ECONOMIC ANALYSIS OF MILLET-BASED PRODUCTION SYSTEMS IN KATSINA STATE, NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS

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DECLARATION

I declare that the work in this dissertation entitled **Economic analysis of millet-based production systems in Katsina State, Nigeria,** has been written by me in the Department of Agricultural Economics and it is a record of my own research work. The information derived from the literature had been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Chukwunonso Chidera OFFOKANSI (Student)	**Date**

CERTIFICATION

The dissertation titled **Economic analysis of millet-based production systems in Katsina State, Nigeria,** carried out by **Chukwunonso Chidera Offokansi,** meet the regulations governing the award of the Degree of Masters of Science (M.Sc) in Agricultural Economics of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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This research work is dedicated to my family and friends for their intense support and encouragement.

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ASTRACT

This study examined the economics of millet-based production systems in Kastina State, Nigeria. This was done using structured questionnaire administered to 196 millet-based farmers. Multi-stage sampling procedure was used, the first stage involved purposive selection of 3 LGAs in the state based on the predominance of millet-based production systems. 10% of villages were selected randomly. Farmers were grouped into millet enterprises which were; Millet/Sorghum, Millet/Sorghum/groundnut/Cowpea, Millet/Sorghum/groundnut, Millet/Sorghum/Cowpea and Sole millet. 10% of farmers in each group were randomly selected to give a sample size of 196 respondents. The analytical tools used were the descriptive statistics, gross margin analysis, data envelopment analysis and Tobit regression model. The results of the socio-economic analysis showed that the mean age of farmers was 49 years, Majority (95.4%) of the farmers were married. About 57.1% had one form of formal education or the other. The mean household size was 9 persons, and the mean farming experience was 31 years. The result of the study shows that about 72.5% of the farmers were mostly engaged in the crop mixture of millet with sorghum, groundnut and cowpea. The study shows that millet production is profitable with millet/sorghum/cowpea with the highest gross margin ₦169,534.7 per hectare. The study revealed that sole millet farmers had the highest mean technical (0.48), allocative (0.91) and economic (0.41) efficiencies than other millet-based farmers. Millet/sorghum farms (75 percent) were operating on constant return to scale which implies that they were more scale efficient than other millet-based farms. Lack of extension service delivery was the major constraint experienced in all the millet-based enterprises. The study recommends encouraging farmers to belong to cooperative societies among others. This is to enable them to benefit from each other and any external support services. It was concluded that of all the enterprises; millet/sorghum/groundnut/cowpea was the most widely practiced millet-based production systems in the study area and that millet-based production systems in the study area are profitable.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Nigeria has a highly diversified agro-ecological condition which makes possible the production of a wide range of agricultural products (Etonihu, Rahman and Usman, 2013). Agriculture is, therefore, one of the most important sectors of the economy. The sector is particularly important in terms of its contribution to Gross Document Product (GDP) which stood at an average of 56 percent in 1960 – 1964 (Oladimeji and Ajao, 2014), now it remains unimpressive as it contributes 25.52 percent to the nominal GDP of the country in 2018 (Nigerian Bureau of Statistics, 2018; Abdulrahman and Yusuf, 2018). Despite this, agriculture still remains one of the largest sectors of the Nigerian economy.

Nigeria is one of the major millet producing countries in Africa with an average annual production of 1.6 million tonnes (Food and Agriculture Organization Statistics (FAOSTAT), 2018). Other important millet-producing countries in Africa are Burkina Faso, Chad, Mali, Niger, Senegal, Sudan and Uganda (Federal Ministry of Agriculture and Rural Development (FMARD), (2017). The world average annual production of millet was reported to be 28 million tonnes, with India being the most producers with 10.2 million tonnes (Muktar, 2018). It is a very important cereal in the savannah areas in Nigeria, where it is fifth to rice, maize, wheat and sorghum in importance. Over 9 and 19 percent of land sown annually to cereals is devoted to millet in Africa and Nigeria respectively (Jidda and Anaso, 2017; Ali, Hudu and Ojeleye, 2018). The average production figure for Nigeria is 1.4 million tonnes which accounts for about 5 percent of total world output of millet (Muktar, 2018).

The northern part of Nigeria provides an ideal agro-ecological condition for the production of millet. For this reason, it is predominantly produced and consumed within the region, making it a staple crop for over 40 percent of the populace (Jirgi, Ogundeji, Viljoen and Adiele, 2010). It is also an important part of the people's livelihoods because no component of the plant is put to waste. As a regional staple, the people have created diverse methods and forms of processing it for consumption such as thick paste (locally called '*tuwo*'), thick dough (locally called '*fura*'), dumplings, grits, porridge and gruel. Beyond food, it is used as feed for animals while the stalks of some varieties are traditionally used as building materials and for firewood. A breakdown of its uses suggests that 78 percent of millet produced in Nigeria is consumed as staple food, 20 percent is used for drinks and other products and 2 percent is used as feed (Usman, Hussaini, Baba-Musami and Sheriff, 2014). The importance of millet extends beyond food: its production also serves as an important source of income generation for farmers. Nigeria's food supply is primarily provided by smallholder farmers, accounting for about 80 percent of the country's total farmers' population (Akinsuyi, 2011). These smallholder farmers are confined to the rural areas where they depend on farming as their main source of income.

The Nigerian consumption level of the rural populace who form 53 percent of the Nigerian population (Cheng and Larochelle 2016) is significant and over the last two decades, an average per capita consumption of 32kg per year was reported by Food and Agricultural Organization (FAO, 2018). Trends reveal a rather stable millet consumption in Nigeria, where per capita consumption was observed to hover around an average of 260kcal per capita per day. The crop is therefore, essential for the nation's food security, as supported by Cheng and Larochelle (2016) who emphasized that households' demand for millet crop will increase as income grows in northern Nigeria, but at a lower rate than the income growth. In recognition of the crucial role millet plays in the regions' food security, the Nigerian government in 1975, established 'Lake Chad Research Institute (LCRI)', mandated to facilitate research in millet production in the country by way of developing improved technologies. Over the years, the agency has made appreciable achievements through the release of improved varieties with potential yield of 3.0 - 4.0 tonnes per hectare with 39 percent yield advantage over the local variety (LCRI, 2018). Other concerted efforts such as with International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) to promote production have been in existence since 2008.

Unfortunately, despite the aforementioned government's efforts aimed at improving millet production in Nigeria, performance of millet among smallholder farmers has either stagnated or declined over the last decade placing the average yield for this vital crop at 1.0 or 1.1 tonnes per hectare as against the 3.0 - 4.0 tonnes per hectare (Mukhtar, 2018). This implies that the yield gap still exists between the farmers' output levels and the expected yields based on the potentials of the improved varieties. This means that huge investments made in the improved millet has not produced considerable result as expected, suggesting that all the efforts made have not contributed much increase in efficiency and improve productivity. FAO (2018) listed the main factors undermining crop production in Nigeria to include reliance on rain fed agriculture, smallholder land holdings and low productivity due to poor planting material, low fertilizer application and a weak agricultural extension system amongst others. The government on its part has not provided significant encouragement to the millet farmers. Recently, the government's attitude of directing policies in the form of subsidies towards promoting rice and maize production will only weaken the millet industry. To compound the situation, religious crises and banditry in the northern part of the country, where millet is highly produced has contributed to its progressive shrinking acreage.

Since, increased productivity has direct correlation with efficiency; this low productivity reflected the possibility of inefficiency among millet farmers in the study area. In Nigeria, inefficiency in millet production may also be associated to agronomic, physiological, political, socio-economical factors and poor resource management practices. Socioeconomic factors (age, experience, family size, education, credit, extension, farm size etc) and poor management (inputs use) are more obvious of all factors (Rahman and Umar, 2009; Ahmed, Mohamed and Illyasu, 2016). Favorable conditions of farm and socioeconomic factors are known to increase production. When socioeconomic and farm factors are unfavorable, farmers allocate disproportionate resources/inputs for production than necessary. Inefficiency may also results from wrong combination of farm inputs, inadequate supply of seed, cultivation of small farm size, poor agricultural practices, poor quality planting materials, use of crude farm tools, inadequate fertilizer application, inadequate of financial resources and lack of extension, among others (Paul, 2011).

Efficiency influences agricultural production directly by increasing available food sources and indirectly by raising income of the farming household. Although, it is not the only key for reducing food insecurity and poverty, but no nation has ever successfully achieved them without first increasing its level of agricultural productivity and efficiency in addition to her industrial and institutional development (Mukhtar, 2018). This highlights the importance of the study of efficiency to all economies, especially the developing ones like Nigeria. Conversely, in the face of declining trend in millet production and productivity in Nigeria, there is an apparent need to study millet production profitability. Low level of production leads to high prices of output which has been a hindering factor towards the full capitalization of the millet sub-sector commercialization process (Ahmad, 2011). Adequate return on investment through profit generation is a good enticing reason for producing high quality products while ensuring economic efficiency (Rembisz, 2011). Consequently, increasing farm efficiency of small-scale farmers increases their output which improves food security by raising smallholder farmers' income (Mango, Makate, Hanyani-Mlamb, Siziba and Lundy, 2015). While inefficiency in farm production raises the costs of production and make a farm or firm less competitive (Alverez and Arias, 2004).

Okpeke and Adaigho (2018) argued that 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. Increase in agricultural productivity will contribute to the well-being of the economy as a whole (Okpeke and Adaigho, 2018). According to Amos (2007), the rural sector consisting of farm families offers great potential for employment generation for the teeming population, but that this potential will not be achieved if productivity and efficiency are not increasing within the rural sector. Therefore, increasing productivity and efficiency in the agricultural sector particularly among small-scale farmers requires a good knowledge of the current efficiency or inefficiency inherent in the sector, as well as, the factors responsible for this efficiency or inefficiency (Amos, 2007).

1.2 Problem Statement

Millet is grown in the large savanna region of Nigeria mostly in a system of intercropping with other crops. The predominance of the intercropping system has been occasioned by Nigeria's climate which is basically tropical and favourable for production, farmer's level of technology and their socio-economic situations (Fakayode, Babatunde and Ajao, 2008). In Nigeria, the increase in food production in recent years has not been able to keep pace with the rapid growth. The population is growing geometrically by nearly 4 percent annually but food production is increasing arithmetically at only half of that rate (Abubakar, 2014). The declining trends on quantities of millet production has been evident at both states and national level,with a majority of the millet farmers recording substantial gaps in average yield of 0.9 tonnes per hectare as against the potential yield of 3.0 - 4.0 tonnes per hectare (Federal Ministry of Agriculture and Water Resources (FMAWR), 2017; Mukhtar, Mohamed, Shamsuddin, Sharifuddin, and Bala, 2018). Since available literatures show a direct correlation between productivity and efficiency, it is safe to say that this low performance of millet in Katsina State and the country as a whole reflects an existence of inefficiency among the millet farmers. This presents a need to bridge the gap between the potential yields and the existing yield average obtained by the farmers. The negative effect of low millet productivity have pervasive consequences such as lowering incomes for farmers and increase in consumption and imports of substitute cereals like maize, rice and wheat to supplement the deficit in food demand of the country.

Previous empirical studies such as; Adebayo, Mohammed and Mshelia (2008); Bashir and Yakaka (2013); Izge and Song (2013) and Okech, Ngigi and Kimurto. (2015) focused their findings on breeding, processing and marketing of millet in Nigeria as a whole. However, there are little empirical findings done such as Abubakar (2014) on the performance of millet production in terms of efficiency such as technical, allocative, economic and profit efficiencies and also productivity in Katsina State. Despite all human and material resources devoted to millet production, the technical efficiency for it still falls under 60 percent (Mukhtar, *et al.*, 2018). In Nigeria, inefficiency in millet production may be associated with agronomic, physiological, political, socioeconomic factors and poor resource management practices.

However, socioeconomic factors such as farming experience, access to credit and extension and poor management in terms of input use stand out (Rahman and Umar, 2009; Ahmed *et al.*, 2016). Considering the prevailing new technology, improvements in the efficiency will greatly enable smallholder farmers to produce the maximum possible output from a given level of inputs. Therefore, millet productivity will be increased by improvement in farmers' efficiency levels.

Conversely, in the face of declining trend in millet production and productivity in Nigeria, there is an apparent need to study millet production profitability. This is because examining profitability measures will shed more insight into the failing millet-based production systems in Nigeria. For example, farming practices with low profits not only mean a creation of and perpetuation of poverty incidences among millet farmers, but also, a deterioration of the industry due to crowding out of farmers from the industry. Adequate return on investment through profit generation is a motivation for producing high quality products while ensuring economic efficiency. Consequently, increasing farm efficiency of small-scale farmers increases their output which increases their output which improves their food security by raising smallholder farmers' income (Mango et al., 2015). Rembisz (2011) supported that improving farm level efficiency can bring about increased profitability. This is explained by the fact that efficient farmers have a tendency to have higher farm incomes which fosters the prosperity and survival of their farm business.

According to Ebukiba (2015), the small-holder farmers are constrained by many problems including use of rudimentary production techniques, poor access to modern inputs and credits, poor infrastructure, inadequate access to market, land degradation, inadequate research and extension services. The continuing decline in production also raises some questions as to whether it is profitable to grow the crop or not. This calls for the examination of the production efficiency, profitability and constraints associated with the crop. The followings research questions therefore became necessary:

(i) what are the socio-economic characteristics of millet-based farmers in the study area?

(ii) what are the common millet-based production systems?

(iii) are millet-based production systems profitable?

(iv) what are the economic efficiency of millet-based production systems?

(v) what are the determinants of economic efficiency of millet-based production systems?

(vi) what are the returns to scale in millet-based production systems?

(vii) are there constraints associated with millet-based production systems in the study area?

1.3 Objectives of the Study

The broad objective of the study was to analyze the productivity of millet-based production systems in Katsina State. The specific objectives were to:

(i) describe the socio-economic characteristics of millet-based farmers in the study area;

(ii) identify and describe the millet-based production systems;

(iii) determine the profitability of millet-based production systems;

(iv) determine the economic efficiency of millet-based production systems;

(v) estimate the determinants of economic efficiency in millet-based production systems;

(vi) estimate the returns to scale in millet-based production systems;

(vii) identify and describe the constraints associated with millet-based production systems in the study area.

1.4 Hypotheses

The hypotheses tested in this study were as follows:

(i) H_0- Millet-based farms are not economically efficient

(ii) H_0- There is no significant relationship between the socio-economic characteristics of the millet producers and economic efficiency in millet-based production systems

1.5 Justification for the Study

The major objectives for food crops as contained in Nigeria's agricultural promotion policy document in 2018 are self-sufficiency in production, improvement in the level of technical and economic efficiency in food crop production and also to increase the dependency of agriculture in the country and above all, increase the Nigerian economy. This is achievable through the introduction and adoption of improved technology, more efficient utilization of farm productivity, reduction in the risk and uncertainties associated in food crop production and the modernization of the structure and organization of the food crop section (Odunze, 2019).

This study is expected to provide information on the millet-based production systems, efficiency, profitability and constraints associated with millet-based production systems in Katsina state. According to Rahman (2013), the measurement of farm production efficiency is important in three areas; as a success indicator and performance measure for evaluating farms, the sources of efficiency differentials can only be identified by measuring efficiency and appreciating its effect and the identification of the sources of inefficiency will enable both public and private establishments to improve farm performance.

Khapayi and Celliers (2016) argued that the measurement of profitability allows the farmers to access the farm businesses financial position and to chart its progress. Therefore, profitability statements are used as a basis for obtaining credit because they provide lenders with the information needed to evaluate loan applications. According to Bello and Madza (2011) diagnostic surveys aim at identifying and describing the problems of the existing agricultural system in an area as an appropriate grass root or bottom-up strategy for developing new technologies that are appropriate to traditional farmer's needs and circumstances.

This study seeks to provide information on production efficiency and help farmers to identify and have proper understanding of the millet-based enterprises that are more profitable and efficient because, farmers with limited resources have limited capacity to tolerate failure in production (Abubakar, 2014). It is also possible for the researchers, policy makers, non-governmental organizations and international organizations to obtain further information on the problems associated with millet-based production systems in the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Millet production in Nigeria

Millet importance is reflected in the position it occupies as the most dependable source of food for a large number of people in the environment for which it has a special adaptation(Jirgi *et al.*, 2010). It is predominantly grown in the north-west and north-east region of the country. The most common millet grown in Nigeria is the pearl millet (Obilana, 2003). For the past two decades of millet improvement activities, area cultivated remained more than 2 million hectares. The ability of the Nigerian agriculture to perform its role in agricultural development according to Ogunsumi and Ogbosuke (2009) has been on the decline in the last two decades.

Recent statistics by Food and Agriculture Organisation FAO (2019) as shown in Table 2.1 reveals an overall alignment between production and area cultivated trends for the two decades, in other words; millet production in Nigeria has not been able to meet potential yield. From 2000 - 2010, millet yield has been between 1.1 - 1.8 tonnes per hectare which is below the potential yield of 5.4 tonnes per hectare. Subsequently, during the past few years, there has been about 22 percent decrease in millet yield production. This indicates inefficiency in inputs used since yields are decreasing and increasing inconsistently and also the country not meeting its full potential yield. Indeed, from 2011, area cultivated remains lower than the previous decade which can also be attributed to low production of millet in the past few years.

Table 2.1: Production of millet in Nigeria and area cultivated

Year	**Area Cultivated (ha)**	**Yield (t/ha)**	**Production (tonnes)**
2000	5,814,000	1.0501	6,105,000
2001	4,254,000	1.3000	5,530,000
2002	4,490,000	1.3105	5,884,000
2003	4,536,000	1.3801	6,260,000
2004	4,620,000	1.4500	6,699,000
2005	4,685,000	1.5300	7,168,000
2006	4,971,000	1.5500	7,705,000
2007	5,056,000	1.6001	8,090,000
2008	4,904,000	1.8483	9,064,000
2009	3,787,730	1.3016	4,929,950
2010	4,364,140	1.1848	5,170,430
2011	2,827,090	0.4497	1,271,370
2012	1,328,200	0.9642	1,280,700
2013	1,485,200	0.6124	909,560
2014	1,511,222	0.9255	1,398,667
2015	1,591,803	0.9331	1,485,387
2016	1,736,048	0.8460	1,468,668
2017	2,212,439	0.6780	1,500,000

Source: FAOSTATS, 2019

2.1.2 Significance of millet

Millet is a staple food for over 100 million people in parts of tropical Africa and India (Onwueme and Singha 1991; Obilana, 2004). The air dried grains contain approximately 12.4 percent water, 11.6 percent protein, 5.0 percent fats, 67.1 percent carbohydrate, 1.27 percent fibre and 2.7 percent ash (Onwueme and Singha, 1991; Ragaee *et al*., 2006). It is therefore an important energy food and the nutritive value is comparable to that of rice and wheat.

After husking, the grains may be cooked like rice or they may be ground into flour to make porridge cake or bread. The grains are also used to produce malt and in Africa the malted seed is an important source of beer. For brewing, the grains are germinated, dried, ground into flour and then boiled in much water. This is then allowed to ferment for about a week. The grain may be fed to livestock and poultry and the green plants provide a useful fodder. The straw which is inferior to that of other cereals, may be fed to livestock or used for bedding, thatching, fencing and fuel (Onwueme and Singha, 1991).

A dye for leather and wood is obtained from red and purple-flowered types. In African traditional medicine, the grain has been applied to treat chest disorders, leprosy and poisonings, and the ground grain as an anthelmintic for children (Brink and Belay, 2006). This crop lacks gluten and hence can be consumed by people suffering from celiac disease (Gabrovska *et al.*, 2002). Millet consumption can also lower glycemic response, which can be helpful for the treatment of Type II diabetes (Choi *et al.*, 2005). Inclusion of millet in the human diet can also lower the risk of duodenal ulcers, anaemia and constipation (Nambiar *et al.*, 2011).

