

**COMPARATIVE ECONOMIC ANALYSIS OF IRRIGATED AND RAIN-FED IRISH  
POTATO (*Solanum tuberosum*)  
FARMING IN PLATEAU STATE, NIGERIA**

**BY**

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**JULY, 2015**

## DECLARATION

I hereby declare that this Dissertation titled “**Comparative Economic Analysis of Irrigated and Rain-fed Irish Potato (*Solonum tuberosum*) Farming in Plateau State, Nigeria**” has been written by me and it is a record of my research work. No part of the work has been presented in my previous application for another degree or diploma at any Institution. All borrowed ideas have been duly acknowledged in the text and the list of references provided.

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## CERTIFICATION

This Dissertation titled “**Comparative Economic Analysis of Irrigated and Rain-fed Irish Potato (*Solonum tuberosum*) Farming in Plateau State, Nigeria**” by Patrick Dachung MAGIT meets the regulations governing the award of the Degree of Doctor of Philosophy of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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## **DEDICATION**

This research work is dedicated to God Almighty, the creator of the whole universe; my late parents; and farmers of Irish potato in Nigeria.

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## **ABBREVIATIONS**

AE – Allocative Efficiency.

ASTC – Agricultural Services and Training Company.

CRS – Constant Returns to Scale.

DEA – Data Envelopment Analysis.

DMRT – Duncan Multiple Range Test.

EAP – Economically Active Person.

EE – Economic Efficiency.

FAO – Food and Agricultural Organisation.

FOS – Federal Office of Statistics.

GFI – Gross Farm Income.

GM – Gross Margin.

GMA - Gross Margin Analysis.

GR – Gross Returns.

IAR - Institute for Agricultural Research.

ICRISAT- International Crop Research Institute for Semi- Arid Tropics.

IFPRI – International Food Policy Research Institute.

IITA – International Institute for Tropical.

IRPF – Irrigated Potato Farming.

LRT – Log- likelihood Ratio Test.

MFC – Marginal Factor Cost.

MLE- Maximum Likelihood Estimate.

MVP – Marginal Value Product.

NAPRI – National Animal Production Research Institute.

NEPAD – New Partnership for Africa’s Development.

NFI – Net Farm Income.

NRCRI- National Root Crop Research Institute.

PADP – Plateau Agricultural Development Programme.

RFPF – Rain-fed Potato Farming.

RTS – Returns to Scale.

SFCF – Stochastic Frontier Cost Function.

SFPF – Stochastic Frontier Production Function.

TC – Total Cost.

TE – Technical Efficiency.

TFC – Total Fixed Cost.

TFP – Total Factor Productivity.

TPP – Total Physical Productivity

TPS – True Potato Seed.

TVC- Total Variable Cost.

UN – United Nations.

VEA – Village Extension Agents.

VRS – Variable Returns to Scale

## ABSTRACT

The main objective of this study was to determine the profitability and estimate the levels of technical, allocative and economic efficiencies of irrigated and rain-fed Irish potato farming in Plateau State. A multi-stage sampling technique; comprising of purposive, systematic and simple random sampling were used for data collection from 103 and 198 farmers of irrigated and rain-fed Irish potato respectively. They were sampled from the 20 villages of the 4 Local Government Areas that are dominant Irish potato producers. The study relied on primary data collected through the use of structured questionnaire for analysis. Data were analyzed using descriptive statistics, gross margin analysis, and the Cobb- Douglas Stochastic frontier models. The results of the socio-economic characteristics of the two groups of respondents showed that the mean ages of the farmers were 41 and 49 years; the mean house-hold sizes were 10 and 11 people; the average farm sizes were 1.90 ha and 2.67ha; the average number of visits by extension agents were 2 times per farming season each; whereas the mean farming experiences were 17 and 18 years respectively. The result also showed that Irish potato farmers belonged to at least one cooperative society. The profitability analysis showed that Irish potato farming was a profitable venture, considering the return per naira invested of ₦1.41 and ₦1.36 in the irrigated and rain-fed farming system respectively. The efficiency estimates from this study revealed that there were disparities between production potentials and the actual levels of production. The average level of efficiencies estimated for the two groups of farmers were 69% and 88% for technical, 66% and 79% for allocative and 45% and 70% for economic respectively. The socio-economic factors that had significant bearings on technical, allocative and economic inefficiencies were age, education, house-hold size, extension visits, and membership of cooperative society. The factors that were significant at 1% level of probability were age, education and extension visits. Household size and membership of cooperative society were significant at 5% level of probability for irrigated and rain-fed Irish potato farming. Some of the main constraints identified were inadequate farm size; poor and inadequate network of rural roads; poor and inadequate storage facilities; and high cost of seeds. Based on these findings, it was recommended that deliberate legal frame- work and policy measures that warrant farmers attain the optimum level of production efficiency be put in place and strictly implemented. In addition government should subsidize key Irish potato inputs such as improved seed varieties, water pumping machines, fertilizer, tractors for farming operations and embark on massive provision of rural infrastructures.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background to the Study

The growth and development of Nigeria today as in the past remains partly dependent on the increasing productivity of the agricultural sector. This is achieved through the provision of adequate food supply for the increasing Nigerian population. However, the rate of Nigeria's food production has been low. Most studies (Ojo 2001, Amos, Chikwendu and Nmadu, 2004, Okezie and Okoye, 2006, Amos *et al.*, 2007, Erhabor and Emokaro, 2007, Onwuchekwu, 2008, FAO, 2008 and Akaate, 2011) show that Nigeria's food production in the aggregate, has been growing at about 2.5 per cent per annum in recent years. Food demand on the other hand, has been growing at a rate of more than 3.5 per cent per annum, largely due to the high rate of population growth which has been put at about 3.5 per cent per annum (FOS, 2006, and World Bank, 2009). As a matter of fact, the situation has been compounded by natural phenomena resulting from climate change (Masimba, 2011). The consequences of the relatively low rate of growth in domestic food production and the relatively high rate of growth in the demand for food are:-

- (a) a widening gap between domestic food supply and the total food requirement;
- (b) an increasing resort to food importation to bridge part of the widening food supply- demand gap ;and
- (c) high rates of increase in food prices due to a growing food supply deficit, despite food importation.

Several agricultural policy measures and strategies have been adopted in Nigeria to arrest the problems. One of the approaches has been attempts at improving high yields of food crops through researches by various agricultural research institutes like the

International Institute for Tropical Agriculture (IITA), Institute for Agricultural Research (IAR) and the National Root Crop Research Institute (NRCRI), among others.

Adopting the classification of food products by the Federal Ministry of Agriculture into nine groups, Ojo (2001) has shown that for the period between 1961-1985, there had been an overwhelming dominance of two grown crops, namely; the Cereals and root and tuber as indicated by their percentage share of the total food production in Nigeria. However, among the root and tuber crops, Irish potatoes have the greatest potential at improving diets in the developing world. Horton (2001) listed several reasons for the above assertion. Some of these include:

- a. Irish Potato is one of the most efficient crops in converting natural resources, labour and capital into high quality food with wide consumers' acceptance.
- b. As one of the most nutritious sources of food, the ratio of its protein to carbohydrate is higher than in many cereals and other root and tuber crops.
- c. Potato is superior to almost every other crop in food production per hectare as it has a shorter growing cycle than other food crops in the tropics.

Okonkwo, Amadi and Nwosu (2009), Okunade and Ibrahim (2011) have shown that potato is by far the most efficient tuber crop in Nigeria in terms of tuber yield and days to maturity, even though it is ranked 5<sup>th</sup> after Cassava, Yam, Sweet potato and cocoyam. According to them, "potato matures in about 60-90 days as compared to 9-12 months for yams and cassava respectively". Due to short maturing period, two or more crops of potatoes are possible in a year, making it the highest yielding tuber crop in the country (Okonkwo *et al.*, 2009). The total annual production, was estimated at 900, 000 metric tons as at 2010 (Jwanya, Dawang, Zarmai and Mashat, 2014) per year. At a price of

₦50, 000 per tonne of potato tuber, Nigeria earns over ₦45 billion from sales in the local markets and West African sub-region (Okonkwo *et al.*, 2009).

The fact that Nigeria and other developing countries have been facing ever worsening food crises, as the growth rate of effective demand for food in those countries continues to out-pace the growth rate of food production (World Bank, 2009 and Amos *et al.*, 2007) have been documented by many researchers (Onaiwu, 2011 and Ashigidigbi, Suleiman and Adesioyan, 2011). Analysts have given some reasons for the deepening food shortage to include: shortage of capital for agricultural investment; the use of inappropriate agricultural technologies; the small and fragmental size of farms; lack of political will to effect desirable land-reform programmes; technical and allocative inefficiencies in the use of resources; uncontrolled population growth; uncoordinated and inconsistent agricultural policies (Akosile, 2003 cited by Onaiwu, 2011).

According to Shehu, Tashikalma and Gabdo, (2007) technical and allocative inefficiencies in the use of resources exists because agricultural production is mainly in the hands of so many small-scales farmers that are poor and therefore have continued to use farming techniques with low resource productivity. Studies have shown that food crop farmers in developing countries in general and Nigeria in particular, have low productivity because of inefficiency in resource use (Idiong, Damisan, Agom and Ohien, 2005, Abang and Agom, 2014).

In order words, the farmers are not making efficient use of existing agricultural technologies, and therefore efforts designed to improve efficiency would be more cost effective than introducing a new technology as a means of increasing agricultural output (Shehu *et al.*, 2007).

This position has been supported by many researchers including Bamire, Oluwasola, and Adesiyon (2007) who asserted that “the measurement of efficiency in factor inputs has remained an area of important research, where resources are meagre and opportunities for developing and adopting better technologies are dwindling”. Tijani (2006) maintained that in an economy where resources are scarce and opportunities for new technologies are lacking, efficiency studies will be able to show that it is possible to raise productivity by improving efficiency without changing the resource base or developing new technology. The study of resource-use efficiency of the irrigated and rain-fed Irish potato farmers in Plateau State is therefore premised on the fact that it is possible to increase productivity of Irish potato by ensuring efficient use of the existing resources.

The economic efficiency of a production system is made up of two components; technical and allocative efficiency. Technical efficiency is the physical component of the production system which deals with the maximization of output from a combination of inputs. A technical efficient production avoids as much waste by producing as much output as input will allow, or by using as little inputs as outputs production will allow (Makombe, Namara, Hagas, Awula, Chew, Ayana and Bossio, 2011). On the other hand, allocative efficiency is the optimization of the production process which takes into consideration input-output price relationship (Makombe *et al.*, 2011).

Profitability measurement was necessary in this study so as to determine if irrigated and rain-fed Irish potato farming enterprises were worth committing the scarce resources into them. Ogundele (2006) argued that the basis of profitability analysis (often referred to as Gross Margin Analysis) is that the farm is as a group of independent and productive

enterprise that is centred on farm unit which provides common services and necessary coordination. Abbott and Makeham (2002) opined that when a farm undertakes several farm production activities, the total Gross Margin is the sum of the Gross Margin of all the farm production activities. However, in the case of this study, the two farm units were treated as separate entities for the purpose of comparing their profitability levels. According to Olukosi and Erahbor (2005), the Gross Margin Analysis (GMA) involves evaluating the efficiency of an individual farm enterprise (or farm plant) so that comparison can be made between the different enterprises.

## **1.2 Problem Statement**

In spite of shift in attention to the petroleum sector, agriculture still remains the mainstay of the Nigerian economy because it contributes about 40% to the total Gross Domestic Product and employs about 77% of the Nigerian population (FAO, 2003 and Ishaka, 2008). According to Olagunju (2005), the agricultural sector is an engine room for sustainable growth of Nigerian economy. However, current estimate indicates that some 200 million or 25 percent of Africa's population are chronically hungry (Onwuchekwu, 2008). The International Food Policy Research Institute (IFPRI, 2002) estimated that about 8 million people go to bed hungry and 24,000 people die of hunger each day, even though the right to food remains a basic human right. High population growth rate which leads to increase in the demand for agricultural products, natural and human disasters such as draught, floods and land degradation, as well as civil conflicts in some parts of Africa, contribute to this alarming situation and accounts for high imports and dependence on food aid by most African countries thereby posing a huge problem of food insecurity and poverty (NEPAD, 2004). Nigeria, being part of Africa,

shares in these problems. Consequently, a determined and well targeted effort must be made to improve on food security, particularly in Nigeria.

Studies have shown that food crop farmers in developing countries in general and Nigeria in particular have low productivity because of inefficiency in resource-use (Idiong *et al.*, 2006, Abang and Agom, 2004). The presence of efficiency in production connotes the ability of increasing output without necessarily using additional inputs and new technology. Unfortunately, Irish potato, which can serve as the benchmark for food security and income generation, in view of its greatest potential for increasing output within a shorter period of time, comparatively is cultivated by so many small-scale poverty stricken farmers and therefore shares in the problem of low-resource productivity. This implies that there is scope for increase in output of Irish potato if resources are properly utilized and allocated efficiently in both irrigated and rain-fed Irish potato farming. Though, a number of research works have been carried out on Irish potato, like those of Okonkwo (1992) and Okonkwo *et al.* (2009), the focus has been on the agronomic aspects of the crop. Little attention has been given to the economic analysis of the production technology. Even where such is considered, like in the studies of Anuebunwa, Eleje and Nwankujo (2002), Lenka, Asumugha, Dung and Nwauzer (2006a and 2006b) and Alabi and Aruna (2006), the scope had been limited. Moreover, emphasis of these studies has usually been on the marketing of the product. As a matter of fact, empirical studies on efficiency of resource use in Irish potato farming in Nigeria have been scanty. It is with this background that this study has been set to bridge the research gap identified above. In doing this, the following research questions were addressed:

- i. What are the socio-economic characteristics of irrigated and rain-fed Irish potatoes farmers in the study area?;

- ii. What are the profitability of irrigated and rain-fed potato farming?;
- iii. What are the input and output relationships of irrigated and rain-fed potato production.
- iv. What are the levels of technical, allocative and economic efficiency of irrigated and rain-fed potato farming?
- v. What are the determinants of technical allocative and economic inefficiency of the irrigated and rain-fed potato farming?
- vi. What are the constraints affecting irrigated and rain-fed potato farming?

### **1.3 Objectives of the Study**

The main objective of this study was to analyse and compare production efficiency of the irrigated and rain-fed potato farmers in Plateau State. The specific objectives were to:-

- i. describe the socio-economic characteristics of irrigated and rain-fed potato farmers in the area of study;
- ii. determine and compare profitability levels of irrigated and rain-fed potato farming;
- iii. estimate the input and output relationships of irrigated and rain-fed potato farming.;
- iv. estimate the levels of technical, allocative and economic efficiency of irrigated and rain-fed potato farming;
- v. Identify the determinants of technical, allocative and economic inefficiency of irrigated and rain-fed potato farming;

- vi. describe the constraints affecting the irrigated and rain-fed potato farmers in the area of study.

#### **1.4 Justification of the Stud**

In-depth enquiries into efficiencies of farmers and factors that determine their levels of technical efficiency in the potato enterprise are necessary and relevant. The identification and understanding of these factors will provide valuable and significant information for policy formulation. The findings of this study, therefore, would help policy makers in designing policies that will include the interest of the potato farmers as regard allocation and efficient utilization of resources so as to further increase their yields of Irish potato in Plateau State. Furthermore, the research will serve as a “spring-board” for further researches by private and public institutions with the aim of improving on the resource-use efficiencies and profitability in the potato farming enterprise. Moreover, through effective extension services, the finding of this study is expected to enable the farmers to efficiently utilize the scarce resources at their disposal so as to maximize their yields of Irish potato. Besides, the study will be a useful source of teaching material in the agricultural research institutes and other educational establishments. Finally, the outcome of the research work would provide information and guidance to donor agencies, non-governmental organizations and development partners wishing to sponsor intervention programmes that will improve on the resource-use efficiencies in the irrigated and rain-fed Irish potato farming enterprise.

## **1.5 Hypotheses**

The following hypotheses were tested.

- i. There is no significant difference in profitability of irrigated and rain-fed potato production.
- ii. There is no significant difference between technical, allocative and economic efficiencies of irrigated and rain-fed Irish potato farming in Plateau State.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Economic Importance of Irish Potato

Most discussions on food production and security in developing countries focus on the adequacy of cereal supplies. In its projection of food needs in 1990, for example, the International Food Policy Research Institute (IFPRI, 2002) expressed all food crops production and consumption in millions of tonnes of cereal and wheat equivalent. This may be useful for analysing energy or caloric supplies and needs, but underrates the economic and nutritional importance of other crops, and therefore helps perpetuate the mistaken view that the world's food problems can at best, or perhaps only be solved by improving grain production and distribution.

Root and tuber crops are of great importance in many areas. At present, in developing countries of Africa, Asia and Latin America, production is around 190 million tonnes, which is more than 40 percent of the volume of total cereal production in the same region (FAO, 2000).

Horton (2001) has shown that “among the root and tuber crops, the Potato (*Solanum tuberosum*) has the greatest potential at improving diets in the developing world”. Indeed, production of potatoes is expanding more rapidly than any other major food crop in the developing countries, and in some areas where they were virtually unknown a few generations ago, they are now a dietary staple (Burton, 2000). The FAO (2000) review on Agriculture and development has reported some useful information about the status of potato. The report shows that:-

- a. Potato is superior to almost every other crop in food production per hectare and per day;
- b. Irish and sweet potatoes rank first in energy production per hectare per day, being significantly above cassava, cereals and pulse; and
- c. Among the crops consumed in fresh form, the potato ranks first in protein production per hectare and per day.

The obvious reasons for the above assertions are the fact that potato has a shorter growing cycle than most other food crops in the tropics, and thus can be more easily incorporated into some cropping systems than other longer cycle crops. (Zaag Vander and Beukema, 1990 and Okonkwo *et al.*, 2009).

The United Nations' FAO (2008) reported that the world production of Irish potatoes in 2006 was 315 million tonnes. The annual diet of an average global citizen in the first decade of the twenty-first century would include about 33kg of Irish potato (FAO, 2008). However, the local importance of Irish potato is extremely variable and rapidly changing. It remains an essential crop in Europe (especially eastern and central Europe), where per capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia. China is now the world's largest potato producing country, and nearly a third of the world's potatoes are harvested in China and India (FAO, 2008). More generally, the geographic shift of Irish potato has been away from wealthier countries towards lower-income areas of the world (FAO, 2008).

In 2008, several International Organisations highlighted the Irish potato's role in world food production, in the face of developing economies problems. They cited its potential derived from its status as a cheap and plentiful crop which can be raised in a wide variety of climates and locations (FAO, 2008). Due to perishability, only about 5 per cent of the world's Irish potato crop is traded internationally, its minimal presence in world financial markets contributed to its stable pricing during the 2007 – 2008 world food price crises. Thus, the United Nations officially declared the year 2008 as the International Year of the Irish Potato to raise its profile in developing nations, calling the crop a “hidden treasure” (FAO, 2008).

Nutritional value of Irish potato is immense in several respects. The Irish potato contains vitamins and minerals that have been identified as vital to human nutrition, as well as an assortment of *phytochemicals*, such as *caroleniods* and *polyphenols* (FAO, 2008). Nutritionally, the Irish potato is best known for its carbohydrates content. The predominant form of these carbohydrates is starch. A small but significant portion of this starch is resistant to digestion by enzymes in the stomach and small intestine, and so reaches the large intestine essentially intact. This resistant starch is considered to have similar physiological effects and health benefits as fibre: it provides bulk; offers protection against colon-cancer; improves glucose tolerance and insulin sensitivity; lowers plasma cholesterol and *triglyceride* concentrations; increase satiety, and possibly even reduce fat storage. The amount of resistant starch in potatoes depends much on preparation methods. Cooking and then cooling potatoes significantly increase resistant starch. For example, cooked potato starch contains about 7 per cent resistant starch, which increases to about 13 per cent upon cooling (FAO, 2008).

