a. less than once () b. 1-2 () c. 3-4 () d. 5-6 () c. 5-6 () d. greater than ()
11. What are your reasons for growing sorghum-based crop mixtures if applicable
.....

SECTION B.INPUTS USED

1. Farm Size (ha)

Plot No	Mode of Acquisition	Area (ha)	Rentage		Crop Combinations			Proportion of sorghum in the Mixture (stands ratio)
			Per ha	TC	Sorghum	Crop 1	Crop 2	
1								
2								
3								

2. Labour Used

Hired Labour for Plot 1

What are the days and the cost of labour for various activities indicated in the table below:

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No=Numbers, C/D=cost per day, TC =Total Costs

Family Labour

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No = Numbers, C/D=cost per day, TC =Total Cost

Plot 2

Hired Labour

What are the days and the cost of labour for various activities indicated in the table below:

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No = Numbers, C/D=cost per day, TC =Total Cost

Family Labour

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No = Numbers, C/D=cost per day, TC =Total Cost

Plot 3

Hired Labour

What are the days and the cost of labour for various activities indicated in the table below:

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No = Numbers, C/D=cost per day, TC =Total Cost

Family Labour

What are the days and the cost of labour for various activities indicated in the table below:

	ADULT MALE				ADULT FEMALE				CHILDREN			
	No	Days	C/D	TC	No	Days	C/D	TC	No	Days	C/D	TC
Land Preparation												
Planting												
Fertilizer Application												
Weeding												
Harvesting												
Packing												
Threshing and bagging												
Transportation												

Key : No = Numbers, C/D=cost per day, TC =Total Cost

Plot 1

OXEN SERVICES

What are the costs of the following oxen services?

Oxen Operators	Cost /ha (₦)	Total Cost(₦)
Ridging		
Earthening up		

Plot2

OXEN SERVICES

What are the costs of the following oxen services?

Oxen Operators	Cost /ha(₦)	Total Cost(₦)
Ridging		
Earthening up		

Plot 3**OXEN SERVICES**

What are the costs of the following oxen services?

Oxen Operators	Cost /ha(₦)	Total Cost (₦)
Ridging		
Earthening up		

3. SEED

Sorghum			Crop 1			Crop2			Sources		
Kg/ Mudu	Cost /kg	TC (₦)	Kg /mudu	Cost /kg	TC (₦)	Kg/mudu	Cost /kg	TC (₦)	A D	Own	Others

4. FERTILIZER

PLOTS	FERTILIZERS			QUANTITY(No of bags 50kg)	Price per bag(₦)	Total Cost(₦)
	NPK	CAN	MANURE			
1						
2						
3						

5. AGROCHEMICALS

PLOTS	AGROCHEMICALS	QUANTITY/LITRES	TOTAL COST (₦)
1			
2			
3			

6. FARM OUTPUT AND INCOME LEVEL

PLOTS	SORGHUM			CROP 1			CROP 2		
	TQ	UNIT PRICE	TR	TQ	UNIT PRICE	TR	TQ	UNIT PRICE	TR
1									
2									
3									

Key :TQ = Total Quantity in 100kg

TR = Total Revenue in Naira

SECTION B (PRODUCTION CONSTRAINTS)

A. List by ranking the problems faced in sorghum-based production enterprises.

S/No	PROBLEMS	RANK	COPING STRATEGY
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

B. Suggest ways to improve sorghum production ?

i.....

.....

ii.....

THANK YOU.

APPENDIX 2

The Indices for Conversion into Kilogramme-Grain Equivalents

Crop	Index
Maize	0.75
Millet	0.68
Sorghum	0.6
Groundnut	1.10
Cowpea	1.12

Source : Clarke and Haswell, 1970.