The agri-tourism and recreational wildlife industries are finding superior results from using pearl millet in rations for bobwhite quail production (Savage 1995), and for supplemental feeding. It also seems to be an excellent feed for other birds, including dove, turkey, song-birds, ducks, and swine. The stalks of the long season, late-maturing pearl millet types called "Maiwa" in Nigeria are used in roofing, fencing and as firewood (ICRISAT, 1996; Obilana and Manyasa, 2002).

2.1.3 Millet production system in Nigeria

A production system is 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 (Emerson, 2010). The cultivation of millet in Nigeria is performed in two major ways depending on the environment and custom of the people concerned. Sole cropping is seldom practiced, the great majority of the millet crop is grown as mixed crop with sorghum, groundnut, cowpea, sesame and hibiscus (Raw Material Research development Council RMRDC, 2004). In the Sahel savanna regions, millet is frequently grown for five or six years successively, followed by a prolonged period of bush fallow. On land that has reached a low level of fertility, three years of successive millet crops alternate with six years of fallow. Normally, millet should be sown in rotation with groundnuts or any other crop. Millet is generally mixed-cropped with sorghum. In some countries such as Chad, Niger and Nigeria, millet is intercropped with groundnuts. Two rows of groundnuts are sown between two rows of millet spaced 140 cm apart. In East Africa millet is also sown with groundnuts, cowpeas and pigeon peas (Emerson, 2010).

2.1.4 Mixed cropping

Mixed cropping is the growing of two or more crops together on the same piece of land at the same time in a haphazard or systematic manner that the growth of some or all of the component plant types overlaps in space and time. Generally, this is synonymous with inter-planting, inter-sowing, intercropping and crop mixture (Oladeji, 2014). This is the dominant cropping system used by small holder farmers in the drought prone, semi-arid tropics of West Africa. In Northern

Nigeria, Norman (1974) recorded 156 different mixtures of crops with 40 percent of the areas devoted to 2-crop combination such as millet with sorghum and millet alongside cowpea. Also, Abubakar (2014) found out the large proportion of millet in Nigeria is mixed with crops like sorghum, groundnut and cowpea.

The advantage of millet mixed cropping system over other cropping systems such as sole planting is that it has been shown that mixed cropping gives higher total yields than sole cropping even if yields of individual components are reduced; mixed result is more efficient utilization of environmental resources (light, water, nutrients) by plants of different height, canopy structure, nutrient requirements and maturity and diseases and pests may not spread as rapidly in mixtures because of differential susceptibility to the pests and pathogens.

Comparing productivity of millet-based cropping systems for unstable environment, Baidu-Ferson (1994) observed that millet yields were generally 50 percent lower than typical on-station yield. However, he credited this to an attempt to copy crop protection conditions of farmer fields, where there is little or no crop protection. Iheanacho (2000) found no difference between the yield stability of inter-crops over sole crops in Northern Nigeria. Nevertheless, when he compared the probabilities of failure, based on disaster level of income, inter-cropping systems were found to be more stable.

2.1.5 The concept of resource productivity

Productivity denotes the efficiency with which various input are converted into product. It signifies the relationship between output and input. Agricultural productivity is the index of the ratio of the value of total farm output to the value of the total input used in farm production (Amaechina and Eboh, 2017).

Productivity measures are sub-divided into partial and total measures. Partial measures are the amount of output per unit of the particular input. Commonly used partial measures are yield (output per unit of land), labour productivity (output per economically active person or per agricultural person - hour). Yield is commonly used to assess the success of new production practices or technology. Labour productivity is often used as a means of comparing the productivity of sectors within or across economies. It is also used as an indicator of rural welfare or living standards since it reflects the ability to acquire income through sale of agricultural goods or agricultural production (Amaechina and Eboh, 2017). Also partial productivity includes capital and management productivity which is the ratio of total output to inputs of capital and management respectively. The computation of this important productivity statistics can be achieved from analysis of production functions. Such productivity statistics include the Average Product (AP), Marginal Product (MP), Marginal Rate of Substitution (MRS), Elasticity of Production (EP), and Return to Scale (RTS).

2.1.6 Concept of farm production efficiency

The concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into output. Farm production efficiency is the ability of a farm to produce a given level of output with the lowest amount of resources (Rahman, 2013). The efficient method of producing a product is the one which uses the least amount of resources to get a given amount of output. Efficient farms make better use of existing resources to produce maximum output or incur the lowest cost, thus, achieving the food security objective. There are six features of efficient farm: zero waste, least cost, minimum risk, maximum output, best quality produce and maximum profit

There are different aspects of production efficiency for measuring farm performance. The common ones include technical, allocative, cost, economic, scale and profit efficiencies.

2.2 Theoretical Framework

2.2.1 Theory of production

Production theory is the economic process of producing outputs from inputs. The production uses resources to create a good or service that are suitable for the exchange in a market economy (Kumar, 2018).

2.2.2 Production function

The production function portrays an input-output relationship. It describes the rate at which resources are transformed into products. There are numerous input-output relationships in agriculture because the rates at which the inputs are transformed into outputs will vary among soil types, animals, technologies, rainfall amount and so forth. Production function is a technical and mathematical relationship describing the manner and extent to which a particular product depends upon the quantities of inputs or services of inputs, used at a given level of technology and in a given period of time (Gabriel, 2018). It shows the quantity of output that can be produced using different levels of inputs. A production function can be expressed in different ways: in written form, enumerating and describing the inputs that have a bearing on the output; by listing inputs and the resulting outputs numerically in a table; depicting in the form of a graph or a diagram; and in the form of an algebraic equation. Symbolically, a production function can be written as:

$$Y = f\ (X1, X2\ , X3\ , \dots \dots .. , Xn) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. (2.1)$$

Where:

Y is output,

X1, X2, X3….. Xn are inputs.

In this study, the various inputs used are; land, seed, labour, fertilizer and agro-chemical. It, however, does not tell which inputs are fixed and which are the variable ones. Since in production, fixed inputs play an important role, these are expressed as:

$$Y = f\ (X1, X2, X3 \ldots\ldots Xn) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

Where;

Y is output

X1, X2 are variable inputs and

X3…..Xn are fixed inputs.

Several types of production functions used in agriculture are: linear production function, quadratic production function, Cobb-Douglas production function, square root production function, Mitscherlich or Spillman function, transcendental function, trans-log production function, constant elasticity of substitution (CES) function and resistance function (Kumar, 2018).

2.2.3 Agricultural productivity and profitability

Productivity and profitability persist to be the two most important indicators in assessing the success or failure of crop production. Productivity and profitability are some of the basic concepts in economics of agricultural production (Itam *et al*., 2014). Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs. Its measures can be subdivided into partial, multifactor and total. Partial factor productivity is the amount of output per unit of a particular input. It only considers a single input in the ratio. For example, it uses yields of crops to determine the productivity of field crops. In this study partial factor productivity was employed in production function. Both Multifactor productivity (MFP) and Total factor productivity (TFP) are defined as the ratio of total agricultural output to a subset of agricultural inputs. They utilize more than a single factor (Mapula *et al.*, 2011).

In other words, Ellis (1998) pointed out that the farmer is an individual decision maker concerned with choices like how much labor to use to cultivate a certain type of crop, whether to use purchased inputs or not, which kind of crops to grow in a certain field, etc. Thus, the author identified three kinds of relationships between farm inputs and outputs that determine the decision making capacity of the farmer. One is input-output relationship which indicates the physical relationship between inputs and outputs. This deals with the varying level of outputs corresponding to the varying level of inputs. For example, the variation in potato output resulting from the different levels of fertilizer. Secondly, factor–factor relationship which refers to the different combination of two or more inputs required to produce a specified output. For example, the different amount of land and labour that can give the same quantity of potatoes. Thirdly, product-product relationship that refers to the varying outputs that can result from a given set of farm inputs. For instance, the different quantities of potatoes and onions that can be obtained from the same area of land.

Output is usually measured as the market value of final output. The production function consists of different functional forms. These include the Cobb Douglas, linear, quadratic polynomials and square root polynomials. Others are semi-log and exponential functional forms (World Bank, 2008). The use of production functions to determine farm productivity is restrictive, as it does not account for disparities in input and output prices across farms. An analysis of farm profits addresses this shortcoming by including the effect of price of agricultural inputs and outputs (Ebukiba, 2015).

Profitability is a measure of the relationship between the levels of profits earned during an accounting period and the level of resources committed to earn those profits. Profitability measures the ability of farmers to recover from their costs and is an important concept, because it provides incentives for entry into and longevity in the farming business. Coker *et al*. (2018) ranked profit, risk minimization and crop complexity respectively as the three most important objectives by farmers. The profit objective was defined in farm as the sum of gross margin of each crop less the costs. The risk minimization objective was based on the principle of minimization of total absolute deviation. The risk values are linked to farmer satisfaction and represent the best or worst possible farm income deviation a farmer would expect over a 5-year period. The number of crop types grown measured the crop complexity. The number of crop types grown is associated with a number of different operations and a level of difficulty.

2.2.4 Profit maximization

Common theories of smallholder production generally fall under profit and utility maximization. According to Ellis (1998), these theories are not mutually exclusive. They have much in common in the starting point, approach, logical method, and sharing of certain key assumptions meaning that they are variations on a single theme. For instance, where income is the only variable in the utility function, then profit maximization and utility maximization coincide. The theory of profit maximization was described in this section.

Economic theory considers a firm as a transformation unit which converts input into output (Abdulrahman and Yusuf, 2018). In the process of such conversion, the firm tries to create a surplus value, called a profit. According to Abdulrahman and Yusuf (2018) the major objective of the firm is profit maximization. He argues that while individual firms and entrepreneurs that run them can have many different objectives such as quality product, growth, market share, and employee job satisfaction, all such objectives are only a means to a fundamental and perhaps a deeper objective of profit maximization.

Profit maximization is considered as a rational behaviour of equilibrium assumption where marginal revenue is equated to marginal cost (Rahman and Umar, 2009). A firm which aims to maximize profit will go on increasing its output till it reaches a maximum profit. The bigger the difference between total revenue and total cost the bigger the profit. Therefore, profit is maximized when there is maximum difference between total revenue and total cost (Ebukiba, 2015). This strong assumption that makes up the theory of the firm that business firms automatically maximize (economic) profit (and minimize costs) has been widely discussed, tested, and in many incidences criticized (Rahman and Umar, 2009).

Immediate criticism is the fact that profit maximization is possible for an ideal market, where the decision-maker has full or perfection information. According to Rembisz (2011), this means that all market participants have full and relevant information that they are always aware of their particular demand curves that they are fully aware of all their costs at all times so that they would consistently set output where marginal revenue equals to marginal cost. Kumar (2018) argue that while it would seem that firms choose the price and the quantity to be sold, in fact, they choose only one. Once they have selected the price, the quantity they will sell is up to the consumers. This is to say that if firms cannot predict with certainty the quantity they will sell then they cannot consistently maximize profit. Thus, Gabriel (2018) argue that time factor, uncertainties, and other factors pertinent to the decision-maker should be considered.

According to Ellis (1998) the theory of profit maximization treats the smallholder farmer as a farm firm, operating in fully formed and competitive input and output markets. Profit maximization predicts a positive response by the farmer to market price changes, i.e. an increase in the real price of output results in higher input use, higher output, and higher net income. But According to Ellis (1998) small scales are characterized by partial engagement in input and output markets which are often imperfect or incomplete markets. With complete markets, the production decisions of households are separable from its consumption decisions. In this case, the household maximizes profit and then maximizes utility subject to budget constraint. However, with incomplete markets, the separation property no longer holds, households fail to maximize profit and production decisions depend on the preferences and endowments of the household (Rembisz, 2011).

2.2.5 Production efficiency

Efficiency is at the core of economic theory. Rahman (2013) defines farm production efficiency as the ability of a farm to produce a given level of output with the lowest amount of resources. The efficient method of producing a product is the one which uses the least amount of resources to get a given amount of output. The theory of production in economics is concerned with optimization, and optimization implies efficiency (Chirwa, 2007). Decision-makers are presumed to be concerned with the maximization of some measure of achievement such as profit or efficiency. The analysis of efficiency in general, focuses on the possibility of producing a certain level of output at lowest cost or of producing the optimal level of output from given resources. Therefore, efficiency measurements that show the scope for improved performance may be useful in the formulation and analysis of agricultural policy (Russell and Young, 1983). Several aspects of production efficiency in the literature for measuring farm performance. For instance, Farrel (1957) distinguished three types of efficiency as technical efficiency, price or allocative efficiency and economic efficiency which is the combination of the first two.

2.2.5.1 technical efficiency

This is defined as the minimum factors by which a vector of inputs can be rescaled and still allow the production of a given vector of outputs (Farrell, 1957). The concept of technical efficiency shows the success of a farm enterprise, as it indicates an ability of a farm to produce maximum output from a set of input mix. From Farrell's analysis, a farm that is technically efficient in resource use, operates on a production frontier, while a technical inefficient farm in resource use, operates below production frontier. Hence, the position of individual farm is relative to the frontier could be influenced by factors ranging from climatic, socio-economic and marketing (Ali and Byerlee, 1991). It relates to the degree in which the farmer produces the maximum feasible output from a given bundle of inputs, or uses the minimum feasible level of inputs to produce a given level of output (Rahman, 2013). A firm is said to be efficient when it is operating on the production frontier (Ali and Byerlee, 1991), on the other hand a firm is said to be technically inefficient when it fails to achieve the maximum outputs, or fails to operate on the production frontier. Mathematically, Farrell's production frontier function begins by considering a stochastic production function with a multiplicative disturbance term of the farm.

$Y = f\ (Xa,;)eE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \ldots\ (2.4)$

Where

Y = output

X = vector of input, = vector of parameter

e = error term

E is stochastic disturbance term consisting two independent element ―V‖ and ―U‖.

Hence.

$$E = U + V \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (2.5)$$

The symmetric element V account for random variation in output quantity attributed to factors outside the farmer‘s control (such as disease, weather). A one – sided component U < O reflects technical inefficiency relative to the stochastic frontier. Thus U = O for farm output that lie on the frontier (i.e. 100% technical efficiency in resource use) and U < O for farm output below the frontier as N ~ (o, Ôu2 v). Thus equation becomes:

$$Y = f\ (X\,;,)e\,u + v \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (2.6)$$

According to Koopmans (1999), a production procedure is technically efficient if it cannot increase one output without decreasing another output or increasing at least one input. Farrell (1957) noted that a production unit is efficient as long as it operates on the production frontier, but not necessarily by the Koopmans definition. If a production unit operated on a part of the production frontier that is parallel to an output axis, it would be able to increase the output associated with the axis without decreasing any other output. Hence, the production unit is not efficient in the Koopmans definition.

2.2.5.2 allocative efficiency (AE): AE is the ability of a farm to use inputs in optimal proportions given their respective prices and the production technology (Chirwa, 2007) cited in Rahman (2013). Under competitive conditions, a farm is allocatively efficient if it equates the marginal returns of factor inputs to the market price of output (Fan, 1999). Allocative efficiency deals with the extent to which farmer’s make efficient decisions by using of inputs up to the level at which their marginal contribution to production value is equal to the factor cost (Akinwumi and Djato, 1997; Rahman, 2013). Allocative efficiency is a measure of the degree of success in achieving the best combination of different inputs in producing a specific level of output, considering the relative prices of these inputs (Taphee, 2015). Allocative efficiency relates to the degree to which a farmer utilizes inputs in optimal proportions, given the observed input prices

(Coelli *et al*., 2002; Ogundari *et al*., 2006). Russell and Young (1983) and Taphee (2015) looked at allocative efficiency (AE) as a condition that exists when resources are allocated within the firm according to market prices.

2.2.5.3 economic efficiency (EE): EE is derived from product of technical and allocative efficiencies (that is technical efficiency multiplied by allocative efficiency). It occurs when a farm chooses resources and enterprises in such a way as to attain economic optimum (Akinwumi and Djato, 1997; Ellis, 1998; Taphee, 2015).Economic efficiency is concerned with the realization of maximum output in monetary terms with the minimum available resources (Rahman, 2013). A farm that is economically efficient should by definition be both technically and allocatively efficient. However, this is not always the case as Akinwumi and Djato (1997) pointed out. It is possible for a farm to have either technical or allocative efficiency without having economic efficiency. The reason may be that the farmer, in this case, is unable to make efficient decisions as far as the use of inputs is concerned. In some cases, a farmer might fail to equate marginal input cost to marginal value product. If technical and allocative efficiency occur together they are both necessary and sufficient conditions for economic efficiency. This assumes that the farmer has made right decision to minimize costs and maximize profits implying operating on the profit frontier.

2.2.6 Returns to scale

This refers to the change in output as a result of a given proportionate change in all the factors of production simultaneously. Returns to scale are a long run concept as all the variables are varied in quantity. Returns to scale are increasing, constant or decreasing depending on whether proportionate simultaneous increase of input factors results in an increasing in output by a greater, same or smaller proportion Coelli, *et al.,* 2002).

2.2.6.1 types of returns to scale

i) Increasing Returns to Scale: Increasing returns to scale or diminishing cost refers to a situation when all factors of production are increased, output increases at a higher rate. It means if all inputs are doubled, output will also increase at the faster rate than double. Hence, it is said to be increasing returns to scale. This increase is due to many reasons like division external economies of scale.

ii) Diminishing Returns to Scale: Diminishing returns or increasing costs refer to that production situation, where if all the factors of production are increased in a given proportion, output increases in a smaller proportion. It means, if inputs are doubled, output will be less than doubled. If 20 percent increase in labour and capital is followed by 10 percent increase in output, then it is an instance of diminishing returns to scale.

iii) Constant Returns to Scale**:** This refers to the production situation in which output increases exactly in the same proportion in which factors of production are increased. In simple terms, if factors of production are doubled output will also be doubled. In this case internal and external economies are exactly equal to internal and external diseconomies. This situation arises when after reaching a certain level of production, economies of scale are balanced by diseconomies of scale. This is known as homogeneous production function. Cobb-Douglas and linear homogenous production function is a good example of this kind. The main cause of the operation of diminishing returns to scale is that internal and external economies are less than internal and external diseconomies.

2.3 Analytical Framework

2.3.1 Measurement of farm profitability

Profitability is the primary goal of business ventures without which the business will not survive in the long run. This involves estimation of costs and return of production. If returns are more than costs, profit is made and if costs exceeds return, loss is made. Two tools for estimating profits and loss in a farm production are Net Farm Income NFI and Gross Margin GM analysis (Ishiaku *et al.*, 2017).

2.3.1.1 net farm income analysis

Johnson (1982) and Kay (1986) recommended the use of net farm income (NFI) in ascertaining the profitability of farming. Net farm income, according to them, is derived from the gross margin (GM). Gross margin is the amount of money realized after deducting variable expenses or costs from total sales or income. NFI is obtained by adjusting net cash farm income for total depreciation, net inventory changes and value of products consumed at home (Onoja *et al.*, 2012). Net farm income, according to Kay (1986), is the only true measure of profit for an accounting period since it includes the above adjustments which could be quite large. NFI is the net profit from the year's operation and represents the return to the farm owner for personal and family labour, land, management and equity capital used in the rice farm.

2.3.1.2 gross margin analysis

Gross margin analysis involves evaluating the efficiency of an individual enterprise so that comparison can be made between enterprises or different farm plans (Olukosi and Erhabor, 1988; Shalma, 2014). It is a very useful tool in situations where fixed capital is a negligible portion of the farming enterprise as is the case in subsistence farming (Shalma, 2014). Gross margin (GM) is the difference between the gross farm income (GFI) and the total variable cost (TVC).

2.3.2 Measurement of farm production efficiency

The most commonly used approaches for measuring farm productivity efficiency are the parametric and non-parametric frontier approaches, stochastic frontier and the data envelopment analysis (DEA) or mathematical programming.