Irish potatoes occupy a prominent position in the world's food economy. As a fresh vegetable, potatoes are consumed in a great variety of ways – boiled, steamed, fried, baked or roasted. They are also processed into many products, such as “potato chips or crisps, dehydrated, frozen French-fries and canned potatoes. *Chuno* – a dehydrated potato product has long been valued as food by the Andean people Moray flour – a cleaner product of *Chuno*, is still prized by the people of South America (FAO, 2008).

Dried and dehydrated potatoes retain all the ingredients originally present in the tuber with the exception of water. Irish potato is a good substrate for the growth of micro-organism. The liquor from boiled potatoes (potato broth) has long been used as nutrient medium in experimental micro biological work. Considerable quantities of surplus potatoes (cull potatoes) in Europe are fed to livestock or processed into commercial products such as starch, alcohols, glucose and lactic acid. Potato starch is used chiefly for sizing cloth and paper, in the laundry industry and in various food preparations. Vodka, a Russian alcoholic “beverage” is prepared by the fermentation of cooked potatoes (Horton, 2001). Certainly, it was the potato that helped to keep Germany alive during the two world wars, as the potato tubers saved underground, could not be destroyed by burning like standing crops of other food plants (FAO, 2000).

Zaag Vander and Beukema (1990) reported that “less than half of the total potato production is used for human consumption”. According to them, “in 1982, almost a third was still used for stocks-feed mainly in Eastern Europe (Poland and USSR)”. Potatoes for starch production are concentrated in the Netherlands, Eastern Europe and Japan.

Potato processing is the application of any process, other the simple preparatory one associated with cooking, which uses the potato as the raw material for making an edible product.

Burton (2000) divided the method of processing potatoes into three categories on the following basis:-

- a) Processes devised primarily to remove undesirable constituents-dehydrated products such as *Tokosh*, *Chuno blanco* and *Chuno negro* are included in this group;
- b) Processes devised to extend storage life of the products – the end products of which include *papa seca* potato strips and dice, rice potato, potato powder or granules, potato flakes and potato flour;
- c) Processes for the production of snacks and convenience foods with products such as crisps or chips, frozen French fries and canned potatoes.

It should be noted that this division is not rigid as, for example, convenience foods can have a long storage life than in the canned or frozen state. The products developed originally to extend storage life may have found a use as convenience foods, and the products of processes devised to remove undesirable constituents have in some cases a longer storage life than those produced with this in mind. Processed potato has the advantage of being stored for several years without spoiling, thus overcoming one of the main objectives to the potato as a staple crop. A requirement for long storage life is the motivation for a number of other methods of processing in situation far removed from the high Andeans. An example is the dehydration of potatoes for supply to combatant troops in war time. In this case, not only do the processed products have a longer

storage life than do fresh potatoes, they have the additional advantages of being less bulky and easier to store and to prepare for food (Burton, 2000).

There is another reason for present day potato processing. Modern affluent societies in the developed industrial countries have shown an increasing predilection for snacks and “convenience food”, in the use of which preparation in the home is unnecessary or reduced to a minimum. Such foods are also much used in catering establishments as a means of reducing labour costs. They are necessarily more expensive as a source of the various nutrients than the unprocessed potatoes (Burton, 2000).

As a result of the growth in demand, more particularly for convenience foods, accompanied by a parallel growth in ownership of domestic facilities such as deep-freezers necessary for the home storage of some of such foods, there has been a remarkable expansion of the food processing industry and of that part of it utilizing potatoes since the end of the 1939-1945 war (Burton, 2000).

Potatoes are prepared in many ways: Skinned – or peeled, whole or cut-up, with seasonings or without. The only requirement involves cooking to swell the starch granules (FAO, 2008). Most potato dishes are served hot, but some are first cooked, then served cold, notably, potato salad and potato chips/crisps.

According to FAO (2008) common dishes of potato are: Mashed potatoes, which are first boiled (usually peeled), and then mashed with milk or yogurt and butter; whole baked potatoes; boiled or steamed potatoes; French-fried potatoes or chips; cut into cubes and roasted; scalloped; diced, or sliced and fried (home fries); grated into small

thin strips and fried (hash browns); grated and formed into dumplings, *Rosti* or potato pancakes. Unlike many foods, potatoes can also be easily cooked in a microwave oven and still retain nearly all of their nutritional value, provided they are covered in ventilated plastic wrap to prevent moisture from escaping; this method produces a meal very similar to a steamed potato, while retaining the appearance of a conventionally baked potato. Potato *chunds* also commonly appear as a stew ingredient.

## **2.2 Irish potato production in Nigeria**

Potato is an important root crop in Nigeria. From the time it was introduced into the country by the European Tin miners on the Jos Plateau in the later part of the 19<sup>th</sup> century and the early part of the 20<sup>th</sup> century, the production has increased by over 25 percent, reaching about 600,000 tonnes in 2001 (NRCRI, 2009). The total production in 2006 was estimated at 750,000 tonnes (NRCRI, 2009). Tubers yields of 10-25 tonnes have been reported under farmer's condition (Okonkwo *et al.*, 2009). Presently, about 90 per cent of the potato grown in Nigeria comes from Jos Plateau (Okonkwo *et al.*, 2009). The remaining 10 per cent comes from such places as Mambilla Plateau (2%), Obudu highlands (0.5%), Biu Plateau (0.5%), Kaduna State (1%), Kano (1%), Borno (.5%), Kebbi (0.5%), Bauchi (1%), Jigawa (0.5%), Sokoto (0.5%) and others (2%) (Okonkwo *et al.*, 2009).

The establishment of the Irish Potato Research Institute in Vom, Jos Plateau in 1976 marked the beginning of rapid expansion of potato production in Nigeria. The institute adopted various strategies aimed at tackling the problems associated with potato production NRCRI, (2009) and Jwanya *et al.* (2014) reported that the total annual production as at 2010 was estimated to 900, 000 metric tons.

Although no accurate figures are available for present day production, the indications are that both land area under potato and the yield per hectare have increased over those of the early nineties. Increases in yield per hectare have been possible by increasing use of fertilizers and irrigation facilities. More and more land which used to be under Acha (*Digitaria exilis*) is now being used for potatoes (Okonkwo *et al.*, 2009). With improvement in consumers preference for potato, and with potatoes fetching good prices in the markets, many more farmers in Jos South, Bassa, B/Ladi. Bokkos, Mangu and Pankshin Local Government Areas are now growing potatoes (Okonkwo *et al.*, 2009). Okonkwo *et al.* (2009) observed that although increasing quantity of the crop is consumed locally, the bulk of the production is transported to major cities in the south and to some northern states of Nigeria not suited for potato production, where they fetch high prices. Potato is therefore not often regarded as a food crop, but as cash crop by many of the farmers. It is envisaged that production will continue to increase in the foreseeable future with a large proportion being converted into processed forms. Moreover, Plateau State will continue to play a leading role in the production of the potato because of its special climatic requirements (Okonkwo *et al.*, 2009).

### **2.3 Empirical Studies on Irish Potato**

Several studies have been conducted on Irish potato. A review of some is necessary in this work. Lenka *et al.* (2006) analysed potato price movement, the cost and return of potato marketing and the effect of storage and marketing on the socio-economic well-being of marketers. The result shows that the marketing return on every naira invested was 59 kobo. The trend analysis shows that four seasonal cycles exist in potato marketing, January – February and August – September, where the percentage trend is above 100% and; March – July and November - December; where percentage trend was

less than 100%. Cycles above 100% show higher prices with quantity trend and vice-versa. Potato marketing is a lucrative business; the profit is used in building houses, purchase of household electronics and training of children. For efficient marketing, they recommend that traders should form cooperative societies so as to reap the benefits associated with membership of the societies which have direct influence on their marketing enterprise. Furthermore, the private sector, government and research institutes should improve on transportation and other infrastructural development so as to facilitate marketing of the crop for greater profitability.

Alabi *et al.* (2006) investigated the marketing of Irish potato in Kaduna LGA of Kaduna State. The results of findings showed that marketing of Irish potatoes was profitable. The net income realised per annum was ₦19,3164.74. The market efficiency gives a value of 57.24%. This shows that the market is efficient. Some of the major problems experienced by the traders include those associated with storage, transport, seasonality, perishability and price fluctuation.

In another study conducted by Lenka *et al.* (2006), to investigate the nature of risk in potato production enterprise and its cost implication with emphasis on the socio-economic risk factors. The study employed the use of Duncan Multiple Range Test (DMRT) to separate the mean estimated risk factors of the local government. The result shows that there were significant difference ( $P \leq 0.05$ ) between the mean values of loss due to pest/diseases, post harvest, fertilizer shortages, poor planting materials and environmental hazards. Measures recommended to improve on the farming risk include: use of high yielding and disease tolerant varieties, diversification of sources of income through multiple enterprise and potato based intercrops, regular sanitation of

fields and storage environment, complex combination of economic, ecological, social and spirited strategies and enactment of law of nuisance as legal avenue for farmers to recover damage done to crops by herdsmen and activities of other farmers. Okunade and Ibrahim (2011) have noted that the production and marketing of Irish potato in the highland zones of Plateau State has become an integral part of the rural economy, both at the raining and dry seasons as it is cultivated in all seasons. Other studies that have been undertaken of recent to determine the profitability of Irish potato farming include those of Kudi, Akpoko and Yada (2008) and Jwanya *et al.* (2014). Kudi *et al.* (2008) maintained that Irish potato gives the highest yield per hectare compared to other roots and tuber crops in Nigeria and that it brings more income to farmers than other roots and tuber crops.

Jwanya *et al.* (2014) examined the economics of irrigated Irish potato production in Plateau State. A multistage sampling techniques using purposive and systematic random sampling was used to obtain data from a sample size of 120 respondents. Data were analyzed using descriptive statistics, Gross Margin Analysis, Benefit-cost analysis and sensitivity analysis. The results of the study showed that majority of the farmers of Irish potato were adults (58.33%), educated (64.17%) with long years of Irish potato irrigation farming and an average of 0.7 hectares of irrigated farm land. The cost and return analysis revealed that costs of seeds, labour and chemical fertilizers made up the highest (89.40%) portion of the average total variable cost of production. The result also showed that irrigated Irish potato production in Plateau State was a profitable lucrative enterprise with a robust economic viability as indicated by the values of Gross Margin (N655.88), benefits –cost ratio (2.64) and sensitivity analysis ration (2.16). The study recommended expansion in irrigated Irish potato farm lands in addition to adoption of

technologies that will minimise cost of seeds, labour and chemical fertilizers. The finding of the profitability analysis of Jwanya *et al.* (2014) is in consonance with this study; especially in respect of high costs of seeds, labour and chemical fertilizer.

Studies on Irish potato have been conducted in other countries and their findings were relevant to this work. Some of these included the works of Bogale and Bogale (2005); Obare, Nyagaka and Nguyo (2010), Abedullah and Ahmad (2006), Nyagaka, Obare and Nguyo (2009) and Njuguna, Munyua and Makal (2014).

Bogale and Bogale (2005) examined the technical efficiency of farmers in the production of irrigated Irish potato using modern and traditional irrigated schemes in the Awi zone of Ethiopia. Based on cross-sectional data collected randomly from selected 80 farmers, the stochastic frontier production function was used for the analysis. The technical efficiency of the farmers was estimated independently for the two groups of farmers. The result of the study showed that the mean level of technical efficiency was 77% and 97% for modern and traditional schemes respectively. The study concluded that improving the level of efficiency could raise productivity under modern scheme, whereas improving productivity under traditional schemes needed introduction of new technology as the farmers' level of productivity has approached the frontier. Years of irrigation experience, commodity rate of production and size of livestock were found to be important variables that determined the level of technical efficiency.

Similarly, Abedullah and Ahmad (2006) examined the technical efficiency in Irish potato production by employing the Cobb-Douglas stochastic frontier production approach. Using data collected from a sample of 100 farmers from the districts of Okara

and Kasun in Pakistan and on the basis of the result from test of the hypothesis, the null hypothesis of no technical inefficiency in the data was rejected. The result from the Cobb-Douglas stochastic frontier production function indicated that potato farmers were 84% technically efficient, implying that there was significant potential in potato production. Furthermore, by shifting average farmer from production frontier, the average yield would increase from 8.33 tons per acre to 9.92 tons per acre using available resources. The study also revealed that the additional quantity of potato gathered through efficiency improvement could generate Rs 990.81 (\$16.51) million of revenue each year. Extension visits contributed significantly to the improvement of technical efficiency and it was therefore recommended that extension department should be one of the major targeted variables from the policy point of view in order to improve technical efficiency in potato production. The findings of this study again revealed the fact that Irish potato enterprise is profitable.

In a similar study, Nyagaka *et al.* (2009) identified and analyzed factors that influence the economic efficiency of small-holder Irish potato producers in Nyandarua North district of Kenya. Using data obtained from randomly selected 127 smallholders farmers, a dual stochastic parametric decomposition technique was employed to disaggregate economic efficiency components and a two – limits Tobit model to derive efficiency indices. Empirical results from the study showed decreasing returns to scale in production. The mean economic efficiency was 0.39 with a range of 0.12 and 0.66. The result of the study showed that education, access to extension services, access to credit and membership of farmers associations positively and significantly influenced economic efficiency. Consequently, innovative institutional arrangements that can

enhance extension services and farmers' training, accompanied with improved access to credit were recommended as these are likely to enhance potato production efficiency.

Another study closely related to that of Nyagaka *et al.* (2009) was the one carried out by Obare, *et al.* (2010). The study analyzed resource use allocative efficiency in Irish potato production in Nyandarua North District of Kenya. Using a random sample of 127 smallholder farmers from the study area, a dual stochastic efficiency and a two – limit Tobit model were applied to analyse the data. The study established that Irish potato production in Nyandarua North district was characterised by decreasing returns to scale with a mean allocative efficiency of 0.57 (or 57%). It was further established that farming experiences, access to extension services and credit, and membership of farmers' association positively and significantly influenced allocative efficiency. The policy implications drawn from the result of the study recommended that government and other non-governmental organizations should focus on establishing innovative institutional arrangements that enhance extension and farmer's access to credit in order to further improve allocative efficiency. The study further recommended the need to foster the formation and development of farmers' associations. In this respect, measures that encourage household membership of farmer's cooperative societies be stepped up.

Finally, another study that was focused more on extension component in order to contribute to the improvement of Irish potato enterprise was carried out by Njuguna *et al.* (2014). The main trust of the study was the investigation of the influence of selected factors on the adoption of improved potato varieties in Mumberes division of Baringo country. The study used cross-sectional survey research design where 128 household heads were sampled and interviewed. Descriptive statistics and ordinal logit regression model were used to analyze the data. The results of the study revealed that perception,

access to extension services, family size and access to credit were the key factors influencing adoption of improved potato varieties. The study recommended that there was need to increase access to extension services in the study area. Credit service providers should intensify their provision of these services. Finally it recommended that research institutions should endeavour to provide new varieties of seeds that are more resistant to blights and other diseases so as to promote further adoption.

#### **2.4 Theoretical/Conceptual Framework of Production Efficiency**

The concepts “production” and “productivity” are related in economic theory. While production can be viewed as the output of goods and services obtained from a production process, productivity is defined as output per unit of inputs used (Nwosu, 2005). According to Adewusi (2006) productivity is the index which allows assessment of efficiency and effective utilization of resources to obtain a certain output. Production function defines the rate at which resources (inputs) are transformed into products. It is the technical relationship between inputs and output in a given period of time (Mijindadi, 1980 as cited in Atagher, 2010).

Mathematically, the production function is continuous and differentiable. The differentiability property warrants its use to estimate the rates of return (Olukosi and Ogunbile, 2005; Adewusi, 2006 and Haruna, Sanni, Yusuf and Balogun, 2008). The main purpose of production function is to identify and measure how variable inputs are able to explain variability in outputs. The greater the extent to which variable inputs explain variation in output, the greater their influence (Atagher, 2010). The correct functional form of any production function can be determined by fitting various feasible

functional forms to obtain the best fit. This is normally selected on the basis of economic, statistical and econometric soundness (Ugwu, 2000).

Increase in productivity, could be due to technological advances, improvement in managerial skills, and techniques of efficient use of inputs in the production process. Adewusi (2006) has identified the following ways of productivity changes.

- i) Increase in output and inputs, with output increasing more proportionately than inputs;
- ii) Increase in output while inputs remain the same;
- iii) Decrease in both output and inputs with inputs decreasing proportionately more than outputs; and
- iv) Decrease in inputs while outputs remain the same.

FAO (2007), observed that increase in productivity can contribute to economic growth in various ways including; provision of more food, increase in prospects for growth and competitiveness in the agricultural market, income distribution, savings and labour migration to other sectors. An increase in a nation's agricultural productivity implies a more efficient distribution and utilization of scarce resources.

Measurement of productivity is divided into two namely: partial and total measure. Partial productivity increase determines the amount of output per unit of a particular input such as labour, land and capital (Atagher, 2010). Commonly used measures are yield (output per unit of land), labour productivity (output per economically active person, EAP) or per agricultural person – hour. Yield is commonly used to assess the success of new production practices or technology.

Total factor productivity (TFP) also known as multifactor productivity, is a ratio of an index of agricultural output to an index of agricultural production inputs (Atagher, 2010). The index of agricultural inputs is the value-weighted sum of all conventional agricultural inputs. These generally include land, labour, physical capital, livestock, chemical fertilizers and pesticides. Growth in TFP is generally considered a measure of technological progress that can be attributed to changes in agricultural research and development, extension services, human capital development such as education and physical infrastructure, as well as government policies, and environmental degradation (Atagher, 2010).

Nwosu (2005) lists three guiding principles in productivity measurement. These are:

- i) Inputs and output should match, if taken from the same universe and should relate to the same period;
- ii) Output and input should be measured independently of each other;
- iii) Output measures should recognize quality variations and changes.

FAO (2001) has identified three different types of economic models used in investigating growth in productivity. These are:

- a) Index numbers or growth accounting techniques
- b) Econometric estimation of production relationships and
- c) Non-parametric approach.

The growth accounting approach involves compiling detailed accounts of inputs and output aggregating them into inputs and outputs indices to calculate total factor productivity (TFP) index. The weakness of this approach is that the use of index numbers imposes several strong assumptions about technology, technical change, constant returns to scale and long run competitive equilibrium (Kaves and Duwert, 2002as cited in Atagher, 2010). Another disadvantage is that since index numbers are

not statistically derived, statistical methods cannot be used to evaluate their reliability (Capalbo, 2004). Furthermore, they have not been particularly informative in identifying source of growth. Their important advantage is that they can be derived regardless of the number of observations and hence they are easy to calculate.

Econometric approach involves estimation of production technology either through the production function (Primal approach) or through the cost function (the dual approach) (Antle and Capalbo, 2008). This approach has the advantage of being statistical hence permitting hypothesis testing, and calculation of confidence interval to test the reliability of the model estimated. The model measures explicitly the marginal contribution of each category of inputs to aggregate agricultural output. The major disadvantage of the econometric approach is that it requires more data than other approaches (Antle and Capalbo, 2008).