2.3.2.1 measurement of farm production efficiency using stochastic frontier production function (SFPF)

The stochastic frontiers involve the use of econometric methods. Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) independently proposed the stochastic frontier production function, in which an additional random error C, is added to the non-negative random variableU_i, in equation to provide:

$$Ln\ (Y_i) = X_i\beta + V_i - U_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .\dots 2.7$$

i = 1, 2… N

The random errorV_i, accounts for measurement error and other random factors, such as the effects of weather, strikes and luck, on the value of the output variable, together with the combined effects of unspecified input variables in the production function. Aigner, Lovell and Schmidt (1977) assumed that the $V's$ were independent and identically distributed (IID) normal random variables with mean zero and constant variance, σV^2 which were assumed to beexponential or half-normal random variables.

The parameters of the stochastic frontier production function, can be estimated using either the maximum-likelihood (ML) method or using a variant of the Corrected Ordinary Least

Squares (COLS) method, suggested by Richmond (1974) as adopted by Aikaterini (2010). The COLS approach is not as computationally demanding as the ML method, which requires numerical maximization of the likelihood function. This distinction, however, has lessened in recent years with the availability of computer software, such as the L1MDEP econometrics package (Greene, 1991) and the FRONTIER programme (Coelli, 1996), both of which automate the ML method for estimation of the parameters of stochastic frontier models.

The ML estimator is asymptotically more efficient than the COLS estimator, but the properties of the two estimators in finite samples cannot be analytically determined. The finite-sample properties of the half-normal frontier model were investigated in a Monte Carlo experiment in Coelli (1995), in which the ML estimator was found to be significantly better than the COLS estimator when the contribution of the technical inefficiency effects to the total variance term is large. Given this result and the availability of automated ML routines, the ML estimatorshould be used in preference to the COLS estimator whenever possible.

The Cobb-Douglas functional form has been commonly used in the empirical estimation of frontier models. Its simplicity is a very attractive feature. A logarithmic transformation provides a model which is linear in the logarithms of the inputs and, hence, the Cobb-Douglas form is easy to estimate. This simplicity, however, is associated with a number of restrictive properties. The Cobb-Douglas production function has constant input elasticities and returns to scale for all firms in the sample. Further, the elasticity of substitution for the Cobb-Douglas function are equal to one.

A number of alternative functional forms have also been used in the frontier literature. The two most popular alternative forms are the trans-log (for example, Greene, 1980) and the Zellner-

Revanka generalized production function (for example, Forsund and Hjalmarsson, 1979; and Kumbhakar, Gosh and McGuckin, 1991). The Zellner-Revankar form removes the returns-to-scale restriction, while the trans-log form imposes no restrictions upon returns to scale or substitution possibilities, but has the drawback of being susceptible to multicollinearity and degrees of freedom problems.

2.3.2.2 data envelopment analysis (DEA)

Data envelopment analysis (DEA) involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data. Efficiency measures are then calculated relative to this surface. Comprehensive reviews of the methodology arc presented by Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Lovell (1991), Charnes et al., (1995) and Seiford (1996).

The piece-wise-linear convex hull approach to frontier estimation, proposed by Farrell (1957), was considered by only a few authors in the two decades following Farrell's paper. Boles (1966) and Afriat (1972) suggested mathematical programming methods which could achieve the task, but the method did not receive wide attention until the paper by Charnes, Cooper and Rhodes (1978), in which the term data envelopment analysis(DEA) was first used. Since then there has been a large number of papers which have extended and applied the DEA methodology.

Charnes Cooper and Rhodes (1978) proposed a model which had an input orientation and assumed constant returns to scale (CRS). Subsequent papers have considered alternative sets of assumptions, such as Banker, Charnes and Cooper (1984) in which a variable returns to scale (VRS) model is proposed.

2.3.2.2.1 data envelopment analysis model specifications

Using the DEA model specification, the technical efficiency score for a given field n is obtained by solving the following linear programming problem:

$$Min\ \theta \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2.8)$$

Subject to:

$$\sum_{i=1}^{j} \lambda_i y_{q_i} \geq y_{p_0}$$

Allocative efficiency**:** Cost minimizing vector of input quantities given the input prices is determined using the model from the program:

Min $x_i^*, \lambda w_i x_i^*$ ……………………………………………………………… (2.9)

Subject to:

$$-y_i + y_\lambda \geq 0$$

$$x_i^* - x_\lambda \geq 0$$

$$\lambda \geq 0$$

Where:

w_i= Vector of input prices for the millet-based farm

x_i^* (Which calculated using linear programming?) = The cost-minimizing vector of input quantities for the millet-based farm, given the input prices $w_i$and the output levels y_i (Hassan, 2014).

Economic efficiency: This is the product of technical efficiency and allocative efficiency.

This is calculated as the ratio of the minimum cost to the observed cost (Hassan, 2014).

$$EE = \frac{w_i^* x_i^*}{w_i x_i} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2.10)$$

2.3.2.2.2 scale efficiency and determination of returns to scale using data envelopment analysis

Scale efficiency is determined for each field as follows:

$SE_n = TE_{CRSn} / TE_{VRSn}$ ………………………………………………………………… (2.11)

Where:

TE_{CRSn} = technical efficiency of field n under constant returns to scale

TE_{VRSn} = technical efficiency of field n under variable returns to scale

The value for SEn will be ≤ one with SEn = 1. This implies that the field is operating at an optimal scale and SEn < 1 meaning the field is scale inefficient with the level of scale inefficiency equal to 1 – SEn. Scale inefficiency arises as a result of the presence of either increasing return to scale (IRS) or decreasing return to scale (DRS). The value derived from the equation can indicate if a field is scale-inefficient but provides no indication as to whether this inefficiency arises as a result of IRS or DRS.

2.3.3 Determinants of efficiency

Various studies on efficiency have considered certain attributes of the farmer and other factors as the possible causes of inefficiency. They have used the Ordinary Least Square (OLS) and Tobit models to show this relationship. Amaza *et al.* (2006) accessing the effect of some socioeconomic factors on technical efficiency differentials between small and medium scale tobacco farmers in Uganda, reported the educational level, credit accessibility and extension services positively influenced farmer‘s efficiency. Ebukiba (2015) also reported that education had a positive impact on technical efficiency. They opined that education is an externality on production since it enhances the adoption and spread of innovations that causes a shift in the production frontier. Amaza *et al.* (2006) reported a positive and significant effect on technical efficiency of food crop farmers in Gombe State, Nigeria. While farming experience and animal traction had a positive relationship with efficiency but were not significant. They also reported a positive and significant relationship technical efficiency and extension contact. Ajibefun *et al.* (2013) reported that age and family size had a negative effect on technical efficiency of food crop farmers in Western Nigeria. They however, found education, credit and farming experience to be positive and significant in influencing technical efficiency. Bravo-Ureta and Emerson (1993) asserted that there was a weak association between education and extension contact on efficiency.

They reported as inconsistent with expected result. They however reported that their findings agreed with that of Xu *et al.* (2015) who opined that elementary education has no effect on farmer‘s productivity. They reported a positive and significant relationship between credit and technical, economic and allocative efficiency, confirming earlier findings by Ebukiba (2015). However, they found no significant relationship between farm size and technical efficiency. Amaza *et al* (2006) also reported a mean positive influence of education and extension contact on allocative and economic efficiency. Xu *et al.* (2015) also asserted that there was a positive and significant relationship between education and economic and allocative efficiency but not with technical efficiency. Land size was significant and positive in one region with respect to technical and economic efficiency but negatively related to economic and technical efficiency in the other two regions. Bravo-Uretta and Emerson (1993) found out that tenure arrangement has a significant and positive effect on technical and allocative efficiency of farmers in Dominican Republic. However its effect on technical efficiency was positive but not significant. They also reported a significant and positive relationship between farm size and allocative and economic efficiency, the relationship between age and efficiency (technical, allocative and economic) was significant and positive while household size had a negative and significant effect on allocative and economic efficiency but positive and non-significant relationship with technical efficiency Empirical applications of stochastic frontier to efficiency studies

2.4 Empirical Framework

Nyagaka *et al.* (2010) studied the technical efficiency in resource use of smallholder Irish potato farmers in Nyandarua north, Kenya. The researchers applied a dual stochastic parametric decomposition technique to derive the technical efficiency indices, a two limit Tobit model to examine the influence of socio-economic characteristics and institutional factors on the technical indices. The researchers found that the average technical efficiency was 67 percent. Education, access to extension, access to credit, membership of farmers' associations and innovations had positive significant effects on technical efficiency. Labour, seed, fertilizer and pesticides had positive influences on the output of the Irish potatoes. According to the researchers, the positive influence of education on technical efficiency implied that the more educated farmers were able to perceive, interpret and adopt improved technology. The positive relationship between extension and technical efficiency indicated how important extension was motivating and educating farmers about existing technology, thereby enhancing efficiency. The researchers added that access to credit enabled farmers to overcome liquidity constraints which enhanced their ability to purchase farm inputs, hence improving inefficiency.

Simonyan and Obiakor (2012) studied the analysis of household labour use in yam production in Anambra West local government area of Anambra State, Nigeria. The researchers employed the use of descriptive statistic, regression model and stochastic frontier production function. The findings revealed that the study area is dominated by aged, male, married, experienced and small holder farmers who mostly attained secondary level of education. The coefficients of age, education, household size, farm size, wage rate, hired labour, credit; cooperative membership and occupational status were all significant at $p<0.01$ and determined the household labour use in the study area. The mean and maximum technical efficiency is 0.88 and 0.99 respectively. Age, education, household size, extension contact, gender were significant and positively related to technical efficiency.

Oladimeji and Abdulsalam (2013) studied analysis of technical efficiency and its determinants among small scale rice farmers in Patigi local government area of Kwara State, Nigeria. Descriptive statistics and stochastic production frontier model were employed in the analysis of the data. The result revealed that 60 percent of the rice farmers had one form of education or the other while the age of rice farmers ranges from between 18 to 67 years with mean age of 38 years. The result of technical efficiency shows that the mean was approximately 0.65. The minimum technical efficiency was 0.10 while the maximum was 0.93. The determinants of technical efficiency in the study area were household size, farming experience, level of education, labour, farm size and non-farm income in paddy rice production.

Aboki *et al*. (2013) studied analysis of technical, economic and allocative efficiencies of cassava production in Taraba State, Nigeria. The researchers employed the use of descriptive statistics and stochastic production frontier. The findings revealed that the study area was dominated by aged, male, literate farmers who owned small farms. The estimated elasticity of production with respect to farm size, family labour, hired labour and fertilizer were statistically significant at $p<0.01$ and $p<0.05$ level of significance respectively. The mean technical, allocative and economic efficiency were 0.887, 0.856 and 0.825 respectively. The result of the study showed that the major factor affecting cassava productions in the study area were farm size, family labour, hired labour, fertilizer, house hold size, years of schooling and source of funds. These factors were significant and have positive influence on cassava output.

Oluwatusin and Shittu (2014) studied the effect of socio-economic characteristics on the farm productivity performance of yam farmers in Nigeria. Descriptive statistics as well as production function analysis was employed to estimate the parameters of the regression model. Findings showed that 80 percent of the sampled farmers were within their economic active working age. It was also revealed that 84.2 percent were men while 15.8 percent of them were women. Moreover, the analysis of production function indicated that the main determinants of yam production performance in the study area were age, educational level, farming experience, farm distance and income level of the farmers which had positive coefficients as well as statistically significant. However, household size had a negative coefficient though not statistically significant, this negate the a priori expectation. Return to scale for yam production was 0.96 and exhibits decreasing return to scale in the study.

Akhilomen *et al*. (2015) studied the economic efficiency analysis of pineapple production in Edo State, Nigeria: A stochastic frontier production approach. Descriptive statistics and the stochastic frontier production and cost function models were employed for this study. Result revealed that while farm size and labour significantly influenced production efficiency, the costs of farm, suckers and output were significant in influencing cost efficiency. Average technical, allocative and economic efficiencies of the farmers were 0.70, 0.68 and 0.64 respectively indicating ample opportunity for farmers to increase their productivity. The return to scale (RTS) for the production function revealed that the farmers operated in the rational zone (stage II) of the production surface having a RTS of 0.52. The analysis further indicated that the presence of technical and allocative inefficiencies had effect on pineapple production as depicted by the significant estimated gamma coefficient of each model and the predicted technical and allocative efficiencies within the farmers.

Sani and Oladimeji (2017) studied the determinants of technical efficiency among sorghum farmers under agricultural transformation agenda in Gombe State, Nigeria. Descriptive statistics and stochastic production frontier model was employed in the analysis of the data. The mean age of the sorghum farmers was found to be 48 years, average farming experience was 18 years and majority of the farmers (63.4 percent) had household size that ranged from 1-10 persons with the average household size of 11 persons. The study revealed that sorghum farmers achieved technical efficiency of 83 percent. The determinants of technical efficiency include: seed, fertilizer and labour. The study also reveals the mean efficiency to be 0.83, with minimum efficiency to be 9.2 while maximum was 92.1.

Cooker *et al*. (2018) studied the effect of household demographics on the technical efficiency of cowpea farmers: evidence from stochastic frontier analysis in Nigeria. Descriptive statistics and stochastic frontier analysis model were used for data analysis. The study revealed that the farmers were aged farmers with small farms. The household demographics and educational status have direct statistical effects on the technical efficiency of the cowpea farmers. The study also revealed that inputs with respect to farm size, hired labour, agrochemicals and seed were all positive and statistically significant at $p<0.01$. Educational level was positive and statistically significant at $p<0.1$ with a coefficient of 0.011. Farm size was negative with coefficient of -0.149 which was also statistically significant at 5 percent. Gender of decision maker on technology utilization, employment, number of extension visits, house ownership, income of household head and access to credit were significant at $p<0.01$ and negative with coefficients -0.096, -0.190, -

0.654, -0.000 and -0.919 respectively. The mean technical efficiency was 0.791 with minimum at 0.44 and maximum at 0.96.

Abdulrahman and Yusuf (2018) studied the analysis and efficiency of cocoyam producers in Kaduna State, Nigeria. The researchers used DEA input model to estimate the economic efficiency scores. The findings revealed that majority of the respondents operated within a technical efficiency range of 0.81 and less than 1.0, allocative range of 0.2 and less than 0.2 and economic efficiency range between 0.029 and 1.0, with a mean efficiency of 0.335. The study also revealed that none of the sampled cocoyam farms reached the frontier threshold and low level of overall economic efficiency is the result of higher cost of allocative inefficiency and scale inefficiency (operating at less than optimal scale size).

2.4.1 Constraints associated with millet production

Adebayo *et al.* (2008) studied constraints of millet production in Gamawa local government area of Bauchi State. They found that high cost of input (81.1 percent) to be the highest problem faced by farmers in the area. Others were inadequate credit (76.7 percent), inadequate and untimely supply of input (57.8 percent), disease and pest problems (44.4 percent), labour shortage during peak periods (38.9 percent) and poor extension services (27.8 percent).

Jirgi *et al.* (2010) found constraints of millet production to be low soil fertility (9.05 percent), lack of improved millet varieties (8.9 percent), inadequate information on improved millet production practices (8.8 percent), millet production practices (8.8 percent), diseases and pest attacks (8.7 percent), unavailability of inorganic fertilizers (8.56 percent), high cost of labour (8.34 percent), lack of finance to carry out necessary farming activities (8.22 percent), lack of planting materials (7.73 percent), lack of adequate rains during critical periods (6.59 percent), lack of efficient post-harvest storage methods (6.53 percent), lack of staking materials (4.99 percent) and inadequate knowledge about the use of inorganic fertilizers (4.8 percent).

Gabriel (2013) studied the constraints in millet marketing in Tanzania. The researcher found out that lack of market (24 percent), low level of mechanization and technology (15.4 percent), high cost of production (14 percent), lack of capital (12 percent) and inadequate extension officers (10 percent) were the major challenges faced by the farmers in producing millet in Tanzania.

Owere *et al.* (2014) studied farmers' perceptions of millet production constraints, varietal preferences and their implications to finger millet breeding in Uganda. In their research, they identified major constraints as high labour requirements (70 percent), since 95 percent of the farmers use broadcasting as method of planting. Other constraints identified were low yield cultivars (17 percent), weed (7 percent) and diseases caused by pest such as; striga (6 percent). Striga (witch weed) is a strong parasitic weed that creates major problem of cereal crops across Africa.

Abubakar (2014) studied the economic analysis of millet-based cropping systems in Bindawa and Charanchi local government area, Katsina State, Nigeria. The study revealed that inadequate fertilizer was the major constraint faced by farmers in the various enterprises observed, other constraints found were lack of storage facilities, pest and diseases problem, poor market, inadequate land and lack of capital.

Shibairo *et al.* (2014) studied millet production in lower Eastern, Kenya. The researchers revealed that lack of seeds, weeds, blast diseases and Bird predation were the major constraints that faced millet production in lower Eastern Kenya. Millet is known to be highly susceptible to blast disease infestation, especially during the long rain season, causing great yield losses. They reported that Quelea birds were the main pest affecting millet in the field. Most of those who grew millet relied on seeds from their own farms or their neighbors and therefore lack access to seeds. This may be attributed to extension work being focused on more popular crops like maize and beans, and opposed to traditional crops like millet that are better adapted to the arid and semi-arid lands (ASAL) regions. High weed infestation was identified as a major constraint as millet looks like certain weeds that are close relatives to the crop. Farmers complained that due to the close similarity of the cereal to weeds, weeding became a difficult and expensive task as the crop required to be weeded more times than other crops to remove weeds that were missed during first weeding.

Dawud *et al.* (2017) studied farmers' production constraints, knowledge of striga and preferred traits of pearl millet in Jigawa State, Nigeria. The researchers highlighted the major constraints in millet production in the study area was land shortage (35 percent), low soil fertility (20 percent), striga (15 percent), downy mildew (12 percent), lack of capital (10 percent), theft (4 percent) and high cost of labour (4 percent).

Girei *et al.* (2018) found the constraint of millet production to be high cost of labour (84 percent), pest and diseases (81 percent), inadequate storage facilities (71 percent), inadequate capital (71 percent), transportation problems (67 percent), marketing problems (67 percent), high cost of inputs (55 percent), pilfering (42 percent), inadequate information (34 percent), reciprocal labour (28 percent) and shared cropping problem (27 percent).

The available empirical studies on millet production in Nigeria (Adebayo, *et al.*, 2008; Abubaka, 2014; Dawud, *et al.*,2017; Girei *et al.*, 2018, among others) focused on the factors limiting millet production in Nigeria, which they enlisted as high cost and supply of inputs, pest and diseases attack, shortage and high cost of labour, inadequate credit and finance. However, it was not specific on the economics of millet-based production systems which this research work tends to achieve.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

The study area is Katsina State. It is located in the northern part of Nigeria, between Latitudes 11^0 07" and 13^0 22" N and Longitudes 6^0 52"and 9^0 22" E of the prime meridian (Kurfi, 2011). It shares common borders with Kano and Jigawa States to the East, Zamfara and Sokoto States to the West, Niger republic to the North and Kaduna State in the South. There are 34 Local Government Areas (LGAs) in the State. The State has a land area of about 24,192 Square kilometers (Abubakar, 2014). Using 3 percent growth rate, the population is projected to 10,718,073 people in 2019 (National Population Commission, NPC, 2006; National Bureau of Statistics, NBS, 2019).

The zone has a mean annual rainfall greater than 650 mm. The climate conditions of the state vary considerably according to month and seasons. A dry season in the months of November to April and a rainy season from May to October. The mean annual temperature for the zone is in the range of 24 - 34 ^{0}C. The mean annual evapotranspiration is order of 200 - 300 mm. The soil types in the State comprises of entisols, inceptisol and alfisols. The first two are young and immature soils, well-drained and derived from recent Aeolian deposits while the third are form of parent materials rich in Quartz, crystalline rocks of basement complex, and on sedimentary deposits (Abubakar, 2014). A wide range of crops are grown in the zone consisting of grains and legumes. The grains include: millet, maize, sorghum and rice. The legumes are groundnut and cowpea. The livestock kept are cattle, fowls, sheep and goats (Kurfi, 2011).