Non-parametric approaches use linear programming to calculate total factor productivity. It shares the advantage of flexible as econometric approach by not imposing assumptions about the technology that generate agricultural output. According to FAO (2001), linear programming techniques are essentially used to identify the input-output combination that defines the production frontier (technological efficiency either over time or across country). The advantage of the non-parametric approach is, it does not impose restrictive assumption on production technology nor is it data intensive hence it can be widely applied (Atagher, 2010). The main disadvantage is that, since the models are not statistical, they cannot be statistically tested and validated. The production function of the econometric approach is to be used in this study.

## 2.5 The concept of efficiency

Efficiency has to do with the relative performance of the processes that turn input into output. Olayide and Heady (1982 cited in Yusuf and Adenegan, 2007) define efficiency as the index of the ratio of the value of total farm output to the value of total input used in farm production. According to Olukosi and Erhabor (2005) efficiency is the quantity of output per unit of input used in the production process. That is, the average physical product. In economics literature, efficiency of a farm firm consists of three components, namely: economic, technical and allocative efficiency.

1. **Economic efficiency** also referred to as total efficiency is the product of technical and allocative efficiencies. (Mijindadi; 1980 cited in Atagher, 2010). An economically efficient input/output combination would be both on the production frontier and the expansion path (Ogundari and Ojo, 2006). Economic efficiency is concerned with the relativity of value of unit output to unit cost of resources used in production. It exists, when the marginal value product (MVP) is not different from marginal factor cost (MFC) (where  $MVP=MFC$ ). In other words, to achieve economic efficiency, the ratio of MVP to MFC must be equal to one. It occurs when a farm firm chooses resources and enterprises in such a way as to attain an economic optimum, so as to achieve maximum profit.
2. **Technical efficiency** is a major component of the measure of productivity. It is a measure of performance (Yusuf and Adenegan, 2007). Technical efficiency is defined as the ability to produce a given level of output with minimum quantity of inputs under a certain technology. It reflects the ability of a farm to obtain maximum output from a given level of inputs. Omotosho, Lawal and Falola (2008) point out that technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible. Okoruwa and Ogundele (2008) maintain that the technical

efficiency of a farm is characterized by the relationship between observed (actual) production and some ideal or potential production. The measurement of firm specific technical efficiency is based upon deviation of observed output from the best production or efficient production frontier. Accordingly, if a firm's production point lies on the frontier, the firm is perfectly efficient; if it lies below the frontier, it is technically inefficient, with the ratio of the actual to the potential defining the level of efficiency of the farm firm (Okoruwa and Ogundele, 2008). Technical efficiency can occur in any of the following situations: i. Where it is possible for a firm to produce with the given know-how, a larger amount of output from the same inputs or, ii. The same output with less of one or more inputs without increasing the amount of other inputs (Yusuf and Adenegan, 2007).

3. **Allocative efficiency** refers to the ability of the farm firm to choose optimum input levels for a given factor prices (Okoruwa and Ogundele, 2008). It is the ability to choose the level of inputs that maximizes profits given factor prices (Abagi, 2004). According to Olukosi and Ogungbile (2005) and Haruna *et al.*, (2008), allocative efficiency is the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the cost of the factor or input. Allocative efficiency is achieved at the point when the marginal value product (MVP) equals the marginal factor cost (MFC). The MVP is calculated from the respective regression coefficients using appropriate optimum level of output price, depending on the lead equation of the functional form. The MFC is the market price of one unit input. An efficiency ratio of unity means economically optimum allocative efficiency. A ratio of less than one implies that input is being over-utilized while a ratio of greater than one means the input is under-utilized. (Olukosi and Ogungbile 2005; Onojah, 2004 and Haruna *et al.*, 2008).

## 2.6 Review of Analytical Tools

The measurement of efficiency in factor inputs has remained an area of important research both in the developed and the developing countries. Especially in developing agricultural economies where resources are meagre and opportunities for developing and adopting better technologies are dwindling (Bamire, Oluwasola and Adesiyan, 2007). Moreover, efficiency is also a very important factor or measure of productivity growth. Amos *et al.* (2004) observe that efficiency studies are able to show that it is possible to raise productivity by improving efficiency without changing the resource base or developing new technology. There are quite a number of approaches to measuring efficiency in the economic literature. It is necessary to review some of them, especially those used in this work in order to appreciate their importance.

### 2.6.1 Stochastic frontier production function (SFPF)

The main feature of the stochastic frontier production function is that the disturbance term is composed of two parts: a systematic and a one-sided component. The symmetric component  $V_i$  - captures the random effects due to statistical noise (e.g. weather, topography, measurement error etc) and the other - non-systematic influences outside the control of the farm firm. It is assumed to have a normal distribution.

The one sided (non-negative) component,  $U_i$  with  $U_i \geq 0$ , captures the technical inefficiency relative to the stochastic frontier. This randomness is under the control of the farmer; its distribution is assumed to be half normal or exponential. The  $V_i$  is assumed to be independently and identically distributed as;  $N(0, \delta^2 v)$  random variables, independent of the  $U_i$ s. The  $U_i$ s are also assumed to be independently and identically

distributed as exponential (Meeusen and Van den Broeck, 1997), half normal (Aigner, Lovell and Schmidt, 1992), truncated and gamma (Greene, 1990)

The typical SFPF model is specified as:  $Y_i = f(x_i\beta_i) + v_i - u_i \quad (i = 1, 2, 3 \dots, n) \dots\dots (1)$

Where:  $Y_i$  = Output of the  $i^{\text{th}}$  farm firm,  $X_i$  = vector of inputs used by  $i^{\text{th}}$  farm,  $\beta_i$  = vector of production coefficients to be estimated,  $V_i$  = Random variability in the production that cannot be influenced by the farmer,  $U_i$  = Deviation from maximum potential output attributable to technical inefficiency. The model is such that the possible production  $Y_i$ , is bounded above by the stochastic quantity  $f(X_i, \beta) \exp(V_i)$  when  $U_i = 0$ , hence the term stochastic frontier (Meeusen and Van de Broeck, 1997).

The stochastic frontier production function model is estimated, using the maximum likelihood Estimation Procedure (MLE) which has been found to be asymptotically more efficient than the corrected ordinary least square and therefore preferred in empirical analysis (Umoh, 2006). The technical efficiency of an individual farm firm is defined in terms of the ratio of observed output ( $Y_i$ ) to the corresponding frontier output ( $y^*_i$ ) conditional on the level of inputs used by the firm, and given the available technology. Thus:

$$TE_i = \frac{y_i}{y^*_i}, \text{ i.e. } TE_i = \frac{f(x_i\beta_i) \exp(v_i - u_i)}{f(x_i\beta_i) \exp v_i} \quad TE_i = \exp(-u_i) \dots\dots\dots (2)$$

Where:  $TE_i$  = Technical efficiency of farmer  $i$ ,  $Y_i$  = observed output from farm  $i$ , and  $y^*_i$  = Frontier output. So that  $0 \leq TE_i \leq 1$ , i.e. it ranges between 0 and 1. Maximum efficiency has a value of 1. Therefore technical inefficiency is equal to  $1 - TE$

**2.6.2 Stochastic frontier cost function (SFCE)**

The stochastic frontier cost function, which is the dual of the frontier production function, is the basis for estimating the allocative and economic efficiencies of a farm (Martin and Taylor, 2003). The model is specified as:

$$C_i = g(Y_i, P_i \alpha_i) + \varepsilon_i (i = 1, 2, 3, \dots, n) \dots\dots\dots (3)$$

Where:  $C_i$  = Total cost of production by  $i^{th}$  farm,  $Y_i$  = Output produced by  $i^{th}$  farm,  $P_i$  = Cost of inputs of  $i^{th}$  farm,  $\alpha_i$  = Parameters of the cost function to be estimated and  $\varepsilon_i$  = the error term, composed of two components related as:

$$e_i = V_i + U_i \dots\dots\dots (4)$$

Where:  $V_i$  and  $U_i$  are as defined earlier. However, because inefficiencies are assumed to always increase costs, therefore the error components have positive signs (Coelli, Prasada, Rao and Battese, 2005).

The farm specific economic efficiency (EE) is defined as the ratio of the minimum observed total production cost ( $C_i^*$ ) to actual total production cost ( $C_i$ )

$$\text{i.e. EE} = \frac{C_i^*}{C_i} \dots\dots\dots (5)$$

The measure of farm specific allocative efficiency is thus obtained from economic and technical efficiencies estimates as:  $AE = \frac{EE}{TE} \dots\dots\dots (6)$

(That is,  $0 < AE < 1$ ) (Martin and Taylor 2003; and Ogundari and Ojo, 2006).

Available literature indicates that Irish potato farming enterprise in Nigeria is yet to benefit significantly from the application of stochastic frontier models. Therefore the models were applied for the purpose of estimating the efficiency of resource use in potato farming on Plateau State.

### 2.6.3 Inefficiency frontier model

The inefficiency frontier model is derived from the composite disturbance term of the stochastic frontier production function. The composite disturbance term equals the sum of two error terms (Meeusen and Van deBroeck 1977 cited in Tijani 2006). One of the components ( $V_i$ ) represents the effect of statistical noise (e.g. weather, topography, measurement error, etc). The other error component ( $U_i$ ) captures systematic influences that are unexplained by the production function and are attributed to production function and are attributed to the effect of technical inefficiency.

Using a variant of the stochastic frontier production function proposed by Coelli et al., (2005), which builds hypothesized efficiency determinants, one can identify focal points for action to bring efficiency to higher levels.

Given the general form of the model:

$$Y_i = \beta_0 + \beta_i X_i + (V_i - U_i) \dots \dots \dots \quad (7)$$

Where  $Q_i$  = the product (output) of the  $i^{\text{th}}$  farm firm  $i$

$X_i$  = a ( $i \times k$ ) Vector of input quantities estimated

$\beta_0, \beta_i$  = a ( $K \times I$ ) Vector of unknown parameters estimated

$V_i$  = are random variables which are assumed to be normally distributed with Zero mean and variance  $\sigma^2$  i.e.  $V_i \sim N [(0, \sigma^2_v)]$ .

and  $U_i$  = represents technical inefficiency and are non-negative, assumed to be independent of the  $V_i$  and normally distributed with mean 0 and variance  $\sigma^2$  i.e.  $[N(0, \sigma^2_u)]$ .

It is further assumed that the average level of technical inefficiency, measured by the mode of the truncated normal distribution (i.e.  $U_i$ ) is a function of factors believed to affect technical inefficiency as shown below:

$$U_i = \delta_i + \delta z_i \dots\dots\dots (8)$$

Where  $Z_i = a (I \times M)$  column vector of hypothesized efficiency determinants which may vary over time and  $\delta_o$  and  $\delta_i =$  the  $(M \times I)$  vector of unknown parameter estimated.

It is clear that if  $U_i$  does not exist in equation 2.7 or  $U_i = \delta^2 u = 0$ , the stochastic frontier production function. In that case, the observed units are equally efficient and residual output is solely explained by unsystematic influences. The distributional parameters,  $U_i$  and the  $\delta^2 u$  are hence inefficiency indicators, the former (i.e  $U_i$ ) indicating the average level of technical inefficiency and the latter (i.e  $\delta^2 u$ ) the dispersion of the inefficiency level across observational units.

#### **2.6.4 Farm budgeting technique**

Farm budgeting technique is a detailed physical and financial plan for the operation of the farm for a certain period (Olukosi and Erhabor, 2005). The aim of a farm budget is to compare how profitable different kinds of enterprise combinations can be. It enables the Manager to have several alternative plans for analysis so that he would be in a position to know which of them gives the highest net farm income (Olukosi and Erhabor, 2005). In a nutshell, farm budgeting involves considering the resources to be used, the choice of enterprises to be pursued and a calculation of expected receipts, expenditures and net farm income. Olukosi and Erhabor (2005) have identified two major groups of farm budget. These are: A total or complete, and a partial budget. The partial can be classified into: the orthodox; gross margin; breakeven; Block and capital budgets. The farm budget technique has advantages and disadvantages. Nwosu (2005), Olukosi and Erhabor (2005) have highlighted some of the advantages of farm budget. These include the following:

- (a) Budgeting assists the farm manager to select factors of production more wisely;
- (b) A budget is a money saver because it is cheaper to make mistakes on paper than in practice;
- (c) Budgeting helps a farm manager to determine when to borrow money and how much to borrow. It can also help in setting up repayment schedules.
- (d) Budgeting provides an excellent device on how to organise or reorganise the farms.
- (e) Banks favour men and women who have written plans. A well thought out budget creates a good impression on people and also gives the impression of a careful scrutiny of one's production and finances.
- (f) As a planning tool, budgeting causes the farm manager to think more accurately, plan more carefully and completely. Through the process of budgeting, the farm manager refines his ideas and is able to make more accurate decisions.
- (g) Lending agencies use budgeting process as a basis for appraising the farm business of their clients.

Quite a number of limitations of budgeting technique have been identified by Nwosu (2005), Olukosi and Erhabor (2005). These include the following:

- (i) Budgeting is a trial and error method. Although it can be used to find the most profitable among two or more plans, budgeting process does not help in the initial choice of plans.
- (ii) Budgeting uses constant average costs and returns and does not take into account diminishing marginal returns and increasing marginal cost
- (iii) For casting future yields, prices and incomes are difficult with budgeting.

(iv) When the hand method is used in budgeting, there is a limitation to the number of alternatives that can be tried at a time as well as the efficiency of performing the budgeting exercise.

#### **2.6.5 The gross margin analysis**

In this study, Gross Margin Analysis which is one of the partial budgeting tools was used in view of its merits. The Gross Margin or profitability method consists of finding the gross margin for each enterprise and whichever gives a higher gross margin is better and should be selected. The profitability measurement is one of the income analysis tools used in farm management. According to Johnson (1990) cited in Ogundele, (2003), the basis of gross margin analysis is that the farm is as a group of independent and productive enterprise that is centred on farm unit, which provides common services and necessary co-ordination. Abbott and Makeham (2002) posit that when a farm undertakes several farm production activities, the Total Gross Margin is the sum of the Gross margins of all the farm production activities. According to Yusuf (2009), costs and returns analysis form the basis for profitability analysis. It involves accurate collection of the different costs and the gross income obtained from a particular enterprise so as to get the net returns. Olukosi and Erhabor (2005) maintained that the Gross Margin is a good approximation of net farm income, since small-scale farmers usually have negligible fixed costs. In other words, the Gross Margin Analysis is a very useful tool in situations where fixed capital is a negligible portion of the farming enterprise as is the case in subsistence agriculture. It is worthy of note that the values obtained from the Gross margin analysis are sometimes subjected to statistical test of significance between them (Yusuf, 2009).

Gross Margin, by definition is the difference between the Gross Farm Income (GFI) and the Total Variable Cost (TVC). It should be noted that Total Cost of production is made up of Total Fixed Cost and Total Variable Cost ( $TC = TFC + TVC$ ).

Fixed costs are those incurred on fixed inputs which cannot be used up during one production cycle. They are considered as being gradually converted into products during the production process and as such, they depreciate over-time (Olukosi and Erhabor, 2005). Examples of fixed inputs are roads, fences, hoes, buildings, wheel barrows, land, etc. Fixed cost is used to compute the Net Farm Income from the Gross Margin. Variable costs are costs that vary according to output and are incurred on variable inputs which can be attributed to specific enterprises.

The Gross Farm Income, also called Total Value Product, is the total physical product multiplied by the unit price of the product ( $GFI = TVP = TPP \text{ unit price}$ ). The usefulness of the Gross Margin Analysis in farm management has been enumerated by Yusuf (2009), Olukosi and Erhabor (2005). Some of the usefulness of gross margin analysis are that it:

- i is easy to compute and interpret;
- ii is highly applicable to subsistence system of farming involving small fixed capital components;
- iii is useful where the same capital items are used in many different enterprises in a given farm;
- iv is used to determine net farm income;
- v serves as a guide to the selection of enterprise by comparing their margins;
- vi helps the farm manager to critically examine the variable cost components;

vii helps in building partial budgets for the farm.

Despite the limitations, cost and returns analysis has been widely used in a variety of research studies. For instance, Iheanacho (2000 cited in Yusuf, 2009) employed cost returns analysis in estimating production costs and returns for millet-based cropping systems in Borno State of Nigeria.

Hill, Biggott and Griffith (2001) used it in the profitability increment generic promotion of Australian dairy products in Australia. Yusuf and Adenegan (2008) discovered that melon (*egusi*) under mixed cropping system had the highest gross margin compared to other crops.

## **2.7 Empirical Studies on Farm Efficiency**

The measurement of efficiency in factor inputs has remained an area of important research both in the developed and developing countries. More so that in developing agricultural economies, resources are scarce and opportunities for developing and adopting better technologies are dwindling (Farrel, 1957, Ali and Chaudhry, 1990). Efficiency is also a very important factor of productivity growth, especially in developing countries where resources are not only inadequate, but chances for new technologies are not sufficient. In this respect efficiency studies will show that it is possible to raise productivity by improving efficiency without changing the resource base or developing new technology (Bamire *et al*, 2007). Estimates on the extent of inefficiency also help decide whether to improve efficiency or to develop new technologies to raise agricultural productivity (Bamire *et al.*, 2007).

The measurements of productivity of a farm relative to other farms have been of interest to agricultural economists. A lot of empirical studies have centred on partial measures

of productivity; such as yield per hectare or output per unit of labour. However, Farrell's (1957) work in which the production functions of firms that are fully efficient were estimated, has led to the development of several techniques for measurement of efficiency of production. One of the techniques is the parametric stochastic frontier production function approach (Aigner *et al.*, 1992; Meeusem and Van den Broeck, 1997). The main strengths of the stochastic frontier are that it deals with stochastic noise and permits statistical test of hypothesis pertaining to production structure and the degree of inefficiency (Coelli, 1995). While the weakness of this model is in imposing an explicit parameter form for the underlying technology and an explicit distributional assumption for inefficiency farm.

There have been many applications of frontier production function to agricultural industry over the years. The first application of the stochastic frontier model to farm level agricultural data was presented by Battese and Corra (1977). They used the 1973 – 1974 data of the Australian Grazing industry to estimate deterministic and stochastic Cobb-Douglas production frontiers for three states in pastoral zone of Eastern Australia. The result of findings indicates that the stochastic frontier production function was significantly different from their corresponding deterministic frontier. Tijani (2006) estimated technical efficiencies on rice farms in Ijesha, Osun State, using the stochastic frontier production function. The result of findings showed that the levels of technical efficiency ranged from 29.4 percent to 98.2 percent with a mean of 86.6 percent, suggesting that average rice output fell by 13.4 percent of the maximum possible level. Furthermore, the study showed that these efficiencies are positively and significantly correlated with the application of traditional preparation methods, and with off-farm

income. Therefore, in the short-run, there is scope of increase technical efficiencies on rice farms in the study area.

In a similar study, Bamire *et al.* (2007) examined the socio-economic and land factors that influenced rice productivity in Osun State using the stochastic frontier model. Results from the frontier estimates showed that farm size and fertilizer significantly influenced rice productivity, while farmers' education, cropping practice and type of rice grown reduced production inefficiencies in the rice farms. With a mean technical efficiency level of 75 percent, there is sample opportunity to improve rice productivity in the area using current production and land use systems. Aye and Oboh (2006) used the stochastic production frontier model to investigate the resource use and factors that influence technical efficiency of rice farmers in Benue State. The inefficiency model reveals that education, household size, access to extension service, access to credit, sex and crop variety significantly and positively affect farmers' efficiency level. Moreover, the result revealed an average technical inefficiency of 22 percent, showing that farmers actually operated with a substantial level of inefficiency. This suggests that a considerable rice yield potential remains to be exploited through better use of available resources.