3.2 Sampling Procedure and Sample Size

A multi-stage sampling procedure was used for this study. The first stage involved a purposive selection of three LGAs in the state based on the predominance of millet-based production systems. They are: Sandamu, Mai'Adua and Daura LGA. There are 24 villages in Sandamu LGA, 29 in Daura LGA and 65 villages in Mai Adua LGA. In the second stage, 10 percent of the villages from each LGA were selected randomly. A reconnaissance survey was carried out with extension agents from Katsina State Agricultural and Rural Development Authority (KTARDA) to identify the farmers who practiced millet-based production systems in the selected villages. The farmers were grouped into five enterprises as follows:

1. Millet / Sorghum
2. Millet / Sorghum / Groundnut / Cowpea
3. Millet / Sorghum / Groundnut
4. Millet / Sorghum / Cowpea
5. Sole millet

From the population of farmers for each of the production systems in each selected village, 10 percent were randomly selected aside from the sole millet farmers that were few in number and 10 percent cannot give an adequate figure. Therefore, all of the sole millet farmers were selected, to give a sample size of one hundred and ninety-six farmers. The rationale for selecting at least 10 percent of the population of millet farmers was in accordance with Kajang and Jatau (2004) adopted by Sani and Oladimeji (2017) who stated that at least 10 percent of the population is a fair representation where there is a large population.

Table 3.1: Distribution of millet-based farmers in the study area

		Sample population						Selected sample (10%)					
LGA	**Village**	**MS**	**MSGC**	**MSG**	**MSC**	**SM**	**Total**	**MS**	**MSGC**	**MSG**	**MSC**	**SM**	**Total**
Sandamu	Fago	50	24	45	16	2	155	5	2	5	2	2	16
	Sandamu	35	30	33	22	2	143	4	3	3	2	2	14
Mai'Adua	Bula	30	30	40	25	1	136	3	3	4	3	1	14
	Daba	40	36	32	29	2	158	4	4	3	3	2	16
	Mai-baga ruwa	41	34	45	30	1	164	4	3	5	3	1	16
	Koza	39	33	40	21	2	149	4	3	4	2	2	15
	Tuga	50	25	44	19	3	168	5	3	4	2	3	17
	Wala	33	29	22	23	2	123	3	3	2	2	2	12
Daura	Kalgo	77	44	79	34	3	264	8	4	8	3	3	26
	Madobi	80	48	74	27	4	267	8	5	7	3	4	27
	Mazoji	70	38	67	23	3	228	7	4	7	2	3	23
Total		545	371	521	269	25	1955	55	37	52	27	25	196

Source: Katsina State Agricultural and Rural development Authority (KTARDA), 2019. Note: MS = millet/sorghum, MSGC = millet/sorghum/groundnut/cowpea, MSG = millet/sorghum/groundnut MSC = millet/sorghum/cowpea and SM = sole millet

Note*: All SM farmers were selected in all villages because they were less than 10 in each case.

3.3 Data Collection

Data was collected from primary source. This was done using structured questionnaire administered to the selected millet-based farmers. Data was obtained from these millet-based farmers on the socio- economic characteristics and they include age, farming experience, household size, non-farm income, extension contact, level of education, membership of farmers' group or association level of education, credit obtained/ loan obtained and farm size. Inputs such as; farm size used for each millet-based production systems, quantities and costs of: seeds planted, labour used for different farm operation, farm tools, inorganic fertilizers and organic manure applied, agro-chemicals used and output realized from crops in the millet-based production system (kg).Constraints associated with millet-based production systems in Katsina State.

3.4 Analytical Techniques

The analytical tools used to achieve the objectives of the study were:

i. Descriptive Statistics

ii. Net Farm Income Analysis

iii. Data Envelopment Analysis (DEA)

iv. Tobit Regression Model

3.4.1 Descriptive statistics

Descriptive statistics was used to achieve objectives (i), (ii) and (vii) of the study. It involved the use of measure of central tendency such as; mean, frequency distribution, percentages and rankings and also measure of dispersion such as range, variance, standard deviation, and coefficient of variation.

3.4.2 Gross margin analysis

The gross margin analysis was used to measure the profitability of millet-based farmers in the study area. The model is specified as thus:

$$GM = TR - TVC \quad (3.1)$$

Where:

GM = Gross margin (Naira)

TR = Total revenue (Naira)

TVC = Total variable cost (Naira)

$$GMms = (TRm + TRs) - (TVCm + TVCs) \quad (3.2)$$

$$GMmsgc = (TRm + TRs + TRg + TRc) - (TVCm + TVCs + TVCg + TVCc) \quad (3.3)$$

$$GMmsg = (TRm + TRs + TRg) - (TVCm + TVCs + TVCg) \quad (3.4)$$

$$GMmsc = (TRm + TRs + TRc) - (TVCm + TVCs + TVCc) \quad (3.5)$$

$$GMsm = (TRm) - (TVCm) \quad (3.6)$$

Where:

m = millet

s = sorghum

g = groundnut

c = cowpea

$$RNI = \frac{TR}{TVC} \quad (3.7)$$

Where

RNI= Return per naira invested

TR = Total revenue (Naira)

TVC = Total variable cost (Naira)

$$RNIms = (TRm + TRs)/(TVCm + TVCs) \ldots\ldots\ldots (3.8)$$

$$RNImsgc = (TRm + TRs + TRg + TRc)/(TVCm + TVCs + TVCg + TVCc) \ldots\ldots (3.9)$$

$$RNImsg = (TRm + TRs + TRg)/(TVCm + TVCs + TVCg) \ldots\ldots\ldots (3.10)$$

$$RNImsc = (TRm + TRs + TRc)/(TVCm + TVCs + TVCc) \ldots\ldots\ldots (3.11)$$

$$RNIsm = (TRm)/(TVCm) \ldots\ldots\ldots (3.12)$$

Where:

m = millet

s = sorghum

g = groundnut

c = cowpea

Production function was developed to determine the physical relationship between inputs and output and used to compare the relative importance for common resources used in millet crop mixtures. The crops output grain equivalent weight (GEW) was adopted from Clark and Haswell (1970) cited in Abubakar (2014) to convert yield or output of different millet based production system to GEW. The implicit form of the model is as follows:

$Y_i = f(Z_1, Z_2, Z_3, Z_4, Z_5, U)$ …………………………………………………………… (2.13)

Where:

Y_i = Crops output in grain equivalent weight (GEW)

i = enterprise $i - n$ (MS = 1; MSGC = 2; MSG = 3; MSC = 4 and Sole millet = 5)

Z_1 = Farm size (Ha)

Z_2 = Seeds in grain equivalent weight (Kg)

Z_3 = Fertilizer (Kg)

Z_4 = Labour (man-days)

Z_5 = Agro-chemical (Litres)

U = Error term

The expression of outputs and seeds in grain equivalent weight (GEW) was to standardize the heterogeneous outputs and seeds quantities in the mixed cropping by multiplying them with given conversion factors based on the grain values of the crops. The conversion factors provided by Abubakar (2014) were used for the purpose of standardization. The conversion factors and method are presented in Appendix IV.

3.4.3 Data envelopment analysis (DEA) model

Input oriented DEA model was used to achieve objectives (iv) and (vi) of this study. The technique of DEA for computing Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE) for individual millet-based farms was used. The data was composed by excel and finally analyzed by using DEA software to get the technical, allocative and economic efficiency of millet-based producers under Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) DEA models. In general, DEA is referred to as a linear programming technique that converts multiple incommensurable inputs and outputs of each decision making unit (DMU) into a scalar measure of operational efficiency, relative to its competing DMUs.

DEA identifies ‘peer’ DMUs for an individual DMU and then estimates the efficiency of the DMU by comparing its performance with that of the best practice DMUs chosen from its peers. Note that the idea here of best practice is not theoretical and possibly unattainable concept, but the DMU(s) performing best amongst their peers, which is assigned efficiency score of 1. These units constitute the referrals ‘standards’ and ‘envelop’ the other units and, thus, form the efficiency frontier. DEA involves solving a linear programming problem for each DMU. The solution to the linear programming problem consists of information about the peers of the DMU and the efficiency of the DMU relative to its peer group. In DEA, technical efficiency (TE) can be viewed from two perspectives. First input oriented TE focuses on the possibility of reducing inputs to produce given outputs levels. Second, output-oriented TE considers the possible expansion in outputs for a given set of input quantities (Mostafa, 2009).

DEA is becoming an increasingly popular management and is commonly used to evaluate the efficiency of a number of producers. A typical statistical approach is characterized as a central tendency approach and evaluates procedures relative to an average producer. In contrast, DEA is an extreme point method and compares each producer with only the "best" producers. In this study, among variable cost, the selected inputs for the DEA models include cost of different sources, such as farm size, labour, seed, inorganic fertilizer, organic manure, agro-chemicals and the output will be the millet produced. Based on the cost of the inputs and output and survey data various DEA models can be computed. Here, the basic DEA model includes the CCR and BCC models (Hassan, 2014). The CCR model is built on the assumption of Constant Return to (CRS) of activities, but the BCC model is built on the assumption of Variable Return to Scale (VRS) of activities.

Production efficiency can be defined in terms of the production function that relates the level of various inputs.

3.4.3.1 technical efficiency (TE): is a measure of farms success in producing maximum output from a given set of inputs. In other words, TE refers to the physical relationship between inputs used in the production process.

$$\sum_{i=1}^{j} \lambda_i x_{q_i} \geq \theta x_{p_0} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 3.14$$

Where:

x = Vector of $\lambda_i$elements representing the influence of each millet-based farmer in determining to technical efficiency of the farm under study

θ = Technical efficiency (TE_{CCR}) (Mostafa, 2009).

Pure technical efficiency

Pure technical efficiency is technical efficiency of Banker, Charnes and Cooper (BCC) model initially proposed by Banker, Charnes and Cooper (1984) and adopted by Hassan (2014). The input oriented BCC model evaluates the efficiency of arms by solving the following functions:

$$Min\ \theta \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.15)$$

Subject to:

$$\sum_{i=1}^{j} \lambda_i y_{q_i} \geq y_{p_0}$$

TE measures output relative to that of the efficient isoquant. Efficient farms produce on the production frontier or alternatively stated on the efficiencies isoquant. TE can be calculated by the ratio of sum of weighed outputs to sum of weighed inputs (Cooper, Seiford and Tone, 2006).

$$\theta = \frac{\sum_p^p = 1 u_p y_{p_j}}{\sum_p^q = 1 v_q x_{q_j}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.16)$$

Where X and Y are inputs and output, V and U are inputs and output weighs respectively, 'q' is the number of inputs (q = 1, 2…., Q), P is the number of outputs (P = 1, 2.…, P) and j represents j-th farm.

The Charnes, Cooper and Rhodes model was initially proposed by Charnes, Cooper and Rhodes (1978) and adopted by Hassan (2014). The CCR model is indicated below:

$$Min\ \theta \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.17)$$

Subject to:

$$\sum_{i=1}^{j} \lambda_i Y_{p_i} \geq Y_{p_0}$$

$$\sum_{i=1}^{j} \lambda_i = 1$$

$$\lambda_i \geq 0$$

The $\sum_{i=1}^{j} \lambda_i = 1$ equation is a convexity constraint, which specified the Variable Return to Scale (VRS) framework (Mostafa, 2009; Hassan, 2014). Without this convexity constraint, the BCC model will be a CCR model describing a Constant Return to Scale (CRS) situation.

3.4.3.2 allocative efficiency (AE): Cost minimizing vector of input quantities given the input prices is determined using the model from the program:

$$\text{Min } x_i^*, \lambda w_i x_i^* \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.18)$$

Subject to:

$$-y_i + y_\lambda \geq 0$$

$$x_i^* - x_\lambda \geq 0$$

$$\lambda \geq 0$$

Where:

w_i= Vector of input prices for the millet-based farm

x_i^* (This calculated using linear programming) = The cost-minimizing vector of input quantities for the millet-based farm, given the input prices $w_i$and the output levels y_i (Hassan, 2014).

3.4.3.3 economic efficiency: This is the product of technical efficiency and allocative efficiency. This is calculated as the ratio of the minimum cost to the observed cost (Hassan, 2014).

$$EE = \frac{w_i^* x_i^*}{w_i x_i} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.19)$$

3.4.4 Tobit regression model

Tobit regression model was used to analyze objective (v). According to Greene (2000) as adopted by Hassan (2014), the Tobit model for a continuous dependent variable is thus:

$$E_i^* = \beta_0 + \beta_i X_i + U_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.20)$$

$$Ei = Y_1^* \, if \, \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + U_i > 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.21)$$

$$E_i = 0 \, if \, \beta_0 + \beta_i X_i + U_i \leq 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.22)$$

Where:

E_i= economic efficiency

E_i^*= latent variable

i = enterprise $i - n$ (MS = 1; MSGC = 2; MSG = 3; MSC = 4 and Sole millet = 5)

β_0= constant term

$\beta_1 - \beta_8$ = coefficients

X_1= age of millet-based farmer (years)

X_2= farming experience (years)

X_3= household size (number of persons eating from the same pot)

X_4= non-farm income (₦)

X_5= extension contact (number of visits)

X_6= level of education (nil = 0, adult education = 1, primary = 2, secondary = 3, tertiary = 4)

X_7= membership of farmers' group or association (years)

X_8= amount of credit (₦)

U_i = error term which is normally distributed with mean 0 and constant variance σ^2.

3.5 Measurement and Operationalization of Variables

3.5.1 Dependent variable

Output (Y_i): This was measured in kilogramme per hectare. The output is the total crops harvested by millet-based farmers after taking into recognition the grain equivalent weight (GEW) of each combination of crop mixtures.

Economic efficiency (E_i): This was derived from the product of technical and allocative efficiencies

3.5.2 Independent variables

Age (X_1)

This was measured in years. It refers to how old the farmer has been from birth to the time of interview. This variable is expected to be negatively related with economic efficiency. The reason is that older farmers seem to be more reluctant in adopting new farm practices than the younger ones (Sani and Oladimeji, 2017). This will reduce economic efficiency.

Farming experience (X_2)

This was measured in years. This is expected to be positively related to economic efficiency. The reason is that farmers who are more experienced in millet-based farming have more ability to make effective farm management decisions, not only adhering to agronomic practices but also with respect to input combination or resource allocation. (Sani and Oladimeji, 2017). This will ensure greater economic efficiency in farming.

Household size (X_3)

This was measured as the number of persons in a household. Household size refers to the total number of people in the house which includes the husband, wife/wives, children and dependents that reside within the same house and eat from the same pot. This is expected to be positively related to economic efficiency. The more the household size, the more the farm labour and this would lead to more land cultivated and thus the more the economic efficiency *ceteris paribus* (Ibrahim *et al*., 2016).

Non-farm income (X_4)

This was measured in Naira. This refers to as the total income from other sources apart from farming. This is expected to be positively related to economic efficiency. The reason is that non-farm income provides cash for investment in the farm, especially when labour and materials must be acquired (Oladimeji *et al.,* 2015; Vasco and Tamayo, 2017). More farm investment will translate into increase in economic efficiency.

Extension contact (X_5)

This was measured by the number of visits per farm season the extension worker made to the farmer and vice-versa. This is expected to be positively related with economic efficiency.The more the number of visits, the greater the chances of adopting new technologies. Number of extension contact is expected to increase the economic efficiency (Sani and Oladimeji, 2017). This is expected to increase farmer's economic efficiency.

Education level (X_6)

This is measured by the highest level attained by the respondents in formal or informal education. Thus farmers scoring 0 have no formal education, adult education will score 1, primary education will score 2, secondary education will score 3, and tertiary education will score 4. The level of education of the farmer is expected to have a positive relationship with economic efficiency (Bello and Madza, 2011; Oladimeji and Abdulsalam, 2013). Therefore, the more a farmer advances in his level of education, the more he tends to understand the importance, intricacies and the need to adopt improved farm practices (Bello and Madza, 2011). This is expected to increase the farmer's economic efficiency.

Membership of farmers' group or associations (X_7)

This was measured as the number of years the millet-based farmer has participated in farmers' groups or associations as at the time of this study. This is expected to be positively related to economic efficiency. The reason is that membership of farmers' association enhances access to material inputs and their use as well as the availability of improved inputs and practices (Ireri, 2015). This is expected to increase economic efficiency. Social group meetings make significant contribution to the adoption of innovations which improves the farmer's economic efficiency (Ibrahim *et al.*, 2016).

Amount of credit (X_8)

This was measured in Naira. It refers to the amount of money received from both formal and informal credit sources. Credit is a very important factor that is needed to acquire or develop farm enterprise. Its availability could determine the extent of production capacity (Sani and Oladimeji, 2017). It is expected to be positively related with economic efficiency. The reason is that availability of credit enhances farmers to purchase and use improved management practices (Ireri, 2015). This is expected to increase farmer's economic efficiency.

Farm size (Z_1)

Farm size was measure in hectares. This is expected to be positively related to economic efficiency. The reason is that a farmer with more land to cultivate will produce more output (Oladimeji and Abdulsalam, 2013). This is expected to increase farmer's economic efficiency.

Quantity of seed (Z_2)

This was measured in kilograms (kg). This is included in the model to investigate the actual kilograms of millet seed used during a production cycle (Girei *et al.,* 2018). It is expected to be positive. This implies that, increase in quantity of seed will bring about increase in yield.

Quantity of fertilizer (Z_3)

This will be measured in kilogram (kg). This is included in the model to investigate the amount of inorganic fertilizer use in millet production (Girei *et al.,* 2018). It is expected to be positive and it implies that more output will be produced with inorganic fertilizer usage.

Quantity of labour (Z_4)

This will be measured in man-days. It consists of both family and hired labour. This is included in the model to examine how variability in labour used will affect output (Girei *et al.,* 2018). This is expected to be positive and it implies that, more labour will bring about increase in yield.

Quantity of agro-chemicals (Z_5)

This was measured in litres (L). This is included in the model to examine the actual amount of agro-chemicals used during the production cycle (Girei *et al.,* 2018). It expected to be positive and it implies that, increase in agro-chemicals used will result to increase in yield.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socioeconomic Characteristics of Farmers

The socioeconomic characteristics of the respondents that were analyzed using descriptive statistics include age, levels of education, household size, years of farming experience, farm size, off-farm income, access to extension agents, extension contact, access to credit, amount of credit obtained and membership of association of the respondents.

4.1.1 Age of farmers

The result of the age distribution of millet-based farmers is presented in Table 4.1. About 22 percent of the respondents were within the ages of 41-50 years. The minimum age of the respondents is 23 years while maximum is 75 years. The mean age of the farmers is 49 years. People within this age range are believed to be dependent on their knowledge and experience rather than their physical strength. This implies that the farmers are inclined to invest in the use of machinery instead of labor input for high agricultural productivity. This is in consonance with Guo *et al*. (2015), who pointed out in a study that aging agricultural producers need technology to compensate for physical deficiency. Knowledge and skills in agriculture, such as production, operation, and management, increase with age.

Age range	Frequency	Percentage
21-30	10	5.1
31-40	40	20.4
41-50	43	21.9
51-60	41	20.9
61-70	40	20.4
71-75	22	11.2
Total	196	
Minimum	23	
Maximum	75	
Mean	49	

4.1.2 Marital status

The result of the distribution of the marital status of the millet-based farmers is presented in Table 4.2. Majority of the farmers (95.4 percent) were found to be married. A few of the farmers (2 percent) were found to be widowed. 2.6 percent of the respondents were single. The significance of high number of married farmers is that it may influence the size of households as married farmers may have larger household who will help in the supply of family labour to accomplish different farm operations in other to increase their income and standard of living. This finding is in agreement with Oluwatusin and Shittu (2014)who posited that it is expected that family labour would be more available where the household heads are married in the study, effect of socio-economic characteristics on the farm productivity performance of yam farmers in Nigeria.Another significance of high number of married farmers is that married couples have the advantage of combined efforts in acquiring agricultural information and pulling funds together to utilize technologies to ensure farm operations are run smoothly (Cooker *et al.*, 2018).

Table 4.2: Distribution of millet-based farmers' based on marital status

Marital Status	Frequency	Percentage
Married	187	95.4
Single	5	2.6
Widow/widower	4	2.0
Total	196	100

4.1.3 Household size of farmers

The result of distribution of household size of millet-based farmers is presented in Table 4.3. About 40.3 percent of the farmers have household size of 6-10 persons; while very few (10.8 percent) had household size of 16 - 25 persons. The mean household size is closely related to what was found by Odoh and Nwibo (2017), where the mean farming household size was 9 persons in socio-economic determinants of rural non-farm households' income diversification in southeast Nigeria. This indicates that there is likelihood of reduced cost of labor, as adequate family labor will be available for farming operations *ceteris paribus*. There is 56.7 percent degree of variation in the household size of farmers in relation to the mean household size of 9 persons.

The significance of household size in agriculture hinges on the fact that the availability of labour for farm production, the total area cultivated to different crop enterprises, the amount of farm produce retained for domestic consumption, and the marketable surplus are all determined by the size of the farm household (Oladimeji and Abdulsalam, 2013). Another significance of large household size is members can share ideologies that would help to run farm operations in other to increase productivity and also more capital can be raised by members of a household with non-farm employment to help to acquire tools and various inputs used to run the farm operations to ensure productivity (Garner and de-la O'Campos, 2014).

Table 4.3: Distribution of millet-based farmers' household size

Household size	Frequency	Percentage
1-5	52	26.5
6-10	79	40.3
11-15	44	22.4
16-25	21	10.8
Total	196	100.0
Mean	9	
Std. Dev	5.1	

4.1.4 Farming experience of millet-based farmers

The distribution of millet-based farmers by years of farming experience is presented in Table 4.4. About 50.5 percent had farming experience of 26 – 35 years with minimum and maximum of 5 years and 57 years' experience respectively. The mean years of farming experience was 31 years. This result shows that majority of the farmers are experienced in millet-based production systems. Many years of experience shows that farmers will be able to make sound decisions that are technically feasible as regards to resources allocation and management of their farm operations that is economically worthwhile. This finding is in line with Oluwatusin and Shittu (2014). He reported that years of farming experience increased agricultural productivity among farming households in Nigeria, the more the number of years of production by the farmer, the more knowledge and skills gained which in turn brings about efficiency. Farmers who have gained a lot of farming experience also have the capacity of maximizing their output and profit at minimum cost. It thus supports the findings of Obasi *et al.* (2013) that farming experience enhances efficient use of scarce resources by farmers in Nigeria.

Table 4.4: Distribution of farmers by years of farming experience

Farming Experience	**Frequency**	**Percentage**
5-15	23	11.7
16-25	65	33.2
26-35	99	50.5
36-50	5	2.6
51-57	4	2.0
Total	196	100
Minimum	5	
Maximum	57	
Mean	30.8	
Std. Dev	13.7	

Another significance is that farmers with a lot of farming experience tend to know about the risk involved in some decisions they are to make and also provide means of managing or averting them. This finding agrees with Onubuogu and Esiobu (2016), who reported that farmers with higher years of experience would be more efficient, have better knowledge of climatic conditions, better knowledge of efficient allocation of resources and market situations and are thus, expected to run a more efficient and profitable agribusiness enterprise. As years of farming experience increases, farmers tend to build strong capacity, develop methods and technical skills to handle various kind of risk they encounter. The implication of the findings is that farmers would set realistic time and cost targets, allocate, combine and utilize better risk-smart options to thwart the negative impact of agricultural risk and enhance agricultural production in the area (Onubuogu and Esiobu, 2016).

4.1.5 Education levels of millet-based farmers

The result of the distribution of education levels of the millet-based farmers is presented in Table 4.5. About 42.9 percent of the farmers had no formal education. Only very few (15.3 percent) of the farmers had tertiary educational qualification while others had primary educational qualification (17.3 percent) and secondary educational qualifications (24.5 percent). This result showed that about 57 percent of the farmers in the study area had one form of formal education or the other, implying that there is potential for increased millet-based production since literate household heads have better ability and knowledge to access and absorb new information, which in turn influence the decision to adopt new technology. Cooker *et al.* (2018) noted that level of education is expected to influence farmers' adoption of agricultural innovations and decision on various aspects of farming. He maintained that education is highly important for sustainable agricultural growth and development.

Another significance of education is that it enhances farmers' ability to make accurate and meaningful management decision. According to Ajah (2012), level of education of a farmer is an important factor that determines his or her ability to understand policies or programmes that affects farming. It also helps farmers to understand the risk involved when they make certain decisions.

Table 4.5: Distribution of education levels of farmers

Level of education	Frequency	Percentage
No formal Education	84	42.9
Primary Education	30	15.3
Secondary Education	48	24.5
Tertiary Education	34	17.3
Total	196	100

4.1.6 Millet-based farmers' access to extension services

The result of the distribution of millet-based farmers' access to extension services as presented in Table 4.6 showed that 88.3 percent of the respondents had no contact with an extension agent, while other farmers had at least one extension contact. The maximum and minimum extension contacts observed was 5 and 0 times in a cropping season respectively. This result is similar with the findings of Adisa (2015) who reported that 205 out of 231 farmers had no extension contact in his study and this indicates a low level access to extension agents in the study area.

The inability of majority of farmers to have access to extension services through extension agents may result in low level adoption of improved millet-based farming practices especially if farmers do not have other sources of information on the benefits of such practices and how they implement the practices (Ajah, 2012). It is expected that extension services should enhance millet-based farmers' ability to efficiently utilize resources through the adoption of improved methods used in millet-based production systems in the study area.

Table 4.6: Distribution of farmers' access to extension contact

No. of Extension contacts	Frequency	Percentage
No contact	173	88.3
Once	3	1.53
Twice	5	2.55
Thrice	13	6.63
Four times	1	0.5
Five times	1	0.5
Total	196	100.0

4.1.7 Millet-based farmer's membership of association

The result shown in Table 4.7 revealed that a large proportion (about 98.5 percent) of the farmers does not belong to any association. The non-membership of association particularly farmer association by most of the farmers suggests the benefits of social capital endowment such as access to information, input and output market, credit, risk sharing amongst others via association is likely to elude the farmers. The result contradicts Okafor and Okafor (2017) where about 70 percent of the farmers were found to be members of one or more farmers' association in the study membership of cooperative society and adoption of agricultural technology in Awka-North local government area of Anambra State, Nigeria.

Ajah (2012), observed that membership of cooperative societies has advantages of accessibility to micro-credit and input subsidy. Also serve as an avenue of availing ideas and information that could help them in pooling of resources together in order to expand their production efficiency and for profit maximization. Membership of cooperatives affords farmers the opportunity of sharing information on modern practices. However, most of these associations are grossly underdeveloped and inactive (Ajah, 2012).

Table 4.7: Distribution of millet-based farmers according to cooperative membership

Farmers Association	Frequency	Percentage
Member	3	1.5
Non-member	193	98.5
Total	196	100

4.1.8 Millet-based farmers' access to credit

The result of the distribution of millet-based farmers' access to credit presented in Table 4.8 showed that majority (99.5 percent) of the farmers in the study area had no access to credit, while 0.5 percent had access to credit from different sources. The implication is that the output of millet-based production will be smaller and other inputs will be affected since capital is not available to enhance production. Majority of the millet-based farmers who are credit constrained corroborates the findings of Abubakar (2014) in the study on millet-based cropping system in Katsina state, Nigeria.

Table 4.8: Distribution of millet-based farmers according to access to credit

Access to credit	Frequency	Percentage
Access	1	0.5
No Access	195	99.5
Total	196	100

Asogwa *et al.* (2014), who asserts that credit, is a very strong factor that is needed to acquire or develop any enterprise; its availability could determine the extent of production capacity. It also agrees with the findings of Okwoche *et al.* (2012), who noted that access to micro-credit could have prospects in improving the productivity of farmers and contributing to uplifting the livelihoods of disadvantaged rural farming communities. According to Mudi (2007), credit is regarded as a major factor in agricultural development and lack of it is usually given as an explanation for many of the problem facing the sector in the developing nations, if credit were made available, the retarded agricultural sector will start moving by their contributions to the modernization of the sector. The low accessibility to credit services have been reported in many parts of Sub-Saharan Africa as well as other developing countries as the limiting factor for increased agricultural productivity (Okoedo-Okojie and Onemolease, 2009).

4.1.9 Farm size owned by respondents

The result of the total farm owned by farmers is presented in Table 4.9. The result showed that about 43.4 percent of the farmers owned between 0.6 – 1.0 hectare of land, while only 5.6 percent owned above 2.5 hectares. The mean farm size owned was 1.3 hectares, indicating that majority of the farmers have small farm size (cultivating less than 3.0 hectares of land) and were not able to enjoy economy of scale in production. This finding almost similar with Obasi *et al.*

(2013), who found out the mean farm size was 1.4 hectares in the study, factors affecting agricultural productivity among arable crop farmers in Imo state, Nigeria. Consequently, small farm size is an impendent to agricultural mechanization because using farm machineries like tractor will be difficult. Small farm sizes might be as a result of the fact that most of the farmers got their land through inheritance in line with studies of Oladimeji *et al.* (2016) on melon production in Kwara State; Sidi *et al.* (2014) on sesame production in Yobe State and Oladimeji and Abdulsalam 2013 on rice production in Kwara State of Nigeria. There is 84.6 percent degree of variation in the size of farm of the farmers in relation to the mean farm size of 1.3 hectares.

Table 4.9: Distribution of farmers based on farm size owned

Farm size (ha)	**Frequency**	**Percentage**
0.1- 0.5	18	9.2
0.6-1.0	85	43.4
1.1-1.5	56	28.6
1.6-2.0	13	6.6
2.1-2.5	13	6.6
2.5-4.0	11	5.6
Total	196	100
Mean (ha)	1.3	
Std. Dev	1.1	

4.2 Millet-Based Production Systems in the Study Area

The different millet-based production systems which the respondents identified are shown in Figure 6. Majority of the farmers (72.5 percent) were mostly engaged in the combination of millet, sorghum, groundnut and cowpea. The uncertainty of harvest (yield) due to the changing climatic conditions may have contributed to the farmer's choice of more crop combinations for security. The choice of four different crop mixtures has an added advantage of resource utilization of land. Only 2 percent of the farmers planted millet solely. This result agrees with Abubakar (2014), who found in a study that: (i) millet, sorghum, groundnut and cowpea were the most important crops in the northern part of Katsina State; and (ii) 4-crop mixtures were more prevalent in the zone than sole, 2-crop mixtures and 3-crop mixtures.

Table 4.10: Distribution of farmers based on their different enterprises

Millet-based production system	Frequency	Percentage (%)
Millet/sorghum (MS)	12	6.1
Millet/sorghum/groundnut/cowpea (MSGC)	142	72.5
Millet/sorghum/groundnut (MSG)	12	6.1
Millet/sorghum/cowpea (MSC)	26	13.3
Sole millet (SM)	4	2.0
Total	196	100

Furthermore, majority of the farmers (91.9 percent) might have known the importance of legumes in agriculture and that could be a good reason why most farmers opted to plant at least one legume crop alongside millet. Alex *et al.* (2011) and Bano and Iqbal (2016), opined in their various studies that agricultural systems have traditionally relied much on legumes for nitrogen input in the soil. They further explained that nitrogen being an inert gas cannot be used by plants, animals and micro-organisms. Legumes help to convert the nitrogen gas into its usable form like ammonia which can be used by the plants and other organisms.

4.3 Profitability of Millet-Based Production Systems in the Study Area

Results presented in Table 4.11 indicated that millet/sorghum/cowpea has the highest gross margin ₦169,534.7, and return per naira invested of 3.27, due to the cost expended on labour is lower than that of other enterprise. This is in line with the findings of Ali *et al.* (2018), who observed that labour accounts for 61 percent of cost of millet production in Funakaye local government area, Gombe State, Nigeria. Similar studies by Ebukiba (2010) and Osugiri *et al*. (2012) also revealed that labour constitutes a higher percentage of production cost in cassava.

The rate of returns on investment (return per naira invested, RNI) for millet/sorghum was 1.66, indicating that for every ₦1 invested in millet/sorghum production in the study area; a profit of ₦0.66 was made. The RNI for millet/sorghum/groundnut/cowpea was 2.83, indicating that for every ₦1 invested in millet/sorghum/groundnut/cowpea production in the study area; a profit of ₦1.83 was made. The RNI for millet/sorghum/groundnut was 2.53, indicating that for every ₦1 invested in millet/sorghum/groundnut production in the study area; a profit of ₦1.53 was made. The RNI for millet/sorghum/cowpea was 3.27, indicating that for every ₦1 invested in millet/sorghum/cowpea production in the study area; a profit of ₦2.27 was made. The RNI for sole millet was 1.56, indicating that for every ₦1 invested in sole millet production in the study area; a profit of ₦0.56 was made. This result agrees with the findings of Abubakar (2014) in his research ofn economic analysis of millet-based cropping systems in Chirachi and Bindawa LGAs, Katsina State, Nigeria.

Table 4.11: Profitability of millet-based production systems

Variables	MS	MSGC	MSG	MSC	SM
Cost of seed ₦/ha	6,495.39	14,341.53	15,368.5	12,964.86	4,062.4
Cost of Labour ₦/ha	25,115.4	42,606.34	36,475	22,321.23	24,800
Cost of fertilizer ₦/ha	4,630	9,363.42	4,335.26	5,779.17	7,500
Cost of pesticides ₦/ha	1,366.22	3,185.43	1,316.67	1,900	2,355
Cost of herbicides ₦/ha	-	-	-	-	3,305
TVC ₦/ha	37,607.01	69,496.72	57,495.43	42,965.26	42,022.4
Total revenue (TR) ₦/ha	105,890.3	228,000	192,641.7	212,500	103,500
Gross Margin ₦/ha	68,283.32	158,503.3	135,146.2	169,534.7	61,477.6
Return per naira invested	1.66	2.38	2.53	3.27	1.56
Operating Ratio	0.36	0.30	0.30	0.20	0.41
Gross ratio	0.60	0.42	0.40	0.31	0.64

The operating ratio of 0.36, 0.30, 0.30, 0.20 and 0.41 for millet/sorghum, millet/sorghum/ground nut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively indicates that 36, 30, 30, 20 and 41 percent of the gross revenue is expended on operating costs of variable resources. This means that millet-based farmers can sustain production and survive for a longer time. The gross ratio which measures the solvency and success of millet-based farming were found to be 0.60, 0.42, 0.40, 0.31 and 0.64 for millet/sorghum, millet/sorghum/ groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively. This means that 60, 42, 40, 31 and 64 percent of the gross income for millet/ sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively are accrued to their total cost. Thus, it could be concluded that millet based production in the study area was economically viable.

4.4 Technical, Allocative and Economic Efficiency of millet-based production system

4.4.1 Technical efficiency of millet-based farmers

The frequency distribution of the technical efficiency estimates of millet-based farmers from the DEA model is presented in Table 4.12. It was observed from the study that about 41.67, 69.97, 41.67, 50.0 and 25.0 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/ sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers respectively, had their technical efficiencies between 0 and 0.20. This implies that reasonable percentage of millet-based farmers were not technically efficient in the in the use of production resources. This maximum possible level attainable may be due to inefficiency and hence results to low productivity.

The mean technical efficiency for the millet-based farmers was 0.4, 0.21, 0.38, 0.32 and 0.48 for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/ cowpea and sole millet respectively. This implies that from a given mixture, respondents are able to obtain about 40, 21, 38, 32 and 48 percent of potential outputs respectively. This results indicates that the farmers are not utilizing their production resources efficiently suggesting that in a short run, there are gaps of (60, 79, 62, 68 and 52 percent) to increase the efficiency levels of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/c owpea and sole millet respectively, through better use of available production resources. The finding agrees with Ibrahim (2018), that Nigerian rural farmers do not obtain maximum output from their given quantum of inputs in the study, economic efficiency of sorghum and millet production for small scale farmers in traditional rain-fed, North Kordofan State, Sudan.

Table 4.12: Distribution of technical efficiency estimates of millet-based farmers

TE levels	MS		MSGC		MSG		MSC		SM	
	F	%	F	%	F	%	F	%	F	%
≤0.20	5	41.7	88	61.97	5	41.67	13	50	1	25
0.21 – 0.40	2	16.7	3	2.1	5	41.67	10	38.45	1	25
0.41 – 0.60	1	8.3	32	22.54	1	8.3	1	3.85	1	25
0.61 – 0.80	1	8.3	15	10.56	0	0	1	3.85	0	0
0.81 – 1.00	3	25	4	2.8	1	8.3	1	3.85	1	25
Total	12	100	142	100	12	100	26	100	4	100
Mean TE	0.4		0.21		0.38		0.32		0.48	
Min	0.14		0.11		0.1		0.1		0.1	
Max	1.0		1.0		1.0		1.0		1.0	

4.4.2 Allocative efficiency of millet-based farmers

The result presented in Table 4.13 shows allocative efficiency of millet-based farmers as obtained in the data envelopment analysis. It was observed from the study that about 25.0, 36.62, 25.0 and 50.0 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/ groundnut and millet/sorghum/cowpea farmers respectively, had their allocative efficiencies between 0.41 and 0.60. This implies that reasonable percentage of millet/sorghum, millet/ sorghum/groundnut/cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea farmers are not allocatively efficient in the use of production resources. This allocative inefficiency could be as a result of under-utilization of scarce resources, therefore reduced return to capital.

Table 4.13: Distribution of allocative efficiency estimates of millet-based farmers

AE levels	MS		MSGC		MSG		MSC		SM	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
≤0.20	2	16.7	6	4.23	0	0	1	3.85	0	0
0.21 – 0.40	3	25	28	19.72	1	8.4	4	15.38	0	0
0.41 – 0.60	3	25	52	36.62	3	25	13	50	0	0
0.61 – 0.80	3	25	34	23.94	4	33.3	3	11.54	2	50
0.81 – 1.00	1	8.3	22	15.49	4	33.3	5	19.23	2	50
Total	12	100	142	100	12	100	26	100	4	100
Mean AE	0.56		0.56		0.67		0.56		0.91	
Min	0.17		0.14		0.24		0.14		0.8	
Max	1.0		1.0		1.0		1.0		1.0	

The mean allocative efficiency for the millet-based farmers was 0.56, 0.55, 0.67, 0.56 and 0.91 for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/ sorghum/cowpea and sole millet respectively. This implies that, on the average, the respondents are able to obtain about 56, 55, 67, 56 and 91 percent of potential allocative efficiency of the aforementioned enterprises respectively. It was also observed from the study that about 8.3, 15.5, 33.3, 3.9 and 50 percent of the millet/sorghum, millet/sorghum/groundnut/cowpea, millet/ sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers had allocative efficiency of 0.81 and above. This implies that millet/sorghum, millet/sorghum/groundnut/cowpea, millet/ sorghum/groundnut and millet/sorghum/cowpea farmers are misallocating the resources in wrong proportions. In other words, about 91.7, 84.5, 66.7, 96.1 and 50 percent of the millet/

sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole farmers are allocatively inefficient.

Furthermore, about 50 percent of sole millet farmers obtained allocative efficiency of 0.81 and above. This implies that, through the utilization of resources in optimal proportions given their respective prices and given the current state of technology, they were able to obtain allocative efficiency of 81 percent and above. Farmers can increase their allocative efficiency by 81 percent and above through the optimal utilization of resources. This finding is in line with Okoye *et al.* (2009) cited in Abdulrahman and Yusuf (2018) and they observed that the most allocatively inefficient farmer will have an efficiency gain of 89.6 percent in cocoyam production, if he or she is to attain the efficiency level of most allocatively efficient farmer in the study area. It also agrees with the findings of Asogwa *et al*. (2011) that Nigerian rural farmers are not utilizing production inputs in the optimal proportions, given input prices.