Essien (2006) employed the use of stochastic frontier in assessing the technical efficiency in the food sector of small and medium industries in Nigeria. The result showed that efficiency in the food sector is generally low, but has been increasing since 2002.

In a more closely related study, Idiong *et al.* (2006) investigated the technical efficiency of swamp and upland rice production systems in Cross River State. A stochastic frontier function that incorporated inefficiency effect was estimated using the maximum

likelihood estimation (MLE) techniques. The results indicate that swamp and upland rice farmers were not fully technically efficient. Their mean efficiencies were 0.77 and 0.87 for swamp and upland rice systems respectively and were not significantly different at the 5 percent level. The results also indicate that farmers' educational level, membership of association and access to credit, positively influenced their levels of efficiency in both production systems. The coefficients of age and household were negative and significant in determining efficiency of upland rice farmers in the state, while in the swamp rice system they had no significant effect, though they carried negative signs.

Rahman (2003) studied profit efficiency among Bangladesh rice farmers using stochastic profit frontier and inefficiency effect model to provide direct measure of production efficiency. The result of the study showed that there were high levels of inefficiency in modern rice cultivation. The mean level of profit efficiency was 77 percent suggesting that an estimated 23 percent of the profit is lost due to a combination of both, technical and allocative inefficiency in modern rice production.

Bravo-Ureta and Evenson (1994) investigated efficiency in agricultural production among peasant farmers in eastern Paraguay. A stochastic efficiency decomposition methodology was used to derive technical, allocative and economic efficiency of 40.1 percent for cotton and of 52.3 percent cassava was found. These suggested considerable room for productivity gains for the farms in sample through better use of available resources given the state of technology.

The agricultural production of Indian farmers was also investigated using stochastic frontier production function which incorporates a model for technical inefficiency effects. Farm level data from the International Crop Research Institute for Semi Arid Tropics (ICRISAT) was used. The variables considered in the model for inefficiency effect include age, level of education, farm size and year of observation. The results indicate that the factors enumerated above did not have significant influence upon the inefficiency effects of the farmers (Coelli and Battese, 1996).

Amos *et al.* (2004) studied the productivity and technical efficiency (TE) of small-scale farmers in the Savannah zone of Nigeria using stochastic frontier production function analysis. Results showed that farmers were in the rational stage of production (stage II) as depicted by the returns to scale (RTS) of 0.27. The technical efficiency of the sole maize farmers was lower (0.5266) compared to that of the mixed (yam/maize) cropping farmers (0.7172). A mean efficiency of 0.622 was observed from all farmers. Over 50% of the mixed crop farmers have technical efficiency exceeding 0.70 as compared to 100% sole farmers who have less than 0.60. The study further showed that year of schooling, farming experiences and cropping pattern positively affected technical efficiency while increase in the age led to decrease in technical efficiency.

In a similar study, Erhabor and Emokaro (2007) employed the use of the stochastic frontier production function in the comparative economic analysis of the relative technical efficiency of cassava farmers in the three agro-ecological zones of Edo State, Nigeria. The empirical estimates showed individual technical efficiency values that range from 23 to 95%, 43 to 97% and 52 to 98%, with a mean of 72, 83 and 91% for Edo South, Edo North and Edo Central agro-ecological zones, respectively. The result

shows that systemic difference in relative technical efficiency levels exist between the three zones and these differences were shown to be related to particular farmer's characteristics.

Other studies in which stochastic frontier approach were used include those of Onwuchekwu (2008), Okezie and Okoye (2006).

Okezie and Okoye (2006) studied the determinant of technical efficiency of eggplant production in Isialangwa Area of Abia State, Nigeria, using the stochastic production function. The results show that the significant factors of technical efficiency are labour, fertilizer and seeds. The socio-economic determinants of technical efficiency in the frontier model include gender, land tenure status, marital status and extension visits. The farmers were not fully technically efficient in the use of production resources. The mean technical efficiency is 0.78. The study recommended that farmers can improve on their efficiency by forming cooperative societies to guarantee security of tenure and take advantage of cooperative farming.

Onwuchekwu (2008) also examined the technical efficiency of cassava farmers in South Eastern Nigeria employing stochastic frontier production function procedure. The results of the study reveal that the technical efficiency of the farmers ranges from 52-95% with a mean 77%. This indicates ample opportunities for the farmers to increase their productivity through improvements of their technical efficiency. Education, farmers' experience, membership of farmers association, credit, and household size improved cassava variety and farm size were found to be significantly related to technical efficiency while age and extension contact were not significantly related to technical efficiency.

## 2.8 Review of Tools for Testing Hypotheses

The hypotheses imbedded in this study and these formulated were tested using the various relevant test tools. It is necessary therefore to review these tools. The two tools used in this work were the student t-test and the generalised log-likelihood ratio test.

### 2.8.1 The generalized Log-likelihood ratio test

To enable us test the hypothesis on efficiency, two different models were estimated in this study. The first model was the traditional response function in which the inefficiency effects are not present. According to Kolawole and Ojo (2007), it is a special case of the stochastic frontier production model in which the total variation of output from the frontier is zero, that is  $\sigma^2 = \delta^2 U / \delta^2 = 0$ . Model two is the general model where there is no restriction and thus variation from the production frontier is not zero: i.e.  $\sigma^2 = \delta^2 U / \delta^2 + 0$ . The models were then compared for the presence of technical inefficiency effects using the generalised log-likelihood ratio test.

The generalised log-likelihood ratio test is defined by the test static, chi-square ( $X^2$ ) and is specified as follows:

$$LR = -2 [\ln(L(H_0)) - L(H_A)],$$

Where:  $L(H_0)$  and  $L(H_A)$  are the values of the likelihood functions under the null and the alternative hypotheses respectively  $H_0$  is the null hypothesis  $\sigma^2 = 0$ . It is the value of the likelihood function for the frontier model and  $H_A$ , the alternative frontier model. If  $H_0$  is true, this test statistic is usually assumed to be asymptotically distributed as a chi-square random variable with degrees of freedom equal to the number of restrictions involved (i.e. number of parameters excluded in the unrestricted model). However, difficulties arise in testing  $H_0: \sigma^2 = 0$ , because  $\sigma^2 = 0$  lies on the boundary of the

parameter space for Y. In which case if  $H_0: \beta = 0$  is true, the LR statistic has asymptotic distribution which is a mixture of chi-square distribution (Coelli, 2005). The generalised likelihood ratio test of size  $\alpha$  is “reject  $H_0: Y=0$  in favour of  $H_A: \beta > 1$  if LR exceeds  $X^2, (2\alpha)$ ”, several studies have employed the use of this test in the different researches conducted. For instance Tijani (2007) used the test in the analysis of the technical efficiency of rice farms in Ijesha land of Osun State, Nigeria. According to him hypothesis tests based on the generalized likelihood ration (LR) test were conducted to select the functional form.

### 2.8.2 T-test of significance difference in profitability

The profitability measurement to determine the farm enterprise with the highest gross margin or net farm income as the basic for decision taking may be a necessary, but not a sufficient condition. The values in the Gross Margin Analysis are normally subjected to statistical test of significance (Yusuf, 2009). The t-statistic is the relevant tool of this test. Frank and Althoen (1994 cited in Mailumo, 2012) maintained that the t-statistic is often used to test the significant differences between two sample means. The t-statistics t model is given as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\delta_1^2}{N_1} + \frac{\delta_2^2}{N_2}}} \dots\dots\dots (9)$$

Where:

- t = Calculated t-value
- $X_1$ = mean of net farm income of irrigated Irish potato farmers
- $X_2$ = mean of net farm income of rain-fed Irish potato farmers

$\delta_1 =$  standard deviation of irrigated potato farmers

$\delta_2 =$  standard deviation of rain-fed potato farmers

$N_1 =$  sample size irrigated Irish potato farmers

$N_2 =$  sample size rain-fed Irish potato farmers

The decision rule in this case is that where t-statistic calculated is greater than t – tabulated the null hypothesis is rejected and the alternative is accepted. According to Anyadike (2009), in calculating t – statistic, it does not matter which of the means (either  $X_1$  or  $X_2$ ) is larger. The absolute values (of  $X_1$  and  $X_2$ ) are used. Similarly, the sample sizes ( $n_1$  and  $n_2$ ) do not need to be the same size. The t – statistic was used in this study to test profitability between the irrigated and rain-fed irish potato farmers.

## CHAPTER THREE

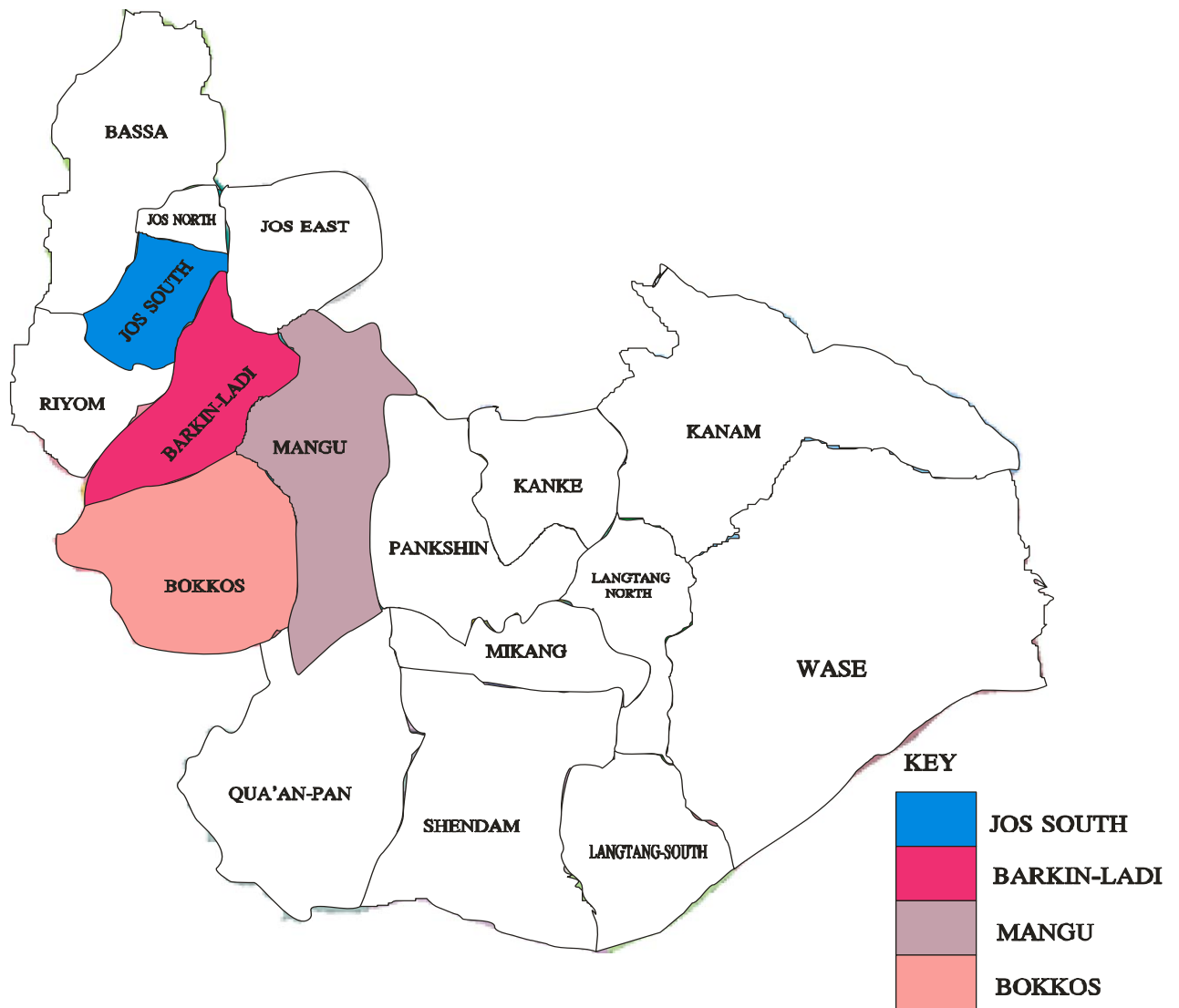
### METHODOLOGY

#### 3.1 The Study Area.

The study area is Plateau State, located in central Nigeria. The state lies between latitude  $8^{\circ}$  N and  $10^{\circ}$  N and longitude  $7^{\circ}$  E and  $11^{\circ}$  E of the prime meridian (PADP, 2000). The state has a landmass covering nearly 53, 585 square kilometres. It had a population of 3, 577, 669 people (NPC, 2006). Based on this figure, the current projected population of the state at a 2.8 per cent growth rate is 4,107,386 people. The state shares borders with four states. These are Bauchi State to the North, Kaduna State to the North-west. To the South- West is Nassarawa State and Taraba State to the South- East.



Fig 1: MAP OF NIGERIA SHOWING PLATEAU STATE



**Fig. 2 MAP OF PLATEAU STATE SHOWING THE STUDY AREA**

The average maximum and minimum temperatures (of 31.7°C and less than 15°C respectively) show that the highest temperatures are recorded in the months of March – May each year while the lowest temperatures are between December and January (Harmattan months). Potato requires an optimum temperature of 15<sup>0</sup> C for tuber formation (Bodlardlaeder *et al.*, 1964, cited in Okonkwo *et al.*, 2009). Jos Plateau meets this condition in both rainy and dry season. The rainfall pattern of Jos Plateau indicates that rains generally start in late April or early May each year and stop in October.

Irish potato is one of the most important root crops grown on the Jos Plateau. Other crops produced in this region include:

- i Vegetables, such as tomatoes, cabbage, onion, carrots, lettuce, cucumber, green beans and apples;
- ii Cereal crops, such as acha, millets, maize, sorghum, rice and wheat;
- iii Other root crops such as cassava, yams, cocoyams, sweet potatoes, groundnuts, and bambara nuts.

### **3.2 Sampling Procedure and Sample Size**

Multi –stage sampling method involving simple random and purposive sampling techniques were used to select respondents for this study. In the first stage, four (4) local government areas were sampled purposively from the Potato producing local government areas. These are Barkin-Ladi, Bokkos, Jos South, and Mangu. The selection of these Local Government Areas was because they are large producers of Irish potato. The next stage involved a selection of five (5) villages each from the four (4) local government areas. This gave a total of twenty (20) villages. The five (5) villages were

selected purposively, on the basis of their scale of production of the crop. A reconnaissance survey was conducted with village extension agents (VEA) of the Plateau Agricultural Development Programme (PADP), to obtain the population of the potato farmers. This involved using a list of Irish potato farmers obtained from the reconnaissance survey to randomly select 10% farmers from each of the twenty (20) villages, giving a sample size of 301 farmers (respondents). The simple random sampling was done through lottery method. The details of the distribution are shown on Table 3.1.

Table 3.1: sampling frame and sample size of Irish potato farmers in the study area

LGA	Villages	Population of Potato farmers			Sample (10%)		
		RF	IRG	Total	RF	IRG	Total
<b>B/Ladi</b>	Zekkerek	60	40	100	6	4	10
	Rakung (Ropp)	100	60	160	10	6	16
	Dorowa	80	60	140	8	6	14
	Heipang	70	50	120	7	5	12
	Kassa	120	60	180	12	6	18
<b>Jos South</b>	Kuru	60	30	90	6	3	9
	Du	50	30	80	5	3	8
	F/Lamba	70	30	100	7	3	10
	K/Vom	40	30	70	4	3	7
	G/Biyu	40	20	60	4	2	6
<b>Bokkos</b>	Mbar	150	70	220	15	7	22
	Bokkos	160	60	220	16	6	22
	Mushere	110	30	140	11	3	14
	Daffo	110	50	160	11	5	16
	Maitako	180	80	260	18	8	26
<b>Mangu</b>	Bwai	100	60	160	10	6	16
	Niyes	100	50	150	10	5	15
	Ngal	80	60	140	8	6	14
	Kerang	110	70	180	11	7	18
	Mangun	190	90	280	19	9	28
<b>Total</b>	<b>20</b>	<b>1980</b>	<b>1030</b>	<b>3010</b>	<b>198</b>	<b>103</b>	<b>301</b>

Source: Reconnaissance Survey, 2010

RF = Rain-fed potato farmers

IRG = Irrigated potato farmers.

### **3.3 Method of Data Collection.**

Primary and secondary data were used for this study. The primary data was collected based on the 2011 farming season with the use of structured questionnaire. This was administered by the researcher with the assistance of trained enumerators to solicit information from the sampled potatoes farmers in the study area. The data collected include: Farmers' socio-economic characteristics, such as age of farmer, education status, household size, farming experience, marital status, extension contact, and membership of cooperative society; Production data, such as period of production, farm size, quantity of Irish potato seeds used, quantity of fertilizers used, farm implements or tools, farm output, labour used for various farm activities, such as land preparation, planting, first and second weeding, fertilizer application, and harvesting; and Data on costs and returns, such as farm input cost, transportation cost, depreciation, total value of potato produced by adding cash receipts from sales of the product plus those consumed at home and those given out as gifts (see details in Appendices I and II). The secondary data and information were sourced from published data from PADP, NRCRI, FAO records, NBS, CBN records and other publications from other sources including government agencies and organizations.

### **3.4 Analytical Tools.**

A combination of analytical tools was used to achieve the objectives of the study. These include: Descriptive statistics, Farm budget technique, and stochastic frontier models.

### 3.4.1 Descriptive statistics.

The descriptive statistics were used to describe and summarize data. It involved the use of percentages, means, range and frequency distribution, as well as standard deviation.

These were used to achieve objectives (i) and (vi).

### 3.4.2 Farm budget techniques

A farm budget is a detailed physical and financial plan for the operation of a farm for a certain period (Olukosi and Ehrabor, 2005). It involves a calculation of expected receipts, expenditure and net farm income. The net revenue derived from production is explicitly stated as:

$$NFI = \sum P_i Y_i - \sum P_{X_j} X_j - \sum F_k \dots \dots \dots (10)$$

Where:

NFI = Net Farm Income (Naira),

$Y_i$  = Potato output (kg),

$P_i$  = Unit price of potato (N/),

$X_j$  = Quantities of variable inputs (where  $j = 1, 2, 3 \dots \dots \dots m$  variable inputs),

$P_{X_j}$  = Price/Unit of variable input (N),

$F_k$  = Cost of fixed inputs (N) (where  $k = 1, 2, 3 \dots \dots \dots k$  fixed inputs).

For the purpose of this study, farm budgeting techniques was used to achieve objective (ii).

The variable inputs considered in this study were:

$X_1$  = labour (including household and hired labour in man/days)

$X_2$  = fertilizer (kg)

$X_3$  = potato seeds (kg)

$X_4$  = Fungicide (litres)

$X_5$  = volume of water (litres)

The fixed inputs include:

$k_1$  = land rent (ha)

$k_2$  = depreciation on farm implements (₦) (straight-line method of depreciation was adopted). This was derived from the formula:

$$D = \frac{P - S}{N} \text{ (Olukosi and Erhabor, 2005)}$$

Where:

D = depreciated value (₦)

P = purchase value (₦)

S = salvage value (₦)

N = life span of asset (years)

### 3.4.3 The stochastic frontier models

Stochastic frontier models were used to estimate economic, technical and allocative efficiency of potato farming enterprise. They were used to achieve objectives iii, iv, and v. The stochastic frontier as an economic method of efficiency measurement in production systems is built around the premise that a production system is bounded by a set of smooth and continuously differential concave production transformation functions for which the frontier offers the limit to the range of all production possibilities (Sharma *et al.*, 1999). It has the advantage of allowing simultaneous estimation of individual farmer as determinant of technical efficiency (Battese and Coelli, 1995).