4.4.3 Economic efficiency of millet-based farmers

Table 4.14 revealed that 75.0, 88.73, 75, 76.85 and 25.0 percent of the millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers respectively, had economic efficiency between 0 and ≤ 0.2. This implies that larger proportions of millet-based farmers are not economically efficient in the use of input resources. This inefficiency could arise from farmer's inability to minimize cost or maximizing the potential profit.

Table 4.14: Distribution of economic efficiency estimates of millet-based farmers

EE levels	M/S		M/S/G/C		M/S/G		M/S/C		SM	
	F	%	F	%	F	%	F	%	F	%
≤ 0.20	9	75	126	88.73	9	75	20	76.85	1	25
0.21 – 0.40	0	0	0	0	1	8.3	3	11.6	2	50
0.41 – 0.60	2	16.7	12	8.45	0	0	1	3.85	0	0
0.61 – 0.80	0	0	2	1.41	1	8.3	1	3.85	0	0
0.81 – 1.00	1	8.3	2	1.41	1	8.3	1	3.85	1	25
Total	12	100	142	100	12	100	26	100	4	100
Mean EE	0.23		0.12		0.26		0.18		0.44	
Minimum	0.02		0.01		0.04		0.02		0.19	
Maximum	1.0		1.0		1.0		1.0		1.0	

The mean economic efficiency was 23, 12, 26, 18 and 44 percent for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively. This indicates that millet-based farmers are not economically efficient. This also suggest that for the average farmer in the study area to achieve economic efficiency of his most efficient counterpart, he could realize about 77, 88, 74, 82 and 56 percent cost savings on millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/ cowpea and sole millet respectively. This finding agrees with the observation of Penda *et al*. (2011) that Nigerian rural farmers are economically inefficient in the study, efficiency and income among the rural farmers in Nigeria.

4.5 Estimates of Determinants of Economic Efficiency

The result of Tobit regression analysis used to estimate the parameters of factors affecting the economic efficiency of millet-based farmers are shown in Table 4.15. The pseudo R^2 are 0.463, 0.0664, 0.9664, 0.2267 and 0.8978 for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively.

This suggests that the models are a good fit. This indicates that 46, 7, 96 22 and 89 percent in the variability in economic efficiency of millet-based farmers for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet enterprises respectively are explained by the explanatory variables specified in the model with 99 percent level of confidence and the log likelihood functions was -12.845, -138.473, -0.406, -38.296 and -8.934 for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet respectively.

Table 4.15: Estimate of the determinants of economic efficiency

Variables	**Millet-based cropping systems**									
	MS		**MSGC**		**MSG**		**MSC**		**SM**	
Economic efficiency	**Marg. Eff**	**Std. err**	**Marg. eff**	**Std. err**	**Marg. eff**	**Std. err**	**Marg. eff**	**Std. err**	**Marg. eff**	**Std. err**
Age	-0.25	0.038***	-0.024	0.009***	-0.086	0.023***	-0.14	0.048	0.002	0.005
Marital status	1.484	0.808*	0.166	0.154	-0.509	0.509	-0.099	0.401	-0.465	0.113***
Level of educa	0.804	0.268***	0.092	0.050*	0.073	0.088	0.954	0.256***	-0.005	0.033
Household size	-0.103	0.12	0.012	0.012	-0.129	0.038***	-0.11	0.055**	0.022	0.012*
Farming exp	0.256	0.045***	0.018	0.009**	0.051	0.014***	0.199	0.057***	0.066	0.009***
Association	-3.271	0.981***	-0.288	0.467	1.196	0.370***	-0.859	0.972	0.893	0.142***
Access to credit	-0.544	0.665	0.39	0.153***	0.859	0.448*	2.086	0.765***	-0.65	0.089***
Off-farm income	-6.47E-06	2.10E-06***	-2.50E-07	4.67E-07	2.92E-06	1.61E-06*	-2.29E-07	2.10E-06	5.40E-07	3.86E-07
Extension contact	-0.121	0.433	0.007	0.07	0.244	0.183	-0.163	0.25	-0.165	0.056***
Diagnostic statistics										
No of observation	12		142		12		26		4	
Log-likelihood	-12.845		-138.473		-0.406		-38.296		-8.934	
Prob > Chi	0.0084		0.019		0.0055		0.0075		0.0000	
LR chi2(9)	22.15***		19.7***		23.34***		22.46***		37.77***	
Pseudo R^2	0.463		0.0664		0.9664		0.2267		0.8978	

Note: **** P <0.01, ** P <0.05 and * P<0.1*

The marginal effect of age was directly related to economic efficiency which is negative and statistically significant at $p<0.01$ influencing the economic efficiency of farmers of millet-based enterprises except for the sole millet enterprise. This implies that holding other factors constant, a year increase in age of millet-based producers will decrease their economic efficiency by 25 percent for the millet/sorghum enterprise, 2 percent for millet/sorghum/groundnut/cowpea, 9 percent for millet/sorghum/groundnut and 14 percent for millet/sorghum/cowpea. The reason is that as the farmers increase in age, they get weaker to carry out daily manual farm operations and this would lead to additional cost of labour. This finding agrees with Iheke and Onyendi (2017) work on economic efficiency and food security status of rural farm households in Abia State of Nigeria. They reported that the risk bearing abilities and innovativeness of a farmer, his mental capacity to cope with the daily challenges and demands of farm production activities and his ability to do manual work decrease with advancing age; and the more he or she is unable to combine his or her resources in an optimal manner given the available technology. The marginal effect of marital status was found to be positive and statistically significant at $p<0.1$ for millet/sorghum. This implies that farmers who are married tend to increase the economic efficiency. This may be as a result of the advantage of the combined efforts of married people in acquiring agricultural information and pulling funds together to utilize technologies as against those of respondents that were single and divorced. This finding agrees with Cooker *et al.*(2018) in their study on the effect of household demographics on the technical efficiency of cowpea farmers: evidence from stochastic frontier analysis in Nigeria. Furthermore, the marginal effect of marital was found to be negative and statistically significant at $p<0.01$ for sole millet enterprise and this decreases the economic efficiency. This agrees with Onyenekwe (2014), who stated that the negative influence of this variable could be that the couple focuses on marital affairs and pay little attention on their farm activities.

The marginal effect of educational level was found to be positive and statistically significant at $p<0.01$ for millet/sorghum and millet/sorghum/cowpea. It was also significant in millet/sorghum/groundnut/cowpea at $p<0.1$. This implies that an increase in the level of education by the millet-based farmers will lead to increase in the economic efficiency by 80 percent for millet/sorghum, 9 percent for millet/sorghum/groundnut/cowpea and 95 percent for millet/sorghum/cowpea enterprises. A plausible explanation to this is that, increase in educational level of the farmers leads to higher rate of improved technology and techniques of production adoption. Also, educated farmers are likely to be more successful in gathering information and understanding new practices and the use of modern input which in turn will improve their economic efficiency. Hence, education is a very important policy tool that can be employed to enhance the economic efficiency of sorghum production in the study area. This agrees with the findings of Akpan *et al.* (2013) and Abdulrahman and Yusuf (2018). The marginal effect of household size was directly related to economic efficiency which are negative and statistically significant at $p<0.01$ and $p<0.05$ influencing the economic efficiency of millet/sorghum/groundnut and millet/sorghum/cowpea farmers respectively. This implies that holding other factors constant, an increase in Household size of the millet-based farmers will decrease their economic efficiency by 13 percent for the millet/sorghum/groundnut enterprise and 11 percent for millet/sorghum/cowpea enterprise. This result could be as a result of the fact that when the farmer's household size increases the farmers could supposedly divert the resources to be invested on his farm to other channels there by reducing farm production and directly affecting economic efficiency. This finding agrees with the findings of Onyenekwe

(2014) in the study, effects of off-farm work on technical efficiency and production risk among rice farmers in Enugu State, Nigeria. On the other hand, the marginal effect of the household size of sole millet farmers was found to be positive and statistically significant at $p<0.1$. This implies that an increase in household size will increase economic efficiency by 2 percent in the sole millet enterprise. This agrees with Aboki *et al.* (2013)and Igboji *et al.* (2015) findings, which an increase in household size would bring about increase in farm labour, less money spent in hiring labour and also increase in farm production there by increasing the economic efficiency.

The marginal effect of farming experience was directly related to economic efficiency which are positive and statistically significant at $p<0.01$ for millet/sorghum, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet enterprises and also significant at $p<0.05$, influencing the economic efficiency of for millet/sorghum/groundnut/cowpea farmers. This implies that a year increase in farming experience will increase economic efficiency by 26 percent for millet/sorghum, 2 percent for millet/sorghum/groundnut/cowpea, 5 percent for millet/sorghum/ groundnut, 20 percent for millet/sorghum/cowpea and 7 percent for sole millet enterprises. This means that over the years farmers tend to gain more experience and make certain decisions alongside with taking certain risks in other to increase production on the farm. This finding agrees with Iheke and Onyendi (2017).

The coefficient of membership of an association was found to be positive and statistically significant at $p<0.01$ influencing the economic efficiency for millet/sorghum/groundnut and sole millet enterprises. This means that farmers who belong to one association or the other will increase their efficiency. This findings agrees with Iheke and Onyendi (2017), who found out that cooperative membership/ farmers' associations are sources of good quality inputs, labour, credit, information and organized marketing of products for farmers and this will lead to increase in economic efficiency. On the other hand, the marginal effect of belonging to an association was found to be negative and statistically significant at $p<0.01$, influencing economic efficiency for millet/sorghum enterprise. This agrees with Onyenekwe (2014) finding that the association they belong to are not bringing relevant and up-to-date information to the farmers.

The marginal effect of access to credit was found to be positive and statistically significant at $p<0.01$, $p<0.1$ and $p<0.01$ influencing the economic efficiency for millet/sorghum/groundnut/ cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea enterprises respectively. This implies that that the economic efficiency of the aforementioned farmers will increase with access to credit and the amount of credit obtained. Furthermore, the marginal effect of access to credit was found to be negative and statistically significant at $p<0.01$ influencing the economic efficiency for sole millet. This disagrees with Asogwa *et al*. (2014), who found out that access to credit was significant in their study. This implies that credit access will decrease economic efficiency which is contrary to *a priori* expectation. The reason could be that cooperative bodies would not want to loan to a sole millet farmer because of the uncertainty of harvest (yield) being that they only produce one crop.

The marginal effect of non-farm income was found to be positive and statistically significant at $p<0.1$ influencing the economic efficiency for millet/sorghum/groundnut. This indicates that increase in off-farm income will leave the farmers with more income can be used on farm production and in turn result to increase in economic efficiency. This finding agrees with Penda *et al*. (2011). Furthermore, the marginal effect of non-farm income was found to be negative and statistically significant at $p<0.01$ influencing the economic efficiency for millet/sorghum enterprise. This implies that non-farm income will decrease economic efficiency which is contrary to *a priori* expectation. The marginal effect of extension contact was found to be negative and statistically significant at $p<0.01$ influencing the economic efficiency for sole millet enterprise. This implies that as the number of extension contact increases, economic efficiency will reduce by 17 percent. This finding agrees with Onyenekwe (2014) who in a study opined that extension agents are not bringing relevant and up-to-date information to the farmers or the farmers are not making use of the information provided to them.

4.6 Returns to Scale of Millet-Based Production Systems

Returns to scale is important because in addition to knowing the number of efficient millet-based farms, degree of inefficiency and optimal scale of operation, it is also vital to know how many farms are operating under increasing returns to scale (IRS), decreasing returns to scale (DRS) or operating at optimal scale. Using DEA every millet-based farm was evaluated, given its size to determine its scale measures. This type of analysis according to Abdulrahman and Yusuf (2018), would be useful to each farm as they could determine the implications for expansion. The number of farms operating under constant, increasing and decreasing returns to scale is shown in Table 4.16.

Table 4.16: Distribution of returns to scale estimates

RTS	M/S		M/S/G/C		M/S/G		M/S/C		SM	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
IRS	1	8.33	110	77.46	8	66.67	22	84.62	3	75
DRS	2	16.67	29	20.42	3	25	1	3.85	0	0
CRS	9	75	3	2.11	1	8.33	3	11.54	1	25
Total	12	100	142	100	12	100	26	100	4	100

Note: RTS- Returns to scale, IRS- Increasing returns to scale, DRS- Decreasing returns to scale and CRS- Constant returns to scale.

About 8, 77, 67, 85 and 75 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms were respectively found operating with increasing return to scale (IRS) or sub-optimal scale. This implies that production scale of these farms could be increased by decreasing costs, given that they were performing below optimum. On the other hand, about 17, 20, 25 and 4 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea farms were respectively found operating with decreasing return to scale (DRS). This implies that the farms were operating above the optimum scale, suggesting that these farms could increase their technical efficiency by reducing their input usage.

However, 75, 2, 8, 12 and 25 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms were respectively found operating with optimal scale. Given that majority of the millet-based farms were operating under IRS and DRS except for millet/sorghum farms, this suggests that millet-based farms in general were scale inefficient, since scale inefficiency is usually due to the presence of either IRS or DRS. This is in agreement with Asogwa *et al.* (2011) which stated that 75 percent of farmers were scale inefficient in their work on economic efficiency of small scale farmers in Benue State.

4.6.1 Sensitivity analysis of millet-based production inputs

Land

The result in Table 4.17 shows that land is not a limiting resource to obtain optimal farm plan, about 0.18, 0.11, 0.28 and 0.16 hectares need to be decreased from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea farms respectively for optimal production. This means that land is not used optimally, but over-used. This finding disagrees with Abdulrahman and Yusuf (2018) who observed that land was optimally used in cocoyam production. On the other hand, land was used optimally by sole millet farmers.

Table 4.17: Sensitivity analysis for optimum plan for land in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	0.7	0	-0.18	0.52
M/S/G/C	0.7	0	-0.11	0.60
M/S/G	1.03	0	-0.28	0.74
M/S/C	0.8	0	-0.16	0.64
SM	0.3	0	0	0.30

Seed

The result in Table 4.18 shows that seed is not a limiting resource and for optimal farm plan, about 7.36, 31.95, 40.6, 35.8 and 6.2 kilogrammes needs to be reduced from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. This over-utilization of seed could have emanated from little use of improved seed varieties. This finding is agrees with Abdulrahman *et al.*(2015) that most farmers have little or no access to improve seeds and continues to recycle seeds that have become exhausted after generations of cultivation. Pest and diseases such as shrinking of the seeds and seed dormancy were responsible for pre-harvest and post-harvest losses.

Table 4.18: Sensitivity analysis for optimum plan for seed in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	26	0	-7.36	18.64
M/S/G/C	81.89	0	-31.95	49.94
M/S/G	84.62	0	-40.63	43.99
M/S/C	71.87	0	-35.83	36.04
SM	10.01	0	-6.16	3.84

Labour

The result in Table 4.19 shows that labour is not a limiting resource and for optimal farm plan, about 8.4, 12.4, 19.48, 15.4 and 2.1 man-days needs to be reduced from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. The abundant availability of human labour contrary to *apriori* expectation is relative to the area, given that an average farmer in the area cultivates small farm size per planting season due to nature of the crop. This finding agrees with Igwe and Onyenweaku (2013) and do not agree with Abdulrahman *et al.* (2015) who opined that family labour was predominant in the study area and that is why there was acute shortage of labour. According to farmers, during active period of production, every household would have been engaged in his family farm work. The demand for labour is normally high and very costly during peak period of land clearing, ridging, harvesting, processing and weeding.

Table 4.19: Sensitivity analysis for optimum plan for labour in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	65.33	0	-8.42	56.91
M/S/G/C	58.44	0	-12.41	46.03
m/s/g	57	0	-19.48	37.52
M/S/C	48.04	0	-15.397	32.64
SM	5.11	0	-2.08	3.03

Fertilizer

The result in Table 4.20 shows that there was over-utilization of fertilizer of about 16.7, 18.1, 17.1, 20.1 and 18.1 Kilogrammes needs to be reduced in the model available for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. According to the farmers, fertilizer is made available when farmers are far into the production period, sometimes at the middle of the raining season. This agrees with Abdulrahman and Yusuf (2018).

Table 4.20: Sensitivity analysis for optimum plan for fertilizer in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	19.79	0	-16.66	3.13
M/S/G/C	22.897	0	-18.11	4.78
M/S/G	19.54	0	-17.08	2.46
M/S/C	21.83	0	-20.08	1.74
SM	40.02	0	-18.11	21.91

Agro-chemical

The result in Table 4.21 shows that there was also over-utilization of agrochemicals of about 1.6, 1.7, 1.4, 1.02 and 0.7 litres needs to be reduced in the model available from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. This findings agrees with Igwe and Onyenweaku (2013).

Table 4.21: Sensitivity analysis for optimum plan for agro-chemical in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	4.71	0	-1.58	3.125
M/S/G/C	3.98	0	-1.74	2.236
M/S/G	3.396	0	-1.366	2.03
M/S/C	2.78	0	-1.02	1.76
SM	2.35	0	-0.74	1.61

Output

The result in Table 4.22 shows that output was not optimized due to the limited resources. About 8,014.66, 11,248.15, 1406.08 and 19,248.13 kilogrammes more need to be produced to obtain optimality for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea farms respectively. This result agrees with Abdulrahman and Yusuf (2018) that farmers did not meet optimality in their work on efficiency of cocoyam farmers in Kaduna State. On the other hand, optimality was reached with about 1650.02 kilogrammes produced for sole millet farms.

Table 4.22: Sensitivity analysis for optimum plan for output in millet-based production

Production system	Original value	Radial movement	Slack movement	Projected value
M/S	7175	8014.655	0	15189.66
M/S/G/C	8165.08	11248.15	0	19413.23
M/S/G	2325	1406.081	0	46272.75
M/S/C	6898.08	19248.13	0	26146.2
SM	1650.02	0	0	1650.017

4.7 Constraints to millet-based production systems

The constraints faced by millet-based farmers in the study area were ranked according to their severity as indicated by the farmers in their different enterprises in table 4.23. Examples of constraints faced by the farmers in the study area are; pest and diseases attack, lack of credit and capital, inadequate supply of inputs, poor extension delivery, high cost of improved seed, high cost of labour, lack of post-harvest storage facilities and high cost of transportation.

4.7.1 Pest and diseases attack

Pest and diseases attack were among the major constraints found in millet/sorghum/groundnut/cowpea ranked 2nd with 19.2 percent, millet/sorghum/groundnut ranked 1st with 17.1 percent and sole millet enterprise ranked 1st with 16 percent. It is also fairly high in millet sorghum ranked 4th with 13.7 percent and millet/sorghum/cowpea ranked 4th with 11.9 percent. By way of implication, it means crops are susceptible to attack by numerous pest and diseases throughout the life cycle which are responsible for pre-harvest and postharvest

Table 4.23: Constraints of millet-based production systems

Constraints	M/S	M/S/G/C	M/S/G	M/S/C	Sole millet
Incidence of pest and diseases attack	(13.7) 4^{th}	(19.2) 2^{nd}	(17.1) 1^{st}	(11.9) 4^{th}	(16) 1^{st}
Late rainfall and climate variability	(16.4) 1^{st}	(5.8) 8^{th}	(5.7) 8^{th}	(2.5) 9^{th}	(12) 5^{th}
Inadequate and untimely supply of inputs	(15.1) 3^{rd}	(6.9) 6^{th}	-	(9.3) 5^{th}	-
Inadequate credit/capital	(13.7) 4^{th}	(8.7) 5^{th}	(10) 6^{th}	(17.8) 2^{nd}	(16) 1^{st}
Poor extension service delivery	(16.4) 1^{st}	(21.0) 1^{st}	(17.1) 1^{st}	(18.6) 1^{st}	(16) 1^{st}
Poor level of post-harvest storage facilities	(5.5) 8^{th}	(9.1) 4^{th}	(8.6) 7^{th}	(8.5) 6^{th}	(12) 5^{th}
High cost of labour	(6.9) 7^{th}	(6.2) 7^{th}	(14.3) 4^{th}	(6.8) 7^{th}	(12) 5^{th}
High cost of improved seed/poor seed varieties	(12.3) 6^{th}	(19.2) 2^{nd}	(15.7)3^{rd}	(17.8) 2^{nd}	(16) 1^{st}
High cost of transportation	-	(4.0) 9^{th}	(11.4) 5^{th}	(6.8) 7^{th}	-
Total	(100)*	(100)*	(100)*	(100)*	(100)*

Multiple responses; M= millet; S= sorghum; G= groundnut; C= cowpea
Note: Figures in parentheses are the percentage

losses. Therefore, effective control of these is necessary if reasonable yield is expected as pest and disease automatically causes a serious decline in quality thereby leading to a reduction in product price. This findings agrees with Ismaila *et al.* (2010), who opined that pest and diseases attack is highly responsible for poor yield on the study of cereal production in Nigeria. It is estimated that worldwide up to 30 percent of agricultural production is lost to animal pests, weeds and diseases each year with losses in tropical regions higher than in temperate areas (Abubakar, 2014).