**(i) Stochastic frontier production function**

The multiplicative stochastic frontier production function for estimating farm level efficiency is given as:

$$Y_i = f(X_{ni}\beta) e^{E_i}, i = 1, 2, \dots, n \dots \dots \dots (11)$$

Where:  $Y_i$  = output of the  $i^{th}$  farm,

$X_{ni}$  = Vector of  $n$  inputs used by the  $i^{th}$  farm,

$\beta$  = Vector of parameters to be estimated,

$E_i$  = Farm specific composite residual term comprising of a random error term

$V_i$  and an inefficiency component  $U_i$ .

While  $E_i = V_i - U_i, i = 1, 2, \dots, n \dots \dots \dots (12)$

The two components,  $V$  and  $U$  are assumed to be independent of each other, where

$V$  = two-sided normally distributed random error  $[(V_i \sim N(O, \delta^2 V))]$ ,

$V_i$  captures random variation in output due to factors outside the control of the farmer.

$U_i$  = one –sided inefficiency component with a half –normal distribution,

$[(U_i \sim N(O, \delta^2 U)]$  (Dawson, 1990 and Sharma *et al.*, 1999).  $U_i$  measures the technical efficiency relative to the stochastic frontier. It represents deviations from maximum potential output attributable to inefficiency.

The variance of the random error term  $\delta^2_v$  and the technical inefficiency effect  $\delta^2_u$  and the overall variance of the model  $\delta^2$  are related as follows:-

$$\delta^2 = \delta^2_v + \delta^2 U \dots \dots \dots (13),$$

and  $\gamma = \delta^2 U / \delta^2$ , measures the total variation of production (output) from the frontier which can be attributed to technical or allocative efficiency (Battese and Corra, 1997).

The maximum likelihood estimation of (3.2) yields estimates for  $\beta$  and  $\hat{y}$ , where  $\beta$  is the vector of parameters  $\beta = \delta^2 U / \delta^2 U$ , being the ratio of the two standard errors as used by Jondrow *et al.*, (1982) so that  $0 \leq \gamma \leq 1$  represents the total variation of output from the frontier which can be attributed to technical efficiency (Battese and Corra, 1997). Dawson and Lingered (1989); Bravo-Ureta and Rieger (1991), and Zaibet and Deharmapala. (1999) have shown that the farm specific technical inefficiency,  $TE_i$  of the farmer can be determined using the conditional expectation of  $U_i$  given the  $E_i$  i.e,  $TE_i = \exp(-U_i)$  so that  $0 \leq TE_i \leq 1$ . The use of MLE procedure has been found to be asymptotically more efficient than the corrected ordinary least square and therefore preferred in the empirical analysis (Umoh, 2006).

#### 3.4.4 Model specification

The Cobb – Douglas frontier production function was used in this study. Taylor and Shinkwiler (1986) noted that as long as interest rests on efficiency measurement and not on the general structure of the production technology, the Cobb – Douglas production function provides an adequate representation of the production technology. It is widely used in farm efficiency analysis both in developing and developed countries (Onyenweaku, Igwe and Mbanasor, 2004; Onyenweaku and Ohajianya, 2005 and Onwuchekwu, 2008).

#### 1. The model for stochastic frontier production function is specified as follows:-

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_i - U_i \dots \dots \dots (14)$$

Where:  $Y_i$  = output of potato from the  $i^{\text{th}}$  farm (kg),

$X_1$  = Land area under potato cultivation (ha),

$X_2$  = potato seeds planted (kg),

$X_3$  = fertilizer used (kg),

$X_4$  = labour used (man-day) (kg),

$X_5$  = volume of water used (litre),

$X_6$  = depreciation on equipment,

$V_i$  = A random error term which accounts for the random variations in output by factors beyond the control of the farmers.

$U_i$  = A random variable called technical inefficiency effects. This is associated with technical inefficiency of production by farmers involved.

ln = the natural logarithm (i.e. to base e),

$\beta_0$ - $\beta_6$  = parameters estimated.

The model was estimated for the two groups of farmers (rain-fed and irrigated Irish potatoes farmers). Estimation of equation (3.5) was accomplished by maximum likelihood estimation (MLE) technique available in the computer programme called Frontier version 4.1 developed by Coelli (1996).

## **(ii) Stochastic frontier cost function**

The stochastic cost function was used to compute the technical and economic efficiencies of the resource use. Given the assumption of Cobb-Douglas technology, the frontier production function is self-dual (Xu and Jeffrey, 1998; Sharma, Loug and Zeleski, 1999; Obare *et al.*, 2010 and Gbigbi 2011). The dual cost frontier can be

derived analytically from the frontier production function equation,  $Y_i = f(X_{ii}, \beta) + E_i$   
 thus:

$$C_i = g(P_i, Y_i, \alpha) \exp e^i \quad i = 1, 2, \dots, n \dots \dots \dots (15)$$

Where:  $C_i$  is the minimum cost associated with potato production,

$P_i$  = Vector of input prices,

$Y_i$  = Potato output,

$\alpha$  = Vector of parameters to be estimated and

$e_i$  = Composite of error term that is composed of two elements.

That is  $e_i = V_i + U_i \dots \dots \dots (16)$

Where  $V_i$  and  $U_i$  are as defined earlier.

However, because inefficiencies are assumed to always increase costs, error components have positive signs (Obare *et al.*, 2010).

The economically efficient input vector for the  $i$ th farm,  $X_{ie_i}$ , is derived by applying Shepard's Lemma (Shepard, 1970) to obtain:

$$\delta C_i / \delta P_i = X_{ie} (P, \gamma^*, \alpha) \dots \dots \dots (17)$$

This is a system of minimum cost input demand equations (Bravo-Ureta and Evenson, 1994; Xu and Jeffery, 1998; Bravo-Ureta and Pinheiro, 1997; and Nwaru *et al.*, 2011). Substituting a farm's input prices and quantity of output in equation (3.6) yields the economically efficient input vector  $X_i$ . With observed levels of output given, the corresponding technically and economically efficient costs of production will be equal

to  $X_{it}P$  and  $X_{ie}P$ , respectively while the actual operating input combination of the farm is  $X_iP$ . In other words:

The technically efficient cost =  $X_{it}.P$

The economically efficient cost =  $X_{ic}.P$  and actual operating input combination of the farm =  $X_i.P$ . The three cost measures can then be used to compute the technical efficiency (TE) and economic efficiency (EE) indices as follows:

$$TE = (X_{it}.P) / (X_i.P) \dots\dots\dots (18),$$

$$\text{and } EE = (X_{ie}.P) / X_i.P \dots\dots\dots (19)$$

The combination of equation (3.9) and (3.10) is used to obtain the allocative efficiency (AE) index as suggested by Farrell (1957) and is as follows: -

$$EE;_e = (X_{ie}.P) / (X_i.P) ,$$

$$TE = (X_{it}.P) / (X_i.P)$$

$$AE = EE/TE = (X_{ie}.P) / (X_{it}.P) \dots\dots\dots (20)$$

In other words, the farm specific economic efficiency (EE) is defined as the ratio of minimum observed total production cost ( $C_i^*$ ) to actual total production cost ( $C_i$ ). That is:

$$EE = C^*/C_i = \frac{E(C_i/U_i=O, Y_i P_i)}{E(C_i/U_i, Y_i P_i)} = E[\exp. (u_i/e_i)] \dots\dots\dots (21)$$

EE takes the value between 0 and 1. Therefore, a measure of farm specific allocative efficiency (AE) is obtained from the technical and economic efficiencies estimated as: -

$$AE = EE/TE \text{ (That is, } 0 < AE < 1) \text{ (Martin and Taylor, 2003; and Ogundari and Ojo, 2006).}$$

### 3 Specification of the stochastic frontier cost function

The Cobb-Douglas cost frontier function was used for the irrigated and rain-fed potato farmers in the study area and is specified as follows: -

$$\ln C_i = \alpha + \alpha_1 \ln P_{1i} + \alpha_2 \ln P_{2i} + \alpha_3 \ln P_{3i} + \alpha_4 \ln P_{4i} + \alpha_5 \ln P_{5i} + \alpha_6 \ln P \gamma^* + V_i + U_i \dots \dots \dots (22)$$

Where:

$\ln$  = Natural logarithm,

$C_i$  = Total cost by the  $i$ th potato farmer in naira,

$P_1$  = Cost of land under potato (N/ha) (actual cost or rent),

$P_2$  = cost of potato seed (N/),

$P_3$  = cost of fertilizer (N/),

$P_4$  = cost of labour (N/man-day)

$P_5$  = cost of Fungicide (N/),

$P_6$  = cost of water used (N/litres),

$\gamma^*$  = adjusted output of potato (kg),

$\alpha_1, \alpha_2, \dots, \alpha_6$  are coefficients of the parameters estimated.

$V_i$  and  $U_i$  are as defined earlier.

## 2. Technical inefficiency model

Apart from determining farmers' technical efficiency in Irish potatoes production, this study has also identified the determinants of farmers' technical efficiency in terms of socio-economic variables. In this respect, an inefficiency model, which assumes that the inefficiency effects are independently distributed having  $N(0, \sigma_u^2)$  distribution and mean  $U_i$  will be used, (Coelli and Battese, 1996). The model was used to achieve objective V and is specified as follows.

$$U_i = \delta_0 + \delta_1 W_1 + \delta_2 W_2 + \delta_3 W_3 + \delta_4 W_4 + \delta_5 W_5 + \delta_6 W_6 + e_i \dots \dots \dots (23)$$

Where:  $U_i$  = Technical inefficiency of the  $i$ th farmer.

$W_1$  = age of the farmers (years),

$W_2$  = Education (years of schooling),

$W_3$  = Years of farming experience,

$W_4$  = Household size of farmer (Number of persons in the household),

$W_5$  = Extension contact (number of visits per farming season),

$W_6$  = Membership of cooperative association,

$e_i$  = Error term,

While  $\delta_0, \delta_1 \dots \delta_6$  are parameters estimated.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Socio-economic Characteristics of the Irish Potato Farmers

The socio-economic characteristics of the respondents in the study were described with respect to age, sex; farm size; extension visits; years of farming experience and membership of cooperative society.

##### 4.1.1 Age of respondents

Analysis of the age distribution of the respondents is presented on Table 4.1. The mean age of the farmers involved in irrigated and rain-fed Irish potato farming enterprises were 41 years and 46 years respectively. Forty six (46%) fell within the age group of 41 – 50 years each for the irrigated and rain-fed farmers respectively, while 26% and 31% fell within the age group of 51 to 60 years for the two categories of farmers respectively. The minimum and maximum age ranges revealed in the result were 20 and 75 years respectively.

The analysis of the respondents of the Irish potato farmers based on their age is very important, as age has direct relationship to the output of crop in any farming enterprise (FAO, 2008). The mean age of 41 years and 49 years for the two groups of farmers respectively implied that Irish potato farming enterprise in the area is dominated by the young and active age group, described by FAO (2002 cited in Haruna, 2010) as economically productive. The more active and virile age group (20 – 30 years) were relatively low. This may be due to their preferences for “white collar jobs”, while others were in schools. The general trend observed in the area was that most of the active and virile youths migrated to cities, such as Abuja and Jos among others, for work in the

construction firms where higher wages are paid comparatively. Quite a number of the youths took to trades such as carpentry, masonry, guardsmen and painting. The result also revealed that the respondents within the age bracket of 61 – 70 years and above constituted 8% and 10% of those involved in irrigated and rain-fed Irish potato farming respectively. This category was low, and most of them have retired from active farming due to old age.

Table 4.1: Age Distribution of Respondents of Irish Potato Farming Enterprise

Age (years)	IRPF		RFPF	
	Frequency	Percentage	Frequency	Percentage
≤ 20	2	1.94	1	0.57
21-30	5	4.86	5	2.53
31-40	14	13.59	40	20.20
41-50	47	45.63	72	36.36
51-60	27	26.21	61	30.80
61-70	6	5.83	18	9.09
>70	2	1.94	1	0.51
Total	103	100	198	100
Mean:	41		Mean:	49
Minimum:	20		Minimum:	20
Maximum:	75		Maximum:	75
S.D	12.2		S.D	9.93

#### 4.1.2 Distribution of respondents based on sex

The distribution of the farmers in respect of sex revealed that 84% and 80% of males were involved in the irrigated and rain-fed Irish potato farming respectively. The Table 4.2 indicated that only 17% and 20% of the respondents involved in the two types of Irish potato farming were females. The analysis implied that Irish potato farming in the area is carried out by more males than females. This scenario may be attributed to cultural background in terms of land ownership. Culturally, females in the area do not own land titles and this limits the extent of their involvement in farming enterprises. This finding is in line with the results obtained by Idiong *et al.* (2006) and Aye and

Oboh (2006) who affirmed that the dominance of the males over females in agriculture, especially in developing countries has cultural explanations. According to them males have unfettered access to production inputs, particularly land in most Nigerian societies.

Table 4.2: Distribution of respondents based on sex

<b>Sex</b>	<b>IRPF</b>		<b>RFPF</b>	
	<b>Frequency</b>	<b>Percentage</b>	<b>Frequency</b>	<b>Percentage</b>
Males	86	83.50	158	79.80
Females	17	16.50	40	20.20
<b>Total</b>	<b>103</b>	<b>100</b>	<b>198</b>	<b>100</b>

#### 4.1.3 Marital Status of respondents

Analysis of the marital status of the Irish potato farmers as presented on Table 4.3 revealed that 70% and 69% of married people took part in the Irrigated and Rain-fed Irish potato farming and only 26% and 24% unmarried people were involved in the irrigated and rain-fed Irish potato farming enterprise respectively. The most likely reason for this scenario may be due to labour force advantage, as households with married status are most likely to have a large family labour size than otherwise. This was also observed by Oluwatayo, Sekuamade, Adesoji (2008) who said that higher household size provides enough persons for family labour.

Table 4.3: Distribution of respondents based on marital status

<b>Marital Status</b>	<b>IRPF</b>		<b>RFPF</b>	
	<b>Frequency</b>	<b>Percentage</b>	<b>Frequency</b>	<b>Percentage</b>
Single	26	26.25	47	23.74
Married	72	69.90	137	69.19
Divorced	-	-	4	2.02
Widowed	5	4.85	10	5.05
<b>Total</b>	<b>103</b>	<b>100</b>	<b>198</b>	<b>100</b>

#### **4.1.4 Educational status of respondents**

The distribution of the respondents according to educational attainment is presented in Table 4.4. The Table revealed that 13% and 10% of the respondents involved in irrigated and rain-fed Irish potato farming respectively had no formal education. However, the levels of formal education for the respondents engaged in irrigated Irish potato farming are made up of 26%, 32% and 29% for primary, secondary and tertiary educational levels respectively. In the case of rain-fed Irish potato farming, 28%, 36% and 25% of the respondents attained the primary, secondary and tertiary educational levels respectively.

In terms of educational status, the analysis revealed that the respondents can be described as being literate, since only a negligible percentage (about 13% and 10%) of those involved in irrigated and rain-fed Irish potato farming respectively had no formal education. In other words 87% and 90% of the farmers involved in irrigated and rain-fed Irish potato farming enterprises respectively attained at least the primary school level of education, therefore, are assumed to be able to read and write. The implication of this finding is that the prospects for acceptance of innovation by the Irish potato farmers is high. This result is in line with the findings of Oyekale and Adjesa (2009 cited in Alabi, 2012) who observed that farmers with formal educational qualifications are more likely to adopt agricultural technological innovations more than those without or with little educational qualifications. The educational level of the farmers does not only increase their productivity but also increases their abilities to undertake and evaluate new techniques. Moreover, education is a social capital which could impact positively on household ability to take good and well-informed production decision.

Furthermore, the mean of the years spent by Irish potato farmers in acquiring education were 11 years and 9 years for irrigated and rain-fed Irish potato farmers respectively. This implied that most of the farmers had at least attended primary school. According to Mailumo (2012) the level of education (years of schooling) helps farmers to use production information efficiently, as more educated persons acquire more information and to that extent, is a better producer.

Table 4.4: Distribution of respondents based on educational status

<b>Educational status</b>	<b>IRPF</b>		<b>RFPF</b>	
	<b>Frequency</b>	<b>Percentage</b>	<b>Frequency</b>	<b>Percentage</b>
Non-formal	13	12.62	20	10.10
Primary	27	26.21	56	28.28
Secondary	33	32.04	72	36.37
Tertiary	30	29.13	50	25.25
Total	103	100	198	100
Mean	11		Mean:	9
Minimum	3		Minimum:	1
Maximum	24		Maximum:	24
S.D	4.98		S.D.	4.94

#### **4.1.5 Households' size**

The size of the household of the respondents is presented in Table 4.5. Analysis of the household size of the respondents involved in irrigated Irish potato farming indicated that 42% of household had between 7-12 family members, 25% had between 1-6 members and 24% had household members of 13-18. However, the highest household size of respondents involved in rain-fed Irish potato farming is made up of 57% with household size of 7-12 members, followed by 21% with household size of 13-18 members and 12% with household size of 1-6 members respectively. This shows that most households were relatively large. The mean household size reported in this study were 10 and 11 for respondents that were into irrigated and rain-fed Irish potato farming respectively. In traditional agriculture which is labour intensive, household size determines the source of farm labour available. Household size has a positive impact on

production, which implies that the larger the household, the more the labour (population) available for boosting productivity (Ahuja, 1998, cited in Mailumo 2012). In a similar vein, Oluwatayo *et al.* (2008) attested that higher household size provides enough persons for family labour and less money needed to pay for hired labour.

Table 4.5: Distribution of respondents based on size of households

Household size (No)	IRPF		RFPF	
	Frequency	Percentage	Frequency	Percentage
1-6	26	25.25	24	12.12
7-12	44	42.71	113	57.07
13-18	25	24.27	41	20.70
19-24	7	6.80	15	7.58
25-30	1	0.97	4	2.02
>30	0	0.00	1	0.51
<b>Total</b>	<b>103</b>	<b>100</b>	<b>198</b>	<b>100</b>
Mean:	10		Mean:	11
Minimum:	3		Minimum:	2
Maximum:	25		Maximum:	30
St. Dev.	3.4		St. Dev.	4.09

#### 4.1.6 Farm size of respondents

Farm size as described in this study refers to the area of land that was actually cultivated for Irish potato production during the period of the survey. The distribution of the respondents on the basis of their farm size is presented in Table 4.6. The analysis showed that majority of the respondents (46% and 55%) in the irrigated and rain-fed Irish potato farming enterprise cultivated between 1.5 – 3.0 hectares of land respectively.

Analysis of the farm size showed that the average farm size of 1.90ha and 2.67ha were cultivated by the respondents of irrigated and rain-fed Irish potato respectively. This indicated that most Irish potato farmers operated on small-scale enterprises. This is in line with the report of Olayide *et al.* (1980 cited in Haruna (2010) which stated that farmers with farmland of between 0.1 to 5.99 hectares belong to the small-scale

farmers' category. In addition, Ogundari and Ojo, (2007) maintained that Agriculture in Nigeria is characterised by a large number of small-scale farmers with small holding ranging from 0.05 to 3.0 hectares of land area.

Table 4.6: Distribution of Respondents based on farm size

Farm size (Ha)	IRPF		RFPF	
	Frequency	Percentage	Frequency	Percentage
≤ 1	15	14.56	17	8.58
1.5-3	47	45.63	109	55.05
3.5-5	25	24.27	53	26.77
> 5	16	15.54	19	9.60
<b>Total</b>	<b>103</b>	<b>100</b>	<b>198</b>	<b>100</b>
Mean:	1.90	Mean:	2.67	
Minimum:	0.40	Minimum:	0.25	
Maximum:	7.0	Maximum:	12	
St. Dev.	1.27	St. Dev.	2.29	

#### 4.1.7 Extension contact

The main aim of extension services is to enhance farmers' ability to efficiently utilize resources through the adoption of new and improved methods in the Irish potato farming enterprise, instead of using traditional methods which are inefficient, resulting to low yield. The distribution of the respondents based on the number of extension visits is presented in Table 4.7. The result of the analysis revealed that 75% and 45% involved in irrigated and rain-fed Irish potato farming respectively, had between 1-2 visits per farming season each by the extension agents of the various agricultural agencies in the area. Only 7% and 23% of the respondents involved in irrigated and rain-fed Irish potato farming had no contact at all with the extension agents.

The research finding revealed that the respondents had an average of extension visits of two (2) times each per farming season for the two groups of Irish potato farming enterprise respectively. In view of the fact that contacts with extension agents by

farmers are expected to enhance their acquisition of new knowledge and therefore bring about efficiency in farm operation, the average of only two visits per farming season is considered inadequate. This could be attributed to low extension agent – farmers ratio in the study area. The importance of the role of extension agents to the improvement of farmers’ efficiency is collaborated by the finding of Seyouem, Battersse and Fleming (2008) who opined that the pieces of advice from extension workers were beneficial in helping farmers implement the practices associated with new technology.

Table 4.7: Distribution of Irish potato farmers according to extension visits

Extension visits (No)	IRPF		RFPF	
	Frequency	Percentage	Frequency	Percentage
0	7	6.80	46	23.23
1-2	77	74.76	90	45.46
3-4	14	13.59	60	30.30
>4	5	4.58	2	1.01
<b>Total</b>	<b>103</b>	<b>100</b>	<b>198</b>	<b>100</b>
Mean:	2	Mean:	2	
Minimum:	1	Minimum:	1	
Maximum:	7	Maximum:	10	
St. Dev.	0.5	St. Dev.	0.41	

#### 4.1.8 Farming experience of Irish potato farmers

The years of farming experience by the respondents is shown on Table 4.8. The result of the analysis showed that 38% and 42% of the two groups of farmers had 11-20 years each of Irish potato farming experience respectively. While 24% and 22% of the irrigated and rain-fed Irish potato farmers had between 1-10 years each of the years of Irish potato farming experience respectively. The mean of the years of farming experience for the two groups of Irish potato farmers were 17 years and 18 years respectively. This finding implies that the farmers in the two categories of the farming enterprises were experienced in the occupation. This result is in line with the report of Food and Agriculture Organisation (FAO, 2002 as cited in Haruna 2010) that farmers with 14 years of farming experience are regarded as “experienced farmers”. Experience

influences individual farmers perception and understanding of the management requirements and consequently improved farm produce (Haruna, 2010). In this respect, Irish potato farming experience shows that farmers are able to make sound decisions as regards resource allocation and management of their farms.

Table 4.8: Distribution of Irish potato farmers based on years of farming experience

<b>Farming experience (years)</b>	<b>IRPF</b>		<b>RFPF</b>	
	<b>Frequency</b>	<b>Percentage</b>	<b>Frequency</b>	<b>Percentage</b>
1-10	25	24.27	43	21.72
11-20	39	37.87	83	41.92
21-30	34	33.01	57	28.79
31-40	5	4.85	11	5.55
>40	0	0.00	4	2.02
Total	103	100	198	100
Mean:	17		18	
Minimum:	2		2	
Maximum:	40		41	
St. Dev.	8.37		5.22	

#### 4.1.9 Membership of co-operative society

Membership of the Irish potato farmers in cooperative societies is presented in Table 4.9. The result of the analysis showed that 58% and 75% of the respondents involved in irrigated and rain-fed Irish potato farming respectively belong to one or more farmers' cooperative societies, and about 42% and 25% respectively were not in any cooperative society. Membership of clubs, association or cooperative societies avails' farmers the opportunity to obtain credit, receive inputs at subsidized or at cheaper rates; and to obtain important and recent information concerning their farming activities. This view is also held by Nwaru, Onyenweaku and Nwosu (2006) and Adeola, Folorunso, Gama, Amadu and Owolabi (2011).

The effect of this result is that Irish potato farmers who belong to the cooperative societies enjoy the benefits accruable to members through the pooling of resources

together for a better expansion of their production frontier; efficient and effective management of resources and for profit maximization.

Table 4.9: Membership of cooperative societies by the respondents

Membership of co-operative societies	IRPF		RFPF	
	Frequency	Percentage	Frequency	Percentage
Yes	60	58.25	148	74.75
No	43	41.75	50	25.25
Total	103	100	198	100

#### 4.2 Profitability Analysis of Irrigated and Rain-fed Irish Potato Farming

The details of profitability analysis of Irish potato farming enterprise are presented in Table 4.10. The production inputs were valued at the prevailing market price for the 2011 farming season. The study revealed that 94% of the cost of production was incurred on the variable inputs for both the irrigated and rain-fed Irish potato farming enterprise. The total variable cost for the irrigated and rain-fed Irish potato farming stood at ₦143,453.68 and ₦114,346.26 respectively. Fixed costs, on the other hand, accounted for over 5% of the total cost of production for each of the Irish potato farming enterprises respectively. Whereas, the total fixed cost incurred in the irrigated Irish potato farming was ₦8,590.00 per hectare, the rain-fed potato farming had a total fixed cost of ₦7,023 respectively. This finding confirmed the observation of Olukosi and Erahbor (2005) that fixed cost of production is usually negligible in subsistence agricultural system.

The most costly variable input in the Irish potato farming in this study was labour, which was ₦107,789.20 per hectare, constituting about 71% of the total cost of production for the irrigated Irish potato farming enterprise. In the rain-fed Irish potato

farming on the other hand, the cost of labour was ₦101,102.00 per hectare or 88% of the total cost of production. This scenario is expected as labour constitutes a high proportion of cost among small-scale farmers involved in agriculture in developing countries, Nigeria inclusive (Amos *et al.*, 2004). The total cost ( $TC = TVC + TFC$ ) recorded in this study stood at ₦152,043.68 and ₦121,369.26 for irrigated and rain-fed Irish potato farming respectively. Given the gross returns (sales) of ₦367,023.50 per hectare and ₦286,917 per hectare for irrigated and rain-fed Irish potato farming respectively, the Gross Margin (GM), which were obtained by subtracting the total variable cost from the gross returns, stood at ₦223,569.32 per hectare and ₦172,570.74 per hectare for the irrigated and rain-fed Irish potato farming respectively. In a similar vein, the net farm income, obtained by subtracting the total cost of production from the gross returns, stood at ₦214,979.82 per hectare and ₦165,547.74 per hectare for irrigated and rain-fed potato farming respectively. This is in line with the findings of Lenka *et al.* (2006), Alabi *et al.* (2006), Okonkwo *et al.* (2009) and Jwanya *et al.* (2014) that Irish potato farming enterprise is profitable.

The result also revealed that the rate of returns on investment for the two Irish potato farming enterprises were 1.41 and 1.36 respectively. This implied that on the average, an irrigated Irish potato farmer realized a profit of 41 kobo for every one naira (₦1.00) invested in the enterprise. Similarly, the rain-fed Irish potato farmer realized a profit of 36 kobo for every one naira (₦1.00) invested in the farming enterprise. This implied that irrigated Irish potato farming in the study was more profitable than the rain-fed potato farming.

Table 4.10: Profitability analysis of Irrigated and Rain-fed Irish potato farming in Plateau State

Variable	Unit price (₦)	IRPF			RFPP		
		Quantity per ha	Value per ha (₦)	Percentage	Quantity per ha	Value per ha (₦)	Percentage
Gross Returns	133.33	2752.745	367,023.50	-	2151.936	286,917.00	-
Variable Costs:							
Seeds (kg)	200	103.8792	20775.84	13.66	100.955	20191	1.80
Labour (man-day)	1000	107.7892	107789.20	70.89	101.102	101102.00	88.30
Fertilizer (kg)	80	76.37025	6109.62	4.03	6.861375	548.19	0.45
Fungicide (litre)	1100	5.6406	6204.66	4.08	9.550064	10505.07	8.66
Vol. Of water (litre)*	5	514.872	2574.36	1.69	-	-	-
<b>Total Variable Cost (₦)</b>	-		<b>143,453.68</b>	<b>94.35</b>		<b>114,346.26</b>	<b>94.21</b>
Fixed Cost							
Rent on land (₦) per ha			5000.00	3.29		5000	4.12
Depreciation on equipment (₦)			3590.00	2.36		2023.00	1.67
<b>Total fixed cost (₦)</b>			<b>8,590.00</b>	<b>5.65</b>		<b>7023</b>	<b>5.79</b>
TC (₦) = (TVC + FC)			152,043.68	100		121,369.26	100
Gross Margin (GR-TVC)			223,569.32			172,570.74	
Net Farm Income (GR-TC)			214,979.82			165,547.74	
Rate of Returns on Investment (NFI/TC)			1.41			1.36	

#### 4.2.1 Test of Significant difference in profitability between irrigated and rain-fed Irish potato farming

The result of test of the hypothesis which states that “there is no significant difference in profitability of irrigated and rain-fed Irish potato farming” is presented on Table 4.11. The hypothesis was tested using t-test statistic. The t-test result of the mean difference in net farm income between irrigated and rain-fed Irish potato farming as presented in Table 4.11 revealed that there was significant difference between the mean net income at one percent (1%) level of probability. Farmers under irrigated Irish potato farming had a mean net farm income of ₦214,979.82 per hectare, while farmers under rain-fed Irish potato farming had a mean net farm income of ₦165,547.74 per hectare. This implied that farmers under irrigated potato farming were on the average ₦49,432.08 per hectare better than the rain-fed potato farmers. In view of this therefore, the null hypothesis that “there is n significance difference in profitability of irrigated and rain-fed Irish potato farming” is rejected and the alternative hypothesis is accepted. The result is in conformity with the findings of Akogun (2014) in which the null hypothesis was rejected and the alternative accepted.

Table 4.11: T-test results of mean difference in net farm income between irrigated and rain-fed Irish potato farming.

<b>Variables</b>	<b>Mean of IRPF</b>	<b>Mean of RFPF</b>	<b>Mean difference</b>	<b>T-value</b>	<b>P-value</b>
Net farm income (₦/ha)	214,979.82	165,547.74	49,432.08	4.91***	0.54
Stard. Dev. (δ)	146,357	26631.90			
Sample size (n)	103	198			

\*\*\* P<0.01

#### 4.3 Input-Output Relationships of Irrigated and Rain-fed Irish Potato Farming in the study Area

#### **4.3.1 Maximum likelihood estimates results of the Cobb-Douglas stochastic frontier production function**

The results of maximum likelihood estimate (MLE) for the production frontier are presented in Table 4.12. The results as presented in the table revealed that the estimated parameters sigma-square ( $\delta^2$ ) were 1.113 and 0.508 for irrigated and rain-fed Irish potato farming respectively, and these were significantly different from zero at one per cent (1%) level of probability, indicating a good fit and the correctness of the specified distributional assumption of the composite error term. The generalized likelihood ratio statistics were 6.21 and 3.93 for irrigated and rain-fed Irish potato farming respectively. This ratio exceeds the critical chi-square value at one percent (1%) level of significance with a number of restrictions of 8 for both the irrigated and rain-fed Irish potato farming. The log-likelihood ratio value represents the value that maximizes the joint-densities in the estimated model. Thus, the functional form (that is Cobb-Douglas) used in this estimation is an adequate representation of the data. The values of the gamma statistics ( $\gamma$ ) 0.483 and 0.102 for the irrigated and rain-fed Irish potato farming respectively implied that 48% and 10% of the changes in the output of Irish potato under irrigated and rain-fed farming respectively, were attributed to farmer's inefficiency factors. The result revealed that technical inefficiency effects were present in Irish potato farming. Therefore, the hypothesis which stated that the parameters estimate of gamma ( $\gamma$ ) equals zero is rejected (Table 4.12 and 4.22). This finding is similar to those of Erhbor and Emokaro (2007), Onwuchekwu (2008), Idiong (2005), Okeze and Okoye (2006).

The estimated coefficients (0.851 and 0.201) for farm size in the irrigated and rain-fed Irish potato farming respectively, were positive and significant at one percent (1%) level of probability. This implied that farm size exerted a positive influence on the output of Irish

potato production under irrigated and rain-fed farming enterprises. This indicated that output of Irish potato increased as farmers in the study area increased their farm size for the cultivation of the crop. These results confirmed the significance of farm size under subsistence agriculture. Large farm size can motivate adoption of innovation which can translate to higher output. This result is consistent with the findings of Onyenweaku *et al.* (2004), Onyenweaku and Ohajiaya (2005). According to Masimba (2011), “in some areas, as in Western Kenya and northern Ethiopia, families have less than the minimum farmland required to support increase in agricultural output”.

The estimated coefficient (-0.228 and -0.135) for seeds obtained for irrigated and rain-fed Irish potato farming respectively were negative and significant at one percent (1%) and 5% level of probability for the two groups of potato farmers respectively. This implied that increase in the utilization of seed would decrease the output of Irish potato in the study area. The negative coefficients of this variable implied that Irish potato farmers were over-utilizing the seeds and this may be attributed to the use of seed from the previous harvest due to high cost of the planting materials. This result is consistent with the finding of Lenka *et al.* (2006) that poor planting materials was one of the causes of low productivity in Irish potato farming in Plateau State and therefore they recommended the use of high yielding and disease tolerant varieties by the farmers.

The coefficient (0.548) for fertilizer was positive and significant at one percent (1%) level of probability for irrigated Irish potato farming. The positive coefficient implied that an increase in fertilizer application is expected to increase the output of Irish potato for the irrigated farming enterprise. This result is in line with the findings of Okezie and Okoye (2006) that

output is dependent on the fertilizer. However, the coefficient of fertilizer in the case of rain-fed Irish potato farming, though positive is not significant. The possible reason for this finding could be due to leaching effect on the soil under the rain-fed Irish potato cultivation. The coefficient (0.160) obtained for labour input was positive and significant at 10% probability level for rain-fed Irish potato production. This implied that labour had a significant positive impact on the output of Irish potato under the rain-fed potato farming. The result for labour in the rain-fed potato farming conformed to the finding of Alabi and Aruna (2005) who opined that the large household size is relevant to agriculture because family labour constitute the bulk of labour supply in subsistence agriculture. In the case of irrigated Irish potato farming however, labour input was not statistically significant. This result is contrary to a priori expectation given that labour is a major input in Irish potato farming. The possible reason for this is the heavy reliance on family and “communal” labour for the farming operations which are relatively cheaper.

Depreciation on equipment was negative (-0.104) and significant at ten percent (10%) level of probability for the rain-fed Irish potato farming. This implied that rain-fed Irish potato farmers were over-utilizing the fixed input in the farming operation. Besides, in the case of irrigated Irish potato farming, the coefficient (0.252), though positive but was not significant. This again confirmed the point made by Olukosi and Erhbor (2005) that in traditional subsistent agriculture, fixed inputs are usually negligible.

Table 4.12: Maximum likelihood estimated results of the Cobb-Douglas Stochastic Frontier Production function.

Variable	Parameter	IRPF			RFPF		
		Co-efficient	S.E	t-value	Co-efficient	S.E	t-value
Constant	$\beta_0$	2.252	1.454	1.548	8.581	0.950	9.031***

Farm size (ha) (X <sub>1</sub> )	$\beta_1$	0.851	0.194	4.368***	0.201	0.072	2.777***
Seed (X <sub>2</sub> )	$\beta_2$	-0.228	0.015	-	-0.135	-	2.444***
Fertilizer (X <sub>3</sub> )	$\beta_3$	0.548	0.165	3.308***	0.035	0.0557	0.628
Labour (man-day) X <sub>4</sub>	$\beta_4$	0.014	0.264	0.053	0.160	0.091	1.745*
Vol. Of water (litre) (X <sub>5</sub> )	$\beta_5$	0.371	1.069	0.347	-	-	-
Depreciation on equipt. (₦) (X <sub>6</sub> )	$\beta_6$	0.252	0.163	1.537	-0.104	-0.539	1.927*
Variance Parameters:							
Sigma squared ( $\delta^2 = \delta^2 v + \delta u$ )		1.113	0.236	4.712***	0.508	0.0536	9.471***
Gamma ( $\square = \delta^2 u / \delta^2$ )		0.483	0.038	12.55***	0.102	0.334	0.305
LR Test		6.21			3.92		
Log-likelihood function		-152.561			-214.27		

\*\*\* P<0.01, \*\*P<0.05, \*P<0.10

#### 4.3.2 Elasticity of production and returns to scale in Irish potato farming

Results of elasticity of production of the Irish potato farming enterprises are presented in Tale 4.13. The returns to scale for the irrigated and rain-fed Irish potato farming were 1.808 and 0.157 respectively. These were obtained from the summation of the coefficient of the estimated input elasticities of production, being one of the characteristics of Cobb-Douglas production functions (Giroh, Mohammed, Valla and Peter, 2008).

The returns to scale (1.808) obtained for irrigated Irish potato production indicated increasing returns to scale. This shows that if all the inputs included in the production model were increased by one percent (1%), output of Irish potato in the irrigated farming system in the study area will increase by 1.808 percent. This implied that Irish potato farming under irrigated system was still in stage one of the production process, the stage of positive increasing returns to scale. This is because the estimated returns to scale is elastic (see Table

4.13). It is suggested that farmers under the irrigated farming system should increase the level of utilization of inputs on this stage so as to sure maximum output from a given level of input. On the other hand, the returns to scale for the rain-fed Irish potato production (0.157) indicated that resources use were inelastic. In other words, a one percent (1%) increase in all the inputs included on the production function model in the rain-fed Irish potato resulted in less than one percent increase (0.157) in output of Irish potato. This implied that production is in stage two of the production process, which is the stage of positive decreasing returns to scale. This is the stage where every producer thrives to maximize profit as well as minimize cost. This result is in conformity with the findings of Amos *et al.* (2004) who discovered that estimated elasticity of the explanatory variables (0.27) indicated that allocation and use of variables were in stage two (economic relevant) of the production function in their study on productivity, technical efficiency and cropping patterns in the savannah zone of Nigeria.

Table 4.13: Elasticity of Production and Returns to scale of Irish potato Farming

Production variables	Elasticity of Production	
	IRPF	RFPF
Farm size (ha)	0.851	0.201
Seeds (kg)	-0.228	-0.135
Fertilizer (kg)	0.548	0.035
Labour (man-day)	0.014	0.160
Volume of water (litre)	0.371	-
Depreciation on equipment (₦)	0.252	-0.104
Returns to scale (RTS)	1.808	0.157

### 4.3.3 Maximum likelihood estimates of the Cobb-Douglas stochastic frontier cost function

The results of the maximum likelihood estimates of the Cobb-Douglas stochastic frontier cost function are presented in Table 4.14. The result revealed that the estimated parameter of sigma square ( $\delta^2$ ) were 2.694 and 1.091 for irrigated and rain-fed Irish potato farming

respectively. The gamma ( $\gamma$ ) were 0.992 and 0.997 for the two groups of farmers respectively. The high and significant values of the sigma square ( $\delta^2$ ) indicate the goodness of fit and correctness of the specified assumption of the composite error terms distribution (Idiong *et al.*, 2006). The gamma ( $\gamma$ ) estimates of 0.992 and 0.997 obtained for the two farming systems respectively were statistically significant at one percent (1%) level of probability. This implied that 99% variation in total cost of production for both irrigated and rain-fed Irish potato farming were due to allocative inefficiency in the model.