4.7.2 Late rainfall and climate variability

This was ranked 1st in millet/sorghum with 16.4 percent. It was fairly ranked high in sole millet as 5th with 12.0 percent. It was ranked low in millet/sorghum/groundnut/cowpea and millet/sorghum/groundnut as 8th with 5.8 and 5.7 percent respectively and ranked 9th in millet/sorghum/cowpea with 2.5 percent. Inadequate rainfall is a major constraint because majority of the farmers are not into any form of irrigation scheme to help in their production. This finding agrees with Fagarigba *et al.* (2018), who found out in a study that low rainfall couple with high temperatures increase the frequency of the dry-up of water bodies such as wells, dams and streams.

4.7.3 Inadequate and untimely supply of inputs

This was ranked as high as 3rd in millet/sorghum with 15.1 percent. It was also fairly ranked high in millet/sorghum/cowpea (5th) and millet/sorghum/groundnut/cowpea (6th) with 9.3 and 6.9 percent respectively. By way of implication, delayed supply of input will obstruct performance in production. This findings agrees with Ogbonna *et al.* (2014), who in a study identified delay in input supply as a major constraint to effective farming and extension performance in green river project of Imo and Rivers states and such was reported to be capable of posing a hindrance to the effective performance in production.

4.7.4 Inadequate credit/capital

This was ranked high in sole millet (1st) and millet/sorghum/cowpea (2nd) with 16 and 17.8 percent respectively. It was ranked fairly high in millet/sorghum (4th) with 13.7 percent, millet/sorghum/groundnut/cowpea (5th) with 8.7 percent and millet /sorghum/groundnut (6th) with 10 percent. This implies that difficulty in securing loans due to high interest rates, inadequate loan amounts and collateral requirements by the banks are some of the major reasons to low access to credit in the area.Credit is a very strong factor that is needed in an agricultural production enterprise and its availability could determine the extent of production capacity. This is in accordance to Ogbonna *et al.* (2014), who found out in a study that lack of capital and credit prevents farmers from acquiring inputs in a timely way, prevents farmers from financing technologies and capital improvements for raising productivity and also prevents farmers from taking advantage of market opportunities.

4.7.5 Poor extension service delivery

This was ranked 1st in millet/sorghum (16.4 percent), millet/sorghum/groundnut/cowpea (21 percent), millet/sorghum/groundnut (17.1 percent), millet/sorghum/cowpea (18.6 percent) and sole millet (16 percent). This implies that most farmers who are ready to communicate and need the help of extension agents to adopt new agricultural technological innovations to improve their farms cannot do so because they have no contact with extension services. According to Danso-Abbeam*et al.* (2018), in agricultural-dependent economies, extension programmes have been the main conductor for disseminating information on farm technologies, support rural adult learning and assists farmers in developing their farm technical and managerial skills.

4.7.6 Poor level of post-harvest storage facilities

This was ranked in millet/sorghum/groundnut/cowpea (4^{th}) with 9.1 percent, sole millet (5^{th}) 12 percent and millet/sorghum/cowpea (6^{th}) with 8.5 percent. It was ranked relatively low in millet/sorghum/groundnut (7^{th}) with 8.6 percent, millet/sorghum (8^{th}) with 5.5 percent. By way of implication, lack of storage facilities will limit the availability of produce. This is in accordance to Abubakar (2014), who found out in a study that lack of storage facilities limits the steady availability of produce and stable market of food prices, prevents farmers and producers from selling their produce at times when they can get best prices; increases losses in quality and quantity and prevent healthy seeds from being made available for planting in the next cropping season.

4.7.7 High cost of labour

This was fairly ranked high in millet/sorghum/groundnut (4^{th}) with 14.3 percent and sole millet (5^{th}) with 12 percent. It was 7^{th} in millet/sorghum (6.9 percent), millet/sorghum/groundnut/ cowpea (6.2 percent) and millet/sorghum/cowpea (6.8 percent). By way of implication, it means when cost of labour is high it hinders the farmers to put full labour commitment on their farms thereby limiting productivity. This finding is similar to Simonyan and Obiakor (2012), who found high cost of labour to be a major constraint in a study, analysis of household labour use in yam production in Anambra-West local government area of Anambra State, Nigeria.

4.7.8 High cost of improved seed/poor seed varieties

This was ranked high in sole millet (1st) with 16 percent, millet/sorghum/cowpea (2nd) with 17.8 percent, millet/sorghum/groundnut/cowpea (2nd) with 19.2 percent and millet/sorghum/ groundnut (3rd) with 15.7 percent. Millet/sorghum was fairly ranked in 6th with 12.3 percent. By way of implication, it means the farmers are stuck with planting old varieties which are more susceptible to pest and diseases attack, which in turn leads to poor yield. This findings agrees with Dawud *et al.* (2017), who opined that most farmers have little or no access to improved seeds because of how costly they are and continues to recycle seeds that have become exhausted after generations of cultivation.

4.7.9 High cost of transportation

Millet/sorghum/groundnut was fairly ranked in 5th with 11.4 percent. It is also relatively ranked low in millet/sorghum/cowpea (7th) with 6.8 percent. Millet/sorghum/groundnut/cowpea was ranked 9th with 4.0 percent. By way of implication, it means high cost of transportation limits the food access to the market and also encourages farmers and producers to increase the cost of their produce. This finding agrees with Akangbe *et al.* (2013), in a study an appraisal of transportation facilities effects on agricultural development in Moro local government area, Kwara State, Nigeria.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The broad objective of this study was to analyze the productivity of millet-based production systems in Katsina State, Nigeria. A multistage sampling procedure was used in selecting the farming households. Primary data of 196 millet-based farming households was collected with the aid of well-structured questionnaire, and data collected were analyzed using descriptive statistics, net farm income, data envelopment analysis and tobit regression model.

The results of the socio-economic analysis showed that the mean age of farmers was approximately 49 years, Majority (95.4 percent) of the farmers were married. About 57.1 percent had one form of formal education or the other. The mean household size was 9 persons, and the mean farming experience was 31 years. Findings showed that larger proportion (83.3 percent) had no access to extension services, and 99.5 percent had no access to credits. Approximately 98.5 percent of the farmers were not members of any cooperative society. Findings revealed that mean off-farm income was ₦190,600 and also mean farm size owned was 1.3 hectares.

Moreover, the result of the study shows that about 72.5 percent of the farmers were mostly engaged in the combination of millet, sorghum, groundnut and cowpea. About 13.3 percent of the farmers planted millet intercropped with sorghum and cowpea. About 6.1 percent of the respondents planted millet alongside with sorghum and another 6.1 percent of the respondents planted millet alongside sorghum and groundnut. Only 2 percent of the farmers planted millet solely. The study also revealed that millet followed by sorghum, cowpea and ground nut combination was the most predominant cropping system in the state. 3-crop and 4-crop mixtures were more prevalent in the zone than sole and 2-crop mixtures.

Furthermore, result indicated that millet/sorghum/cowpea has the highest gross margin ₦169,534.7 and return per naira invested of 3.27, due to the cost expended on labour is lower than that of other enterprise. The rate of returns on investment (return per naira invested) for millet/sorghum was 1.66, for millet/sorghum/groundnut/cowpea was 2.83, for millet/sorghum/ groundnut was 2.53, for millet/sorghum/cowpea was 3.27 and for sole millet was 1.56. This shows that millet based production in the study area was economically viable.

Using DEA, the mean TE were 40, 21, 38, 32 and 48 percent for millet/sorghum, millet/ sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers respectively. The mean AE were 56, 55, 67, 56 and 91 percent for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers respectively. The mean EE were 23, 12, 26, 18 and 44 percent for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farmers respectively.

The Tobit regression result of the factors affecting the economic efficiency of millet-based farmers shows that the pseudo R^2 are 0.463, 0.0664, 0.9664, 0.2267 and 0.8978 for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/ cowpea and sole millet respectively. For millet/sorghum farmers; age, membership of associatio and off-farm income were negatively significant at $p<0.01$ each while marital status was positively significant at $p<0.1$. For millet/sorghum/groundnut/cowpea; level of education was positively significant at $p<0.1$ while only age was negatively significant at $p<0.01$. For millet/sorghum/groundnut; farming experience was positively significant at p<0.01 while household size were negatively significant at p<0.01. For millet/sorghum/cowpea farmers; level of education was positively significant at p<0.01 while household size were negatively significant at p<0.05. For sole millet farmers; household size was positively significant at p<0.1 while marital status was negatively significant at p<0.01.

DEA also revealed the result for returns to scale. About 8, 77, 67, 85 and 75 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/ cowpea and sole millet farms were respectively found operating with increasing return to scale (IRS) or sub - optimal scale. About 17, 20, 25 and 4 percent of millet/sorghum, millet/sorghum/ groundnut/cowpea, millet/sorghum/groundnut and millet/sorghum/cowpea farms were respectively found operating with decreasing return to scale (DRS) or supra-optimal scale.75, 2, 8, 12 and 25 percent of millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/ groundnut, millet/sorghum/cowpea and sole millet farms were respectively found operating with optimal scale.

Furthermore, the result showed that land was used optimally by sole millet farmers only. Result also revealed that seed is not a limiting resource and for optimal farm plan, about 7.36, 31.95, 40.6, 35.8 and 6.2 kilogrammes needs to be reduced from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. Labour is not a limiting resource and for optimal farm plan, about 8.4, 12.4, 19.48, 15.4 and 2.1 man-days needs to be reduced from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/ cowpea and sole millet farms respectively for optimal production. Result also showed that there was over-utilization of fertilizer for millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. It revealed that there was also over utilization of agrochemicals from millet/sorghum, millet/sorghum/groundnut/cowpea, millet/sorghum/groundnut, millet/sorghum/cowpea and sole millet farms respectively for optimal production. The result showed that output was not properly optimized due to the limited resources. Lack of extension service delivery, pest and diseases attack, lack of credit and capital, inadequate supply of inputs, high cost of improved seeds, high cost of labour, lack of post-harvest storage facilities and high cost of transportation were the major constraints found in the study,

5.2 Conclusion

It can be concluded that out of all the enterprises; millet/sorghum/groundnut/cowpea was the most widely practiced millet-based production systems in the study area. It also reveals that millet-based production systems in the study area are profitable. However, these millet-based farmers did not achieve absolute efficiency in terms of input-output relationship and cost thereby, leading to majority attaining technical efficiency levels of less than 50 percent. It was found that millet-based farms in general were scale inefficient. The findings further showed that outputs were not optimized due to under or over utilization of inputs. Given that millet is an important staple food in Nigeria, any attempt to increase its productivity would be a right step towards the resolution of food crises.

5.3 Contribution to Knowledge

i. The study identified that millet/sorghum/groundnut/cowpea with 72.5 percent is the most dominant crop combinations.

ii. The NFI of millet/sorghum/cowpea was the most profitable with the highest return per naira invested of 3.27.

iii. The study revealed that sole millet farmers had the highest mean technical (0.48), allocative (0.91) and economic (0.44) efficiencies compared to other millet-based farmers.

iv. The study revealed that millet/sorghum farms (75 percent) were the most scale efficient than other millet-based farms.

v. For the constraints identified with millet-based production systems, lack of extension service delivery was ranked 1st in all the millet-based production systems.

5.4 Recommendations

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

i. Since education is statistically significant, farmers should collaborate with relevant agencies both public and private that can assist in organizing workshops and trainings for millet-based farmers. This will increase the potentials of farmers and bridge the gap between potential and actual yield and hence improve the level of efficiency and productivity.

ii. A significant proportion of the respondents do not belong to cooperative society, this therefore calls for policy that would encourage farmers join cooperative association. This will enable the farmers to benefit from the government and non-governmental organizations' incentives support as they prefer to deal with farmers in groups.

iii. Extension contact is one of the major constraints faced by millet-based farmers. It is generally known that investment in extensions service is critical to reducing the level of inefficiency. There should be improved extension linkages to sensitize millet-based farmers on the need to adopt the recommended practices for production.

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Appendix I: Research Questionnaire

Economic Analysis of Millet-Based Production System in Katsina State, Nigeria

Dear Sir/Madam,

I am a postgraduate student of the above named institution conducting an M.sc research on the **Economic Analysis of Millet-Based Production System in Katsina State, Nigeria.** Kindly answer the under listed questions with utmost sincerity. You are assured of absolute confidentiality with regards to the information given, as this exercise is carried out purely for research purpose.

Background Information

1. Name of farmer: ……..............……………………………………………….
2. Phone Number …………………………………………………………………
3. Village: ………………………………....……………………………………..
4. LGA: ……………………………………………….…………………………….

Section A: Socioeconomic Characteristics of the Millet Farmer

5. Age: …………………years,
6. Sex: Male ( ) Female ( )
7. Occupation: Major ………………………….. Minor …………………………. …..
8. Marital status: a) Married ( ) b) Single ( ) c) Divorced ( ) d) Widow or Widower ( )
9. Highest level of Education: (a) No Formal Education ( ) (b) Primary school Education ( )
   (c) Secondary School Education ( ) (d) Tertiary Education ( )
10. Are you the head of your household? Yes ( ) No ( )
11. Household size ……………………………..

Categories	Males (No)	Females (No)
Children (Not capable of farm work, 1-15 years)		
Children (Capable of Farm work, 16-30)		
Dependents (Not capable of Farm work, > 60 years)		
Dependents (Capable of farm work, 15-49 years)		

12. Years of farming experience: …………………………………………………years
13. Do you belong to any cooperative society/farmers' associations? Yes ( ) No ( )
14. If yes, for how long? ....years
15. Do you have access to loan? Yes ( ) No ( )
16. If yes, what is/are your source(s) of loan (money)?
    a) Informal sources (e.g. friends, neighbours, family members) ( )
    b) Private Commercial Banks ( )

c) Government Loan scheme ( )
d) Non-Governmental organizations ( )
e) Others (Please specify) …………………………………………………..................

17. How much did you obtain from your source(s) of loan in the last millet production period (2018)? ₦ ....……………………………………………………………………
18. Do you have access to credit? Yes ( ) No ( )
19. If yes, what is/are your source(s) of credit (farm inputs)?
    a) Informal sources (e.g. friends, neighbours, family members) ( )
    b) Private Commercial Banks ( )
    c) Government Loan scheme ( )
    d) Non-Governmental organizations ( )
    e) Others (Please specify): …………………………………………………………………
20. Do you have any off - farm employment? Yes ( ) No ( )
21. If yes, mention it: (i) …………..………………. (ii) …………………………………. (iii) ………………………… (iv) ………………………… (v) ………………………...
22. How much do you earn in a year, from the off-farm employment ₦ …………………
23. Have you had contacts with extension agents? Yes ( ) No ( )
24. If yes, how many times did you receive extension contacts last season (2018)? ……................
25. How many times did you visit extension agent(s)/agency last season? ……………………......
26. What activities did the agent teach you? ....
27. Was the training beneficial to you?
    a. Not beneficial ( ) b. somehow beneficial ( ) c. beneficial ( ) d. very beneficial ( )
28. Did you obtain any intervention or aid to improve your level of production? Yes ( ) No ( )
29. If yes, from who?
    a) Federal government ( ) b) State government ( )
    c) Local government ( ) d) Others (please specify): …......................
30. What is the nature of the intervention or aid?
    a) Loan (money) ( )
    b) Credit (farm inputs) ( )
    c) Capacity building ( )
    d) Others (please specify): ....
31. If loan, how much? ₦ ……………………………………………………........................

If credit (farm inputs), name them: ....……………………

32. Indicate the millet-based production system(s) on your farm by ticking

Millet-based production system	Indicate by ticking
Millet/sorghum (MS)	
Millet/sorghum/groundnut/cowpea (M/S/G/C)	
Millet/sorghum/groundnut (M/S/G)	
Millet/sorghum/cowpea (M/S/C)	
Sole millet	
Others (specify)	

Section B: Information on Input

Farm size (Ha)

1. How many millet farm plots do you have? ....
2. How did you acquire your land?
   A. inheritance ( ) B. Borrowed ( ) C. Leased ( ) D. Purchased ( ) E. Gift ( )
3. How much does it cost to rent one hectare of land per season in your village?
   ₦....…….............
4. How much does it cost to purchase one hectare of land per season in your village?
   ₦....…….............

Tools and machineries used

Tools	Quantity of tools purchased	Cost	Quantity of tools borrowed	Cost
Cutlass				
Hoe				
Shovel				
Sickle				
Wheelbarrow				
Tractor				
Harrow				
Ridger				
Plough				
Others (specify)				

(ii) Variable inputs (Last production Cycle)

(a) Information on seed input

Pro. Syst.	Millet		Sorghum		G-Nut		Cowpea		Others	
	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)	Qty (kg)	Cost (₦/kg)	Qty (kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)
M/S										
M/S/G/C										
M/S/G										
M/S/C										
SM										
Other										

s (specify)										

(b) Information on fertilizer input used and cost

Production system	NPK (Kamfa)		Super phosphate (sulfa)		Muriate Of potash		Urea	
	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)
M/S								
M/S/G/C								
M/S/G								
M/S/C								
Sole millet								
Others (specify)								

(c) Information on organic manure used

Production system	Poultry		Goat		Sheep		Cattle	
	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)	Qty(kg)	Cost (₦/kg)
M/S								
M/S/G/C								
M/S/G								
M/S/C								
Sole millet								
Others (specify)								

(d) Information on agro-chemicals used

Production system	Insecticides		Herbicides		Others (specify)	
	Qty(kg)	Cost (₦/ltr)	Qty(kg)	Cost (₦/ltr)	Qty(kg)	Cost (₦/ltr)
M/S						
M/S/G/C						
M/S/G						
M/S/C						
Sole millet						
Others (specify)						

(iii) Labour input

(a) Labour for land clearing

Production system	Method of land	Hired Labour	Family Labour	

	clearing	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S								
M/S/G/C								
M/S/G								
M/S/C								
Sole millet								
Others (specify)								

(b) Labour for ridging

Production system	Hired Labour			Family Labour			
	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

(c) Labour for planting

Production system	Hire Labour			Family Labour			
	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

(d) Labour for first weeding

Production system	Hire Labour			Family Labour			
	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

(e) Labour for second weeding

Production system	Hire Labour	Family Labour	

	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

(f) Labour for fertilizer application

Production system	No of application	Hire Labour			Family Labour			
		No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S								
M/S/G/C								
M/S/G								
M/S/C								
Sole millet								
Others (specify)								

(g) Labour for spraying chemicals

Production system	No of application	Hire Labour			Family Labour			
		No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S								
M/S/G/C								
M/S/G								
M/S/C								
Sole millet								
Others (specify)								

(h) Labour for harvesting

Production system	Hire Labour			Family Labour			
	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

(i) Labour for threshing

Production system	Hire Labour	Family Labour	

	No of people	No of days	Cost (₦)	No of people	No of days	Cost (₦)	Total cost (₦)
M/S							
M/S/G/C							
M/S/G							
M/S/C							
Sole millet							
Others (specify)							

Information on output on sole millet and millet mixtures

Information on the quantity sold of each of the component crops

Production system	Output (kg)				
	Millet	Sorghum	Groundnut	Cowpea	Others (specify)
M/S					
M/S/G/C					
M/S/G					
M/S/C					
Sole millet					
Others (specify)					

How much was the revenue from the quantities you sold of each of the component crops?

Production system	Millet (₦)	Sorghum (₦)	Groundnut (₦)	Cowpea (₦)	Total revenue (₦)
M/S					
M/S/G/C					
M/S/G					
M/S/C					
Sole millet					
Others (specify)					

Constraints to Millet Production

1. What serious constraints did you encounter in millet production?

Millet-based enterprises	Major constraints
M/S	
M/S/G/C	
M/S/G	
M/S/C	
Sole millet	
Others (specify)	

2. Suggest ways to overcome the constraints listed above

Millet-based enterprises	Suggestions to overcome constraints
M/S	
M/S/G/C	
M/S/G	

M/S/C	
Sole millet	
Others (specify)	

THANK YOU.

Appendix II: DEA Input Model and Results

SUMMARY OF COST MINIMISING INPUT QUANTITIES:
Millet/Sorghum

Firm input:	1	2	3	4	5
1	0.300	5.000	4.000	2.500	2.500
2	0.219	3.654	2.923	1.827	1.827
3	0.083	1.385	1.108	0.692	0.692
4	0.005	0.077	0.062	0.038	0.038
5	0.042	0.692	0.554	0.346	0.346
6	0.051	0.846	0.677	0.423	0.423
7	0.531	8.846	7.077	4.423	4.423
8	0.106	1.769	1.415	0.885	0.885
9	0.065	1.077	0.862	0.538	0.538
10	0.305	5.077	4.062	2.538	2.538
11	0.337	11.217	44.870	1.870	0.935
12	0.083	1.385	1.108	0.692	0.692

SUMMARY OF COST MINIMISING INPUT QUANTITIES:
Millet/Sorghum/Groundnut/Cowpea

Firm input:	1	2	3	4	5
1	0.043	6.729	1.700	0.142	0.071
2	0.016	2.454	0.620	0.052	0.026
3	0.010	1.583	0.400	0.033	0.017
4	0.040	6.333	1.600	0.133	0.067
5	0.012	1.900	0.480	0.040	0.020
6	0.010	1.504	0.380	0.032	0.016
7	0.004	0.562	0.360	0.037	0.035
8	0.002	0.317	0.080	0.007	0.003
9	0.006	1.045	1.275	0.105	0.021
10	0.300	37.500	24.000	2.500	2.350
11	0.057	9.025	2.280	0.190	0.095
12	0.003	0.475	0.120	0.010	0.005
13	0.048	7.521	1.900	0.158	0.079
14	0.015	2.375	0.600	0.050	0.025
15	0.040	6.254	1.580	0.132	0.066
16	0.027	4.196	1.060	0.088	0.044
17	0.007	1.029	0.260	0.022	0.011
18	0.013	2.058	0.520	0.043	0.022
19	0.021	3.325	0.840	0.070	0.035
20	0.003	0.328	0.210	0.022	0.021
21	0.015	2.375	0.600	0.050	0.025
22	0.011	1.662	0.420	0.035	0.018
23	0.024	3.721	0.940	0.078	0.039
24	0.001	0.079	0.020	0.002	0.001

25	0.011	1.742	0.440	0.037	0.018
26	0.026	3.281	2.100	0.219	0.206
27	0.045	7.125	1.800	0.150	0.075
28	0.002	0.317	0.080	0.007	0.003
29	0.035	5.542	1.400	0.117	0.058
30	0.022	3.483	0.880	0.073	0.037
31	0.026	4.037	1.020	0.085	0.043
32	0.006	0.871	0.220	0.018	0.009
33	0.000	0.000	0.000	0.000	0.000
34	0.004	0.469	0.300	0.031	0.029
35	0.014	2.138	0.540	0.045	0.023
36	0.000	0.000	0.000	0.000	0.000
37	0.015	2.296	0.580	0.048	0.024
38	0.000	0.000	0.000	0.000	0.000
39	0.049	7.679	1.940	0.162	0.081
40	0.000	0.000	0.000	0.000	0.000
41	0.002	0.237	0.060	0.005	0.003
42	0.000	0.000	0.000	0.000	0.000
43	0.028	3.516	2.250	0.234	0.220
44	0.092	14.488	3.660	0.305	0.153
45	0.051	8.075	2.040	0.170	0.085
46	0.550	87.083	22.000	1.833	0.917
47	0.000	0.000	0.000	0.000	0.000
48	0.005	0.792	0.200	0.017	0.008
49	0.022	3.483	0.880	0.073	0.037
50	0.014	2.217	0.560	0.047	0.023
51	0.000	0.000	0.000	0.000	0.000
52	0.022	3.562	0.900	0.075	0.038
53	0.015	2.375	0.600	0.050	0.025
54	0.020	3.087	0.780	0.065	0.033
55	0.012	1.821	0.460	0.038	0.019
56	0.031	4.908	1.240	0.103	0.052
57	0.006	0.750	0.480	0.050	0.047
58	0.010	1.583	0.400	0.033	0.017
59	0.017	2.692	0.680	0.057	0.028
60	0.014	2.138	0.540	0.045	0.023
61	0.003	0.500	0.610	0.050	0.010
62	0.012	2.045	2.495	0.205	0.041
63	0.027	4.275	1.080	0.090	0.045
64	0.000	0.000	0.000	0.000	0.000
65	0.019	3.008	0.760	0.063	0.032
66	0.020	3.087	0.780	0.065	0.033
67	0.015	2.375	0.600	0.050	0.025
68	0.033	5.146	1.300	0.108	0.054
69	0.028	4.354	1.100	0.092	0.046
70	0.004	0.554	0.140	0.012	0.006
71	0.000	0.000	0.000	0.000	0.000
72	0.012	1.547	0.990	0.103	0.097
73	0.013	1.979	0.500	0.042	0.021
74	0.002	0.317	0.080	0.007	0.003
75	0.045	7.125	1.800	0.150	0.075
76	0.009	1.346	0.340	0.028	0.014
77	0.001	0.079	0.020	0.002	0.001
78	0.065	10.292	2.600	0.217	0.108

79	0.011	1.662	0.420	0.035	0.018
80	0.002	0.237	0.060	0.005	0.003
81	0.019	3.008	0.760	0.063	0.032
82	0.002	0.317	0.080	0.007	0.003
83	0.500	79.167	20.000	1.667	0.833
84	0.031	4.829	1.220	0.102	0.051
85	0.009	1.425	0.360	0.030	0.015
86	0.009	1.172	0.750	0.078	0.073
87	0.031	4.908	1.240	0.103	0.052
88	0.010	1.266	0.810	0.084	0.079
89	0.007	1.029	0.260	0.022	0.011
90	0.007	1.108	0.280	0.023	0.012
91	0.008	1.267	0.320	0.027	0.013
92	0.105	13.125	8.400	0.875	0.822
93	0.028	4.433	1.120	0.093	0.047
94	0.029	4.513	1.140	0.095	0.048
95	0.017	2.612	0.660	0.055	0.028
96	0.016	2.533	0.640	0.053	0.027
97	0.004	0.633	0.160	0.013	0.007
98	0.014	2.217	0.560	0.047	0.023
99	0.025	3.958	1.000	0.083	0.042
100	0.014	2.217	0.560	0.047	0.023
101	0.029	3.609	2.310	0.241	0.226
102	0.003	0.396	0.100	0.008	0.004
103	0.001	0.079	0.020	0.002	0.001
104	0.002	0.317	0.080	0.007	0.003
105	0.001	0.158	0.040	0.003	0.002
106	0.004	0.633	0.160	0.013	0.007
107	0.006	0.950	0.240	0.020	0.010
108	0.083	13.062	3.300	0.275	0.138
109	0.000	0.000	0.000	0.000	0.000
110	0.014	2.138	0.540	0.045	0.023
111	0.009	1.425	0.360	0.030	0.015
112	0.013	2.058	0.520	0.043	0.022
113	0.007	1.108	0.280	0.023	0.012
114	0.044	6.888	1.740	0.145	0.073
115	0.013	2.058	0.520	0.043	0.022
116	0.006	0.950	0.240	0.020	0.010
117	0.600	95.000	24.000	2.000	1.000
118	0.014	2.217	0.560	0.047	0.023
119	0.025	3.958	1.000	0.083	0.042
120	0.065	10.292	2.600	0.217	0.108
121	0.000	0.000	0.000	0.000	0.000
122	0.000	0.000	0.000	0.000	0.000
123	0.017	2.692	0.680	0.057	0.028
124	0.013	2.058	0.520	0.043	0.022
125	0.016	2.533	0.640	0.053	0.027
126	0.021	3.246	0.820	0.068	0.034
127	0.036	5.621	1.420	0.118	0.059
128	0.015	2.375	0.600	0.050	0.025
129	0.036	5.700	1.440	0.120	0.060
130	0.010	1.583	0.400	0.033	0.017
131	0.013	2.058	0.520	0.043	0.022
132	0.033	5.146	1.300	0.108	0.054

133	0.000	0.000	0.000	0.000	0.000
134	0.004	0.633	0.160	0.013	0.007
135	0.006	0.950	0.240	0.020	0.010
136	0.026	4.117	1.040	0.087	0.043
137	0.038	6.096	1.540	0.128	0.064
138	0.027	4.196	1.060	0.088	0.044
139	0.028	4.354	1.100	0.092	0.046
140	0.021	3.246	0.820	0.068	0.034
141	0.008	1.267	0.320	0.027	0.013
142	0.028	4.433	1.120	0.093	0.047

SUMMARY OF COST MINIMISING INPUT QUANTITIES:
Millet/Sorghum/Groundnut

Firm input:	1	2	3	4	5
1	0.004	0.165	0.243	0.012	0.007
2	0.045	2.059	3.033	0.150	0.088
3	0.000	0.000	0.000	0.000	0.000
4	1.200	55.000	81.000	4.000	2.350
5	0.017	0.769	1.132	0.056	0.033
6	0.068	3.130	4.610	0.228	0.134
7	0.001	0.055	0.081	0.004	0.002
8	0.002	0.082	0.121	0.006	0.004
9	0.000	0.000	0.000	0.000	0.000
10	0.010	0.467	0.687	0.034	0.020
11	0.011	0.494	0.728	0.036	0.021
12	0.011	0.494	0.728	0.036	0.021

SUMMARY OF COST MINIMISING INPUT QUANTITIES:
Millet/Sorghum/Cowpea

Firm input:	1	2	3	4	5
1	0.065	1.221	3.257	0.109	0.054
2	0.099	1.864	4.971	0.166	0.083
3	0.015	0.289	0.771	0.026	0.013
4	0.020	0.370	0.986	0.033	0.016
5	0.221	4.146	11.057	0.369	0.184
6	0.009	0.161	0.429	0.014	0.007
7	0.036	0.675	1.800	0.060	0.030
8	0.041	0.771	2.057	0.069	0.034
9	0.314	5.882	15.686	0.523	0.261
10	0.000	0.000	0.000	0.000	0.000
11	0.079	1.479	3.943	0.131	0.066
12	0.093	1.736	4.629	0.154	0.077
13	0.000	0.000	0.000	0.000	0.000
14	0.033	0.611	1.629	0.054	0.027
15	0.182	3.407	9.086	0.303	0.151
16	0.000	0.000	0.000	0.000	0.000
17	1.200	22.500	60.000	2.000	1.000
18	0.005	0.096	0.257	0.009	0.004
19	0.009	0.161	0.429	0.014	0.007
20	0.086	1.607	4.286	0.143	0.071
21	0.000	0.000	0.000	0.000	0.000
22	0.050	0.932	2.486	0.083	0.041
23	0.039	0.739	1.971	0.066	0.033
24	0.386	7.232	19.286	0.643	0.321

25	0.021	0.386	1.029	0.034	0.017
26	0.074	1.382	3.686	0.123	0.061

SUMMARY OF COST MINIMISING INPUT QUANTITIES:
Sole millet

Firm input:	1	2	3	4	5
1	0.094	1.571	3.457	0.786	0.739
2	0.171	2.857	6.286	1.429	1.343
3	0.300	5.000	11.000	2.500	2.350
4	0.000	0.000	0.000	0.000	0.000

Appendix III: Tobit Regression Model Results

MILLET/SORGHUM

Tobit economicefficiency ageyears maritalstatus levelofeducation householdsize number farmingexperienceyears association accesstocredit off-farm income number of contacts,ll

Tobit regression		Number of obs	=	12
		LR chi2(9)	=	22.15
		Prob > chi2	=	0.0084
Log likelihood = -12.845176		Pseudo R2	=	0.4630

Economic e~y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ageyrs	-.2498094	.0374515	-6.67	0.007	-.3689967	-.1306221
maritalsta~s	1.484069	.8079085	1.84	0.164	-1.087056	4.055194
levelofedu~n	.8040292	.268333	3.00	0.058	-.0499262	1.657985
households~o	-.1026836	.1198032	-0.86	0.454	-.4839509	.2785837
farmingexp~s	.2555092	.0445084	5.74	0.010	.1138637	.3971547
association	-3.271091	.9806466	-3.34	0.045	-6.391947	-.1502363
accesstocr~t	-.544178	.6650354	-0.82	0.473	-2.660617	1.572261
offfarminc~e	-6.47e-06	2.10e-06	-3.08	0.054	-.0000132	2.24e-07
noofcontacts	-.1211082	.4324607	-0.28	0.798	-1.497391	1.255175
_cons	6.718637	1.895384	3.54	0.038	.6866787	12.75059
/sigma	.7108598	.1549008			.2178962	1.203823

MILLET/SORGHUM/GROUNDNUT/COWPEA

Tobit economicefficiency ageyears maritalstatus levelofeducation householdsize number farmingexperienceyears association accesstocredit off-farm income number of contacts,ll

Tobit regression		Number of obs	=	142
		LR chi2(9)	=	19.70
		Prob > chi2	=	0.0199
Log likelihood = -138.47249		Pseudo R2	=	0.0664

economicef~y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ageyrs	-.0239469	.0088188	-2.72	0.007	-.0413901	-.0065036
maritalsta~s	.1663497	.1544071	1.08	0.283	-.1390617	.471761

levelofedu~n	.0922053	.0504018	1.83	0.070	-.0074874	.191898
households~o	.0123905	.0118823	1.04	0.299	-.0111122	.0358932
farmingexp~s	.0180113	.0086808	2.07	0.040	.0008409	.0351816
association	-.2884756	.4669228	-0.62	0.538	-1.212031	.6350796
accesstocr~t	.3902117	.1529099	2.55	0.012	.0877619	.6926615
offfarminc~e	-2.50e-07	4.67e-07	-0.54	0.593	-1.17e-06	6.74e-07
noofcontacts	.0070946	.0702317	0.10	0.920	-.131821	.1460103
_cons	1.240305	.325307	3.81	0.000	.5968603	1.883749
/sigma	.6344461	.0394923			.556332	.7125603

MILLET/SORGHUM/GROUNDNUT

Tobit economicefficiency ageyears maritalstatus levelofeducation householdsize number farmingexperienceyears association accesstocredit off-farm income number of contacts,ll

Tobit regression — Number of obs = 12; LR chi2(9) = 23.34; Prob > chi2 = 0.0055

Log likelihood = -.40623505 — Pseudo R2 = 0.9664

economicef~y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ageyrs	.0860695	.0231596	3.72	0.034	.0123653	.1597736
maritalsta~s	-.5093536	.5090966	-1.00	0.391	-2.129526	1.110819
levelofedu~n	.0728149	.0877761	0.83	0.468	-.2065279	.3521578
households~o	-.1285803	.0376832	-3.41	0.042	-.2485051	-.0086554
farmingexp~s	-.0512996	.013613	-3.77	0.033	-.0946223	-.0079769
association	1.195889	.3699353	3.23	0.048	.0185896	2.373188
accesstocr~t	.8587921	.4480519	1.92	0.151	-.5671091	2.284693
offfarminc~e	2.92e-06	1.61e-06	1.82	0.166	-2.19e-06	8.03e-06
noofcontacts	.2436456	.1826189	1.33	0.274	-.3375294	.8248205
_cons	-1.179584	.9912988	-1.19	0.320	-4.334339	1.975171
/sigma	.221214	.0514527			.0574685	.3849594

MILLET/SORGHUM/COWPEA

Tobit economicefficiency ageyears maritalstatus levelofeducation householdsize number farmingexperienceyears association accesstocredit off-farm income number of contacts,ll

Tobit regression — Number of obs = 26; LR chi2(9) = 22.46; Prob > chi2 = 0.0075

Log likelihood = -38.296306 — Pseudo R2 = 0.2267

economicef~y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ageyrs	-.1403921	.0481053	-2.92	0.010	-.2418854	-.0388988
maritalsta~s	-.0986244	.4011584	-0.25	0.809	-.9449946	.7477458
levelofedu~n	.9539423	.2562424	3.72	0.002	.413318	1.494567
households~o	-.110178	.0547839	-2.01	0.060	-.2257619	.0054058
farmingexp~s	.1987547	.0572891	3.47	0.003	.0778853	.319624
association	-.8588283	.9716384	-0.88	0.389	-2.908806	1.19115
accesstocr~t	-2.086498	.7650135	-2.73	0.014	-3.700535	-.4724609
offfarminc~e	-2.29e-07	2.10e-06	-0.11	0.914	-4.66e-06	4.20e-06
noofcontacts	-.1630504	.2502589	-0.65	0.523	-.6910504	.3649496
_cons	1.79894	1.359912	1.32	0.203	-1.070225	4.668105

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-------------+----------------------------------------------------------------
      /sigma |   1.075333   .1531327                      .7522516    1.398415
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SOLE MILLET

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Tobit economicefficiency ageyears maritalstatus levelofeducation householdsize number
farmingexperienceyears association accesstocredit off-farm income number of
contacts,ll

Tobit regression                                  Number of obs     =          4
                                                  LR chi2(9)        =      37.77
                                                  Prob > chi2       =     0.0000
Log likelihood = -8.9341832                       Pseudo R2         =     1.8978

------------------------------------------------------------------------------
economicef~y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ageyrs |  -.0021142   .0047223    -0.45   0.685    -.0171428    .0129144
maritalsta~s |   -.464811   .1134153    -4.10   0.026     -.825749   -.103873
levelofedu~n |  -.0048299   .0327832    -0.15   0.892    -.1091607     .099501
households~o |   .0220267   .0118389     1.86   0.160    -.0156499    .0597033
farmingexp~s |   .0658159   .0085128     7.73   0.004     .0387245    .0929074
 association |   .8927742   .1420904     6.28   0.008     .4405791    1.344969
accesstocr~t |  -.6499531   .0885211    -7.34   0.005    -.9316669   -.3682393
offfarminc~e |   5.40e-07   3.86e-07     1.40   0.257    -6.89e-07    1.77e-06
noofcontacts |  -.1648504    .055974    -2.95   0.060    -.3429846    .0132837
       _cons |     .46606   .2546848     1.83   0.165    -.3444605    1.276581
-------------+----------------------------------------------------------------
      /sigma |   .1026482   .0222393                      .0318728    .1734236
```

Appendix IV: Grain Equivalent Weight Conversion Factors and Calculation Method

Grain Equivalent Weight (GEWS) of component crops in the studied millet-based production systems

Crops	GEW*
Millet	0.68
Sorghum	0.60
Cowpea	1.12
Groundnut	1.83

*Source: Abubakar (2014).