The coefficients of the cost of farmland (0.318 and 0.198) were positive and significant at one percent (1%) level of probability for both the irrigated and rain-fed Irish potato production. The positive relationship of cost of farmland indicated that an increase in the cost resulted to an increase in total cost of production. This implied that the cost of farmland is an important component in the production of Irish potato in the study area.

The coefficient for cost of potato seeds (0.115 and 0.228) was also positive and statistically significant at one percent (1%) level of probability for both irrigated and rain-fed Irish potato farming. This underscores the relevance of cost of seed in the total cost of production seed is a very important component in the production of Irish potato as without good and improved varieties of seed production of Irish potato in the two farming types cannot be embarked upon.

Similarly, the estimates for fertilizer cost (0.279 and 0.232) and cost of labour (0.238 and 0.173) for irrigated and rain-fed Irish potato production respectively were all positive and significant at one percent (1%) level of probability. This meant that cost of fertilizer and

labour had direct relationship with the total cost of production for both the irrigated and rain-fed Irish potato production system. This justifies the importance of fertilizer and labour in agricultural production in the study area. This finding implied that if the cost of fertilizer and labour increase, total cost of production will also increase.

The study revealed that the coefficient for the cost of chemical-fungicides (0.145 and 0.067) were positive and statistically significant at one percent (1%) level of probability both for the two groups of farmers respectively. The positive estimates implied that increase in the cost of chemical (fungicide) increased the total cost of producing Irish potato.

Finally, the estimate for cost of water (0.101) was positive and significant at five percent (5%) level of probability for irrigated Irish potato farming. This implied that the cost of water in irrigation had a direct relationship with the total cost of producing Irish potato. In other words, an increase in the cost of water for irrigating Irish potato increased the total cost of producing Irish potato through irrigation system.

Table 4.14: Maximum likelihood estimate result of the Cobb-Douglas stochastic frontier cost function of Irish potato farming

Variable	Parameter	IRPF			RFPF		
		Co-efficient	S.E	t-value	Co-efficient	S.E	t-value
Constant	$\alpha_0$	0.173	0.655	0.264	2.066	0.272	7.569***
Cost of farmland (€/ha)	$\alpha_1$	0.318	0.019	16.42***	0.198	0.0135	14.563** *
Cost of seed (€/kg)	$\alpha_2$	0.115	0.031	3.669***	0.228	0.016	14.242** *
Cost of Fertilizer (€/kg)	$\alpha_3$	0.279	0.032	8.575***	0.232	0.0164	14.086** *
Cost of Labour (€/man-day)	$\alpha_4$	0.238	0.035	6.676***	0.173	0.0134	12.901** *
Cost of fungicide (€/litre)	$\alpha_5$	0.145	0.034	4.156***	0.067	0.0159	4.202***
Cost of water (€/litre)	$\alpha_6$	0.101	0.043	2.332**	-	-	-
Output (Y)		0.014	0.026	0.520	0.0149	0.018	0.826
Variance parameter							
Sigma square ( $\delta^2 = \delta^2 v + \delta^2 u$ )		2.694	0.237	11.363** *	1.091	0.3279	3.327**
Gamma ( $\square = \delta^2 u / \delta^2$ )		0.992	0.077	12.83***	0.997	0.0109	98.756** *
LR Test		46.17			2.493		
Log-likelihood function		-24.7335			-179.31		

\*\*\* P<0.01, \*\*P<0.05, \*P<0.10

#### 4.4 Levels of Technical, Allocation and Economic Efficiencies of Irrigated and Rain-fed Irish Potato Farming

##### 4.4.1 Distribution of Irish potato farmers based on their technical efficiency

The results of the technical efficiency of the Irish potato farmers are presented in Table 4.15. The results revealed that technical efficiency varied from a minimum of 0.81 to a maximum of 0.99 for irrigated Irish potato farming, with a mean of 0.69, while the minimum and maximum technical efficiency obtained for rain-fed Irish potato production were 0.60 and 1.00 respectively, with an average of 0.88. Majority of the irrigated and rain-fed Irish potato

farmers (21.35% and 44.95%) had technical efficiency indices of between 0.91 and 1.00 respectively. The result implied that Irish potato farmers in the study area had wide differences in their technical efficiency operation. The least technical efficiency indices of 0.31 to 0.40 and 0.61 to 0.70 were obtained for irrigated and rain-fed Irish potato farmers respectively.

The analysis also revealed that about 99% of the rain-fed Irish potato farmers had technical efficiency greater than 70%, while less than 50% of the respondents who were into irrigated Irish potato farming had technical efficiency greater than 70%. These findings are consistent with the result obtained by Bifarin *et al.* (2010) who discovered that over 92% of plantain farmers in Ondo State were operating above 50% technical efficiency. The average technical efficiency obtained for the respondents who were into irrigated and rain-fed Irish potato production were 0.68 and 0.88 respectively. This indicated that Irish potato farmers in the study area operated below their frontier levels, which shows a shortfall in the technical efficiencies for the two groups of farmers. This implied that the farmers of irrigated and rain-fed Irish potato in the area had 32% and 12% potentials respectively. In other words, farmers in the irrigated Irish potato farming can increase their technical efficiency level by 32% using the existing technology. Similarly, farmers in the rain-fed Irish potato farming had the opportunity to increase their potato technical efficiency by 12% with the existing resources.

The implication of these results was that the average farmer in the irrigated Irish potato farming required 31% , that is  $[(1-0.69/0.99) \times 100]$  input/resource savings to attain the status of the most technically efficient Irish potato farmer.

The least performing farmer in the irrigated Irish potato farming needed 69% input/resource savings, which is  $[(1-0.31/0.99) \times 100]$  to become the most efficient farmer. This result is in line with the findings of Bravo-Ureta and Pinheiro (1994) who obtained resource savings of 18% for the average farmer and 50% for the most inefficient farmer in the Dominican Republic. The fact that the technical efficiencies of all the respondents in the irrigated Irish potato production were less than one implied that no farmer in this category reached the frontier of production. This means that farmers had the potentials to increase their efficiency level. On the other hand, an average farmer of rain-fed Irish potato required 12%, that is  $[(1-0.88/1.00) \times 100]$  input/resource savings to attain the status of the most efficient farmer of rain-fed Irish potato. The least performing farmer in this category needed 40% input/resource savings, which is  $[(1-0.60/1.00) \times 100]$  to become the most efficient farmer. The results of technical efficiency by respondents who were into rain-fed Irish potato farming revealed that 11% of the farmers operated at the frontier level.

Table 4.15: Frequency Distribution of Technical Efficiency Estimate of Irish potato Farmers

<b>Technical efficiency range</b>	<b>IRPF</b>	<b>RFPF</b>
0.31 – 0.40	7(6.80)	Nil
0.41 – 0.50	18(17.48)	Nil
0.51 – 0.60	15(14.56)	Nil
0.61 – 0.70	16(15.53)	2(1.01)
0.71 – 80	18(17.48)	33(16.67)
0.81 0.90	7(6.68)	74(37.37)
0.91 – 1.00	22(21.35)	89(44.95)
Total	103(100)	198(100)
Mean	0.69	0.88
Minimum	0.31	0.60
Maximum	0.99	1.00

Figures in parentheses are percentages.

#### **4.4.2 Distribution of Irish potato farmers based on their allocative efficiency**

The results of the distribution of allocative efficiency of the farmers as presented in Table 4.16 revealed that the average allocative efficiency of the farmers who were into irrigated and rain-fed Irish potato farming were 0.66 and 0.79 respectively. The minimum and maximum allocative efficiencies of farmers of irrigated Irish potato were 0.14 and 0.91 respectively. On the other hand, the minimum and maximum allocative efficiencies of the farmers of rain-fed Irish potato were 0.12 and 0.98 respectively. The result also showed that about 85% and 94%

of the farmers had allocative efficiencies greater than 50% in the irrigated and rain-fed production respectively.

The results showed that if the average farmer in the irrigated Irish potato farming was to achieve allocative efficiency level of his most efficient counterpart, then he had to realize 28% that is  $[(1-0.66/0.91) \times 100]$  cost savings. A similar calculation for the most allocative inefficient farmer revealed that a cost saving of 85%, which is,  $[(1-0.14/0.91) \times 100]$ . It is evident from these results therefore that allocative inefficiency constituted a more serious problem than the technical inefficiency in the study area.

On the other hand, if an average farmer who was into rain-fed Irish potato production were to achieve allocative efficiency level of the most efficient farmer, he needed a cost saving of 19%, that is,  $[(1-0.12/0.98) \times 100]$  to become the most allocative farmer in the rain-fed Irish potato farming.

Table 4.16: Frequency distribution of allocative efficiency estimates of Irish potato farmers

<b>Allocative efficiency range</b>	<b>IRPF</b>	<b>RFPF</b>
0.1 – 0.20	1(0.97)	2(1.01)
0.21 – 0.30	5(4.85)	2(1.01)
0.31 – 0.40	5(4.85)	2(1.01)
0.41 – 0.50	4(3.88)	6(3.03)
0.51 – 0.60	19(18.45)	12(6.06)
0.61 – 0.70	21(20.39)	22(11.11)
0.71 – 0.80	23(22.33)	39(19.70)
0.81 – 0.90	23(22.33)	59(29.80)
0.91 – 1.00	2(1.94)	54(27.27)
Total	103(100)	198(100)
Mean	0.66	0.79
Minimum	0.14	0.12
Maximum	0.91	0.98

Figures in parentheses are percentages.

#### **4.4.3 Distribution of Irish potato farmers based on their economic efficiency**

The frequency distribution of economic efficiency of the sampled irrigated and rain-fed Irish potato farmers are presented in Table 4.17. The results showed that the mean economic efficiencies for the two groups of farmers were 0.45 and 0.70 respectively. The minimum and maximum economic efficiencies for irrigated Irish potato farmers were 0.10 and 0.89 respectively, while the minimum and maximum for rain-fed Irish potato farmers were 0.10 and 0.98 respectively.

Economic efficiency which was obtained by multiplying technical and allocative efficiencies gave a revealing result. The finding showed that 39% and about 90% of the farmers who were into irrigated and rain-fed Irish potato production respectively had economic efficiency greater than 50%. This implied that farmers of Irish potato in the rain-fed system performed better in terms of their economic efficiency than those in the irrigated production system.

Consequently, on the average, the best farmer in the irrigated Irish potato farming needed a cost saving of 49%, which is  $[(1-0.45/0.89) \times 100]$  to attain the frontier. Whereas, the worst farmer in terms of economic efficiency, required a cost savings of 89%, that is  $[(1-0.1/0.89) \times 100]$  to become the most economic efficient farmer in this group. Similarly, the average best farmer in the rain-fed Irish potato farming needed a cost saving of 29%, that is,  $[(1-0.10/0.98) \times 100]$  to become the most economic efficient among the rain-fed Irish potato production.

Table 4.17: Frequency distribution of economic efficiency estimates of Irish potato farmers

<b>Economic efficiency range</b>	<b>IRPF</b>	<b>RFPF</b>
0.1 – 0.20	8(7.77)	3(1.52)
0.21 – 0.30	16(15.53)	3(1.52)
0.31 – 0.40	18(17.48)	1(0.51)
0.41 – 0.50	21(20.39)	10(5.05)
0.51 – 0.60	22(21.36)	32(16.16)
0.61 – 0.70	8(7.77)	43(21.72)
0.71 – 0.80	5(4.85)	51(25.76)
0.81 – 0.90	5(4.85)	45(22.73)
0.91 – 1.00	Nil	10(5.05)
<b>Total</b>	<b>103(100)</b>	<b>198(100)</b>
Mean	0.45	0.70
Minimum	0.10	0.10
Maximum	0.89	0.98

Figures in parentheses are percentages.

#### **4.4.4 Test of hypothesis ii: No significant difference in the levels of technical, allocative and economic efficiencies in Irish potato farming**

The results of hypothesis test of no significant difference in the levels of efficiencies in Irish potato farming are presented in Table 4.18. The hypothesis was tested using t-test statistic. The results of the test showed that the means of the technical, allocative and economic efficiencies were significant at one percent (1%) level of probability for both the irrigated and rain-fed Irish potato farming in the study area. Therefore, the null hypothesis was rejected and the alternative hypothesis accepted. This implied that there is significant difference in the levels of technical, allocative and economic efficiencies of the two types of Irish potato farming. It was observed from this study that the level of technical efficiencies were greater than those of allocative and economic efficiencies in both the irrigated and rain-fed potato

farming. Similarly the levels of allocative efficiencies are greater than that of economic efficiencies in the two Irish potato production systems.

Table 4.18: Hypothesis test result for significant difference in levels of efficiencies in Irish potato farming

<b>Mean efficiency</b>	<b>IRPF</b>	<b>RFPF</b>	<b>T-value</b>	<b>H<sub>0</sub></b>	<b>H<sub>A</sub></b>
Technical	0.69	0.88	6.33***	Rejected	Accepted
Allocative	0.66	0.79	15.92***	Rejected	Accepted
Economic	0.45	0.70	6.25***	Rejected	Accepted

\*\*\* P<0.01

#### **4.5 Determinants of Technical, Allocative and Economic Inefficiencies of Irish Potato Farming**

##### **4.5.1 Determinants of technical inefficiency**

The results of the determinants of technical inefficiency in Irish potato production are presented in Table 4.19. The results showed that the coefficients for age, education, household size, extension visits and membership of cooperative society were negative for both irrigated and rain-fed Irish potato farming enterprises respectively.

##### **a) Age of the farmers:**

The results showed that the coefficient for age (-1.495 and -0.435) were negative and statistically significant at one percent level of probability for both farmers that were into irrigated and rain-fed Irish potato farming. This implied that as farmers advance in age the technical inefficiency reduces. Age is an important factor in crop production. Adubi (2002) argued that age in correlation with farming experience, has a significant influence on the decision making process of farmers with respect to risk aversion, adoption of improved

agricultural technologies, and other production – related decisions. Moreover, age is associated with skills enhancement (experience), accumulation of resources and extensive social capital that ought to contribute positively to well being.

**b) Educational status:**

The estimated parameters (-0.298 and -0.768) obtained for education were negative and significant at one percent level of probability for the two groups of farmers. This scenario indicated a significant and positive relationship with technical inefficiency, which implied that as years of education increases, farmers' technical inefficiency reduces. In other words, farmers with greater years of schooling tend to be more efficient, because technical inefficiency tends to reduce as years of schooling increases. Educational attainment is very important because it could lead to awareness of the advantages of modern farming techniques. Educated farmers are able to gather, understand and use information from research and extension services more easily than illiterate farmers. Moreover, educated farmers are likely to be less risk – averse and therefore more willing to try out modern technologies. Kalirajan and Shard (2005) observed that education sharpens managerial input and leads to a better assessment of the importance and complexities of good decisions in farming.

**c) Household size:**

The estimated parameters (-0.285 and -1.082) obtained for household size showed a negative relation with predicted technical inefficiency and statistically significant at one percent level of probability for the farmers who were into irrigated and rain fed Irish potato farming respectively. This implied that farmers who had large household sizes were more technically efficient. The reason for this relationship is that as the number of people in a household increases, a pool of family labour becomes available. Therefore, an increase in the number of

people in a household was expected to lead to a decline in technical inefficiency of the farmers.

**d) Extension contact:**

The coefficient for extension contact (-8.910 and -1.762) obtained from the analysis were negative and significant at one percent level of probability for farmers in both irrigated and rain fed Irish potato production. This implied that technical inefficiency reduced as a result of more contact with the farmers, by the agricultural extension agents. This was because extension contacts enhanced farmers' accessibility to information on improved techniques of Irish potato farming.

**e) Membership of cooperative societies:**

The estimated parameter for membership of cooperative society (-3.090 and -7.798) were all negative and significant at one percent probability level for farmers that were engaged in irrigated and rain-fed Irish potato farming. This implied that membership of cooperative association reduced technical inefficiency of the farmers. Membership of association afforded the farmers the opportunity of sharing information on modern farming practices interacting with other farmers. Moreover, it afforded the farmers opportunity to draw from the benefits of membership which include purchase of inputs at subsidized rates and access to credit facilities at lower rates of interest. This result is in line with the findings of Nwaru *et al.* (2006) who observed that membership of cooperatives and farmers associations are expected to increase the farmers' interactions with their fellow farmers and other entrepreneurs which in turn should increase their capacity to access current information and be involved in other economic activities.

**(f) Years of Farming experience**

Farming experiences by the farmers were significant at one percent (1%) level of probability. This implied that experience in farming reduced technical inefficiency.

Table 4.19: Socio-economic factors influencing technical inefficiency

Variable	Parameter	IRPF			RFPF		
		Co-efficient	S.E	t-value	Co-efficient	S.E	t-value
Constant	Z <sub>t0</sub>	25.701	1.156	22.22***	13.610	0.292	22.96***
Age (years)	Z <sub>t1</sub>	-1.459	-0.023	63.43***	-0.435	-0.009	46.96***
Education (years)	Z <sub>t2</sub>	-0.298	0.056	-5.27**	-0.768	0.019	-
Farming experience (yrs)	Z <sub>t3</sub>	0.382	0.035	10.91***	-0.148	-0.017	8.35***
Household size (No)	Z <sub>t4</sub>	-0.285	0.082	-3.45	-1.082	0.023	-
Extension visits (No)	Z <sub>t5</sub>	-8.90	0.533	-	-1.762	0.225	-7.81***
Membership of cooperative society	Z <sub>t6</sub>	-3.09	0.537	16.69***	-7.798	-0.186	41.88**

\*\*\* P<0.01, \*\* P<0.05

#### 4.5.2 Determinants of allocative inefficiency

The results of the determinants of allocative inefficiency in Irish potato farming are presented in Table 4.20. Age, education, farming experience, household size and membership of cooperative society were identified as factors that determined allocative inefficiency in the Irish potato farming enterprises. These factor are discussed as follows:

##### a) Age of the farmers:

The coefficients (-0.942 and -0.077) for the age of the farmers of Irish potato were found to be negative and statistically significant at one percent probability level. Age is usually associated with accumulation of skills, more experience and accumulation of assets thereby enhancing farmer's accessibility to production inputs thus reducing allocative inefficiency.

**b) Educational status:**

The coefficient for education (-0.600) in respect of farmers in the irrigated Irish potato production was negative and statistically significant at one percent probability level. This implied that increase in educational level raises the allocative efficiency of the farmers. In other words, it reduced the allocative inefficiency. Weir and Knight (2000) in their study observed that education enhances a farmer's ability to seek and make good use of information about production inputs. Educated farmers may better understand and process information provided by different sources regarding new investments thereby reducing their allocative inefficiency. The study however, revealed that the estimated parameter for education (0.022) in respect of farmers that were into rain-fed Irish potato production was not only positive but insignificant.

**c) Farming experience**

Even though the estimated parameter for farming experience (-0.092 and -0.251) were negative for both groups of farmers in the irrigated and rain-fed Irish potato farming only the coefficient for farmers that participated in the rain-fed Irish potato production was statistically significant at one percent level of probability. This implied that the farmers allocative inefficiency reduced with more years of farming experience. This is in line with the findings of Nwaru *et al.* (2011) who reported that the more experience a farmer is the more efficient he is in farm decisions making processes.

**d) Household size:**

The coefficient for household size (-1.614 and -0.090) were negative and significant at five percent level of probability for both groups of farmers. This implied that farmers with large household size relied on family labour and subsequently enhanced reduction in cost and their allocative inefficiency. This result is in agreement with the finding of Alabi and Aruna

(2005) who reported that allocative inefficiency in poultry production decreased with increase in household size.

**e) Membership of cooperative societies**

The estimated parameter (-2.755) was negative and significant at one percent probability level for farmers in the rain fed Irish potato farming. However, the coefficient (-8.122) for farmers in the irrigated Irish potato group though negative, was not statistically significant. This implied that the allocative inefficiency was reduced as a result of farmers membership of cooperative societies. Membership of cooperative enhanced the accessibility of farmers to credit facility and served as media for exchange of ideas which improved their farm activities thus reducing the allocative inefficiency. This result is in line with the findings of Okoye, Onyenweaku and Asumugha (2005) who reported that the coefficient of the age of small-holder cocoyam farmers in Anambra State was negative and significant at 5% level of probability implying that increase in age of the respondents resulted in a reduction of their allocative inefficiency.

Table 4.20: Socio-economic factors influencing allocative inefficiency of Irish potato farming

Variable	Parameter	IRPF			RFPF		
		Co-efficient	S.E	t-value	Co-efficient	S.E	t-value
Constant	Z <sub>a0</sub>	82.315	7.914	10.40***	15.592	2.771	5.626***
Age (years)	Z <sub>a1</sub>	-9.42	0.182	-5.17***	-0.077	0.024	-3.172***
Education (years)	Z <sub>a2</sub>	-0.600	0.054	-11.03***	0.022	0.022	0.988
Farming experience (yrs)	Z <sub>a3</sub>	-0.092	0.344	-0.267	-0.251	0.082	-3.036***
Household size (No)	Z <sub>a4</sub>	-1.614	0.770	-2.094**	0.090	0.045	-1.97**
Extension visits (No)	Z <sub>a5</sub>	0.910	5.352	0.17	0.201	0.478	0.420
Membership of cooperative society	Z <sub>a6</sub>	-8.112	5.206	-1.558	-2.755	1.012	-2.722***

\*\*\* P<0.01, \*\*P<0.05

### **4.5.3 Determinants of economic inefficiency**

The results presented in Table 4.21 are the estimated parameters of the economic inefficiency model. The parameters for education, age and cooperative participation were all negative for both irrigated and rain-fed Irish potato farming enterprises. Similarly, the coefficients for extension visits were significant at 10% and 5% levels of probability for irrigated and rain-fed potato production respectively. The details of the results are discussed as follows:

#### **a) Age of farmer:**

The estimated parameters for age (-0.154 and -0.331) of farmers in the irrigated and rain-fed Irish potato farming were all negative, but significant at one percent level of probability for farmers in the rain-fed Irish potato production only. This implied that economic inefficiency reduced with advancement in age, as increase in age implies accumulation of skills, experience and wisdom, all things being equal.

#### **b) Educational status:**

The coefficients for education (-1.031 and -0.454) were negative and statistically significant at five percent level of probability for both groups of farmers. The negative sign of the coefficient of education implied that economic inefficiency reduced as this variable (education) increased. Education is a central ingredient in a strategy to improve agricultural productivity, especially where the use of modern inputs are emphasized. In his estimation of economic efficiency of smallholder sweet potatoes produced in Delta State of Nigeria Gbigbi (2011) found that better performance by more educated farmers attributed to educational access and this gave the farmers ability to perceive, interpret and respond to new information.

#### **c) Household size:**

The estimated parameter for household size (-2.184) was negative and statistically significant at one percent probability level for farmers of irrigated Irish potato. In respect of farmers in the rain-fed Irish potato production group, the coefficient (0.561) was positive but significant at five percent level of probability.

**d) Extension contact:**

The coefficient for extension visits (-8.324 and -2.977) were negative and statistically significant at ten percent and five percent level of probability for irrigated and rain fed Irish potato groups of the farmers respectively. This implied that economic inefficiency reduced with increase in extension contact. Nwaru *et al.* (2006) opined that by ensuring resources are better mobilized and used more efficiently, a vibrant and functional extension system could be a solution to the problem of acute scarcity of resources in the rural community which are complicated by inefficient use of such resources.

**e) Membership of cooperative association:**

These had negative coefficients (-7.889 and -6.871) and were statistically significant at one percent level of probability for farmers who were into rain-fed Irish potato production. This implied that increase in years of membership of a cooperative association reduced the level of economic inefficiency. Membership of cooperative society can serve as a medium for exchange of ideas that can improve their farm operations. Adeola *et al.* (2011) reported that membership of cooperative can serve as an avenue through which innovations are diffused among farmers.

Table 4.21: socio-economic factors influencing economic inefficiency

Variable	Parameter	IRPF			RFPF		
		Co-efficient	S.E	t-value	Co-efficient	S.E	t-value
Constant	$Ze_0$	94.263	5.368	17.56***	-1.918	6.850	-0.28
Age (years)	$Ze_1$	-0.154	0.173	-0.889	-0.331	0.106	-3.10***
Education (years)	$Ze_2$	-1.031	0.518	-1.987***	-0.454	0.221	-2.05**
Farming experience (yrs)	$Ze_3$	0.326	0.331	0.983	-0.087	0.202	-0.43
Household size (No)	$Ze_4$	-2.184	0.736	-2.967***	0.561	0.264	2.12**
Extension visits (No)	$Ze_5$	-8.324	5.014	-1.66*	2.977	-1.391	-2.14**
Membership of cooperative society	$Ze_6$	-7.889	4.967	-1.588	-6.871	2.140	-3.21***

\*\*\* P<0.01, \*\*P<0.05, \*P<0.10

#### 4.6 Log-likelihood Ratio Test of Hypotheses

The generalized log-likelihood ratio test is defined by the test statistic Chi-square ( $X^2$ ) and is specified as follows:

$$LR = -2[\ln(LH_0) - L(H_A)],$$

Where:  $L(H_0)$  and  $L(H_A)$  are the values of the likelihood functions under the null and the alternative hypotheses respectively.  $H_0$  is the null hypothesis.  $\square = 0$ . It is the value of the likelihood function for the frontier model and  $H_A$ , the alternative hypothesis that  $\square = 0$  for the general frontier model.

The result of the log-likelihood ratio test is presented in Table 4.22. The result showed that the critical values of both the production functions and the inefficiency models for the irrigated and rain-fed Irish potato farming were significant at one percent (1%) level of probability. This implied that the null hypotheses that: “the total variation of output of Irish potato from irrigated and rain-fed farming from the production frontier were zero” and “there were no

presence of technical, allocative and economic inefficiency effects in the models” were rejected. This finding is in line with the result obtained by Kolawole and Ojo (2007).

Table 4.22: Log-likelihood ratio test of hypotheses

<b>Null hypotheses</b>	<b>Ln (H<sub>0</sub>)</b>	<b><math>\lambda</math></b>	<b>*** Critical value</b>	<b>Decision</b>
<b>Production function model</b>				
H <sub>0</sub> : $\beta_0 = 0$ Irrigated	-155.76	0	41.13	Reject H <sub>0</sub>
H <sub>0</sub> : $\beta_0 = 0$ Rain-fed	-216.00	0.51	27.79	Reject H <sub>0</sub>
<b>Inefficiency Model</b>				
H <sub>0</sub> : $\lambda = 0$ Irrigated	-152.64	0.48	6.22	Reject H <sub>0</sub>
H <sub>0</sub> : $\lambda = 0$ Rain-fed	-214.26	0.10	3.93	Reject H <sub>0</sub>

\*\*\* P<0.01

#### **4.7 Constraints Experienced by Irish Potato Farmers in the Study Area and the Coping Strategies Adopted**

The Irish potato farmers had some constraints in the farming enterprises and these constraints are presented in Table 4.23. The constraints experienced for both the irrigated and rain-fed Irish potato farming were: pests and diseases; high cost of fertilizers; insecurity; high cost of Irish potato seeds; poor market prices; among others. The details are presented in Table 4.23.

The prominent constraints encountered by farmers who were into both irrigated and rain fed Irish potato farming were presented in Table 4.16 and include: pests and diseases, high cost of fertilizers; insecurity and reoccurrence of attacks by herdsmen; high cost of Irish potato seeds; poor market prices; among others. Problem of pests and diseases was reported by 13.52 percent and 19.49 percent of the irrigated and rain-fed Irish potato farmers respectively. The most pronounced pests and diseases that affected Irish potato farming enterprise in the area of study were Potato blight infestation; Potato moths; rodents’ attacks and rottenness due to poor storage facilities. The coping strategies adopted by the farmers included the use of pesticides, fungicides and other relevant drugs. Farmers that could not afford resources to purchase the

drugs resorted to the use of cultural practices, such as sorting and removal of diseased-potato seeds, as well as the potato seeds from the farm, to avoid further infestation of unaffected ones.

The inadequacy of fertilizer utilization by the farmers was as a result of high cost of the product. The high cost of fertilizer was the second most important constraint reported by irrigated (12.23 percent) and rain-fed (16.03 percent) Irish potato farmers in the study area. The cost of fertilizer was not only exorbitant, but the market was flooded with fake and adulterated fertilizer. Supplies by the Government were not forthcoming due to the bottlenecks associated with its distribution. Moreover, Government supplies usually arrived late. In order to mitigate these constraints, most farmers resorted to the use of organic manure, like ‘poultry droppings’, while others reduced the farm size devoted to Irish potato production. Some few farmers, however, resorted to the production of crops that do not require much use of fertilizer, such as Acha, tamba and doro.

The problem of insecurity due to rampant attacks by Fulani herdsmen was reported by 10.73 percent and 15.92 percent of irrigated and rain-fed Irish potato farmers in the area. This problem was remedied by ensuring that farmers went to their farmlands in groups. Others abandoned farmlands that were far from their residences and concentrated on those close to their homes. Limited water supply was experienced more in the dry season. This posed a major constraint to the irrigated Irish potato farmers. About 9.23 percent of the irrigated Irish potato farmers reported the problem. A lot of the farmers in this category dug wells, some excavated soil for water in shallow and dry rivers, and quite a number of the farmers

constructed mini dams. These measures were of tremendous help throughout the season of irrigation.

Poor market prices for Irish potato produce was another constraint reported by 8.58 percent and 9.17 percent of the irrigated and rain-fed Irish potato farmers in this study. The low prices, especially in the rain fed farming enterprise, forced the farmers to sell their products at the low prevailing market prices. More especially farmers that had no good storage facilities as to keep the ware potato in stock awaiting future rise in prices. Quite a number of the farmers sold their products in the farms. The planting materials (Potato seeds) were expensive. This posed another constraint which was reported by 8.58 percent and 7.52 percent of the irrigated and rain-fed Irish potato farmers in this study respectively. As a result of this problem, some of the farmers made use of the reserves which were kept for that purpose. Those who did not keep the seeds from previous harvest due to poor storage facilities had to reduce the size of the farmland for Irish potato cultivation. A few farmers that were better off financially, bought the seeds at the prevailing exorbitant market prices.

Poor and inadequate network of rural roads posed serious constraints for both the irrigated and rain-fed Irish potato farmers. This problem was reported by 7.94 percent and 7.13 percent of the irrigated and rain-fed Irish potato farmers respectively. Most of the rural road were seasonal and in most cases not motor- able, especially in raining season. Road networks are needed for easy transportation of inputs to and from the farms, and the farm produce to the markets. The farmers had little option, other than to manage the existing road networks in spite of their conditions. In most cases the existing bush paths were used.

A reoccurring constraints that affected both the irrigated and rain fed Irish potato farmers was poor storage facilities that are capable of accommodating both ware and other grades of the potato produced to take advantage of future rise in prices of the commodity, as well as reserve seeds for planting in the subsequent planting season. This constraint was reported by 6.44 percent and 6.88 percent of the irrigated and rain fed Irish potato farmers respectively. While so many farmers sold out their produce at the prevailing low market prices due to this constraint, some converted their well ventilated and spacious rooms for storage; and yet a few used chemicals to preserve the products to avoid rottenness due to lack of stores. High cost of labour was a common constraint for the set of Irish potato farmers under study. Over 6.01 percent and 6.37 percent of irrigated and rain fed Irish potato farmers respectively, reported this problem. The coping strategies of this problem were: resort to use of family labour more, which is less expensive; reduction in size of farmland for Irish potato cultivation and the hiring of tractor services.

Inadequate credit facilities which was reported by 5.79 percent and 6.37 percent of irrigated and rain-fed Irish potato farmers, respectively, were mitigated by resorting to personal savings and borrowing from friends and relatives. Bank loans were not contemplated due to stiff conditions usually associated with such. Finally, high cost of fuel, especially for the irrigated Irish potato farmers who operated water pumping machines was also a constraint. This constraint was reported by 6.66 percent and 5.10 percent of the irrigated and rain-fed Irish potato farmers respectively. The only remedy to this was the reduction of the frequency of usage of the fuel and the rate of pumping water for the irrigation. These constraints have acted as problems that have hindered the smooth Irish potato farming enterprise in the area under study.

Table 4.23: Distribution of Irish Potato Farmers on the basis of Constraints Experienced in the Study Area

<b>Constraints</b>	<b>IRPF</b>	<b>Rank</b>	<b>RFPF</b>	<b>Rank</b>
Pests of diseases	63(13.52)	1 <sup>st</sup>	153(19.49)	1 <sup>st</sup>
High cost of fertilizer	57(12.23)	2 <sup>nd</sup>	126(16.05)	2 <sup>nd</sup>
Insecurity	50(10.73)	3 <sup>rd</sup>	125(15.92)	3 <sup>rd</sup>
Limited water supply	43(9.23)	4 <sup>th</sup>	-	
Poor market prices	40(8.58)	5 <sup>th</sup>	72(9.17)	4 <sup>th</sup>
High cost of Potato seeds	40(8.58)	5 <sup>th</sup>	59(7.52)	5 <sup>th</sup>
Poor of inadequate rural roads network	37(7.94)	7 <sup>th</sup>	56(7.13)	6 <sup>th</sup>
Poor storage facilities	30(6.44)	9 <sup>th</sup>	54(6.88)	7 <sup>th</sup>
High cost of labour	28(6.01)	10 <sup>th</sup>	50(6.37)	8 <sup>th</sup>
Inadequate credit facilities	27(5.79)	11 <sup>th</sup>	50(6.37)	8 <sup>th</sup>
High cost of water pumping machine	20(4.29)	12 <sup>th</sup>	-	-
High cost of petroleum	31(6.66)	8 <sup>th</sup>	40(5.10)	10 <sup>th</sup>
<b>Total</b>	<b>466*(100)</b>		<b>785*(100)</b>	

\* Multiple Responses: Figures in parentheses are percentages

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSION, RECOMMENDATIONS AND CONTRIBUTION TO KNOWLEDGE**

#### **5.1 Summary**

The study examined the resource use efficiency of irrigated and rain-fed Irish potato farming in four local Government areas of Plateau State. The specific objectives were to: describe the socio-economic characteristics of the irrigated and rain-fed Irish potato farmers in the study area; determine the costs, returns and profitability levels of the irrigated and rainfed potato farmers; estimate the input and output relationship of the irrigated and rain-fed Irish potato farming; estimate the levels of technical, allocative and economic efficiencies of the irrigated and rain-fed Irish potato farmers; determine the effects of socio-economic characteristics on the level of technical efficiency of the irrigated and rain-fed potato farmers and finally to identify the farm specific constraints affecting the irrigated and rain-fed Irish potato farmers in the study area.

Primary data for the study were collected using a structured questionnaire administered to 103 and 198 irrigated and rain-fed Irish potato farmers respectively during the 2010/2011 potato farming seasons. Making a total sample size of 301 farmers altogether. Multi-stage sampling technique was employed in selecting the respondents. Data collected were analysed using a combination of analytical tools which include: Descriptive statistics, farm budget techniques (Net farm income analysis) and stochastic frontier models.

The major findings of the study indicated that: most of the Irish potato farmers were within the economically productive age bracket of 41 – 49 years. The study also revealed that the

Irish potato farming enterprises is dominated more by males than females. Eighty-four and a half (84%) percent and about eighty (80%) percent of the irrigated and rain-fed farmers respectively were males. With respect to education, the study revealed that the farmers of Irish potato were considered to be literate as 87 percent and 90 percent of the irrigated and rain-fed potato farmers respectively had one level of formal education or the other (Primary, Secondary and Tertiary).

The mean household sizes for the irrigated and rain-fed Irish potato farmers in the study area were 10 and 11 people respectively, indicating large household sizes. The research revealed that the Irish potato farmers had farm sizes of 1.90ha and 2.67ha on the average for irrigated and rain-fed Irish potato farmers. The study also revealed that the farmers had extension visits of two times on the average per farming seasons. Besides, the mean Irish potato farming experience observed in this study for both the irrigated and rain-fed potato farmers were 17 and 18 years respectively. Furthermore, the study revealed that 58 percent and 75 percent of the irrigated and rain-fed potato farmers respectively belong to one or more cooperative societies. This was expected to avail the farmers the opportunity to obtain inputs at subsidized rates.

Profitability analysis showed that Irish potato farming was profitable for the two groups of farmers respectively. The Net farm incomes were N214, 979.52 and N165, 547 per hectare respectively. The Returns per Naira invested on the Irish potato farming enterprise showed that a naira invested, returned N1.41 and N1.36 for the irrigated and rain-fed farmers respectively.

Maximum likelihood estimates for the parameters of the function model revealed that sigma-squared ( $\sigma^2$ ) for irrigated and rain-fed Irish potato production were 1.113 and 0.508 respectively and these values were significantly different from Zero at one percent (1%) level of significance. The generalized likelihood ratio statistics were 6.21 and 3.93 for irrigated and rain-fed potato farming enterprise respectively. These ratios exceeded the critical chi-square values at one percent level of significance for both irrigated and rain-fed Irish potato farming. The values of the gamma ( $\gamma$ ) statistics 0.483 and 0.102 for irrigated and rain-fed Irish potato respectively imply that 48.3 percent and 10.2 percent of the changes in the output of Irish potato under irrigated and rain-fed respectively are attributed to farmer's inefficiency factors. The results revealed that technical inefficiency effects were present in Irish potato production. Therefore, the hypothesis which states that the parameter estimate of gamma equals to zero is rejected.

The returns-to-scale estimates (1.808) for irrigated potato production obtained from the summation of the coefficients of the estimated input elasticities (in line of Cobb-Douglas stochastic frontier production function) indicated increasing returns to scale, implying that Irish potato production under irrigated system was in stage 1 of production process. On the other hand, the returns to scale for rain-fed Irish potato production was 0.157, indicating that resources used in the rain-fed potato production were inelastic. This implied that production under the rain-fed system was in stage 2 the stage of positive decreasing returns to scale.

The results of the cost function showed that the estimated parameter of sigma squared ( $\sigma^2$ ) were 2.694 and 1.091 for irrigated and rain-fed Irish potato production respectively and were statistically significant at one percent level of probability. The costs of farmland, seeds,

fertilizer, labour and chemical were all positive and significant at one percent level of probability for both irrigated and rain-fed Irish potato production in the study area. The study revealed also that the cost of water was positive and significant at 10 percent level of probability for irrigated Irish potato production.

In respect of the determinants of technical inefficiency of the Irish potato farming enterprise in the study area, the result revealed that the coefficients of age, education and households size, were negative and significant at one percent level of probability for both irrigated and rain-fed Irish potato farmers. Similarly, the coefficient for educational level for irrigated Irish potato farmers was negatively related to allocative inefficiency at one percent level of probability.

The socio-economic factors that had significant influence on economic inefficiency in the Irish potato farming enterprises were age, level of education, household size, extension contact and membership of cooperatives. The result revealed that the estimated parameters for education, age and cooperative participation were all negative for both irrigated and rain-fed Irish potato farmers at either one percent (1%), 5% or 10% levels of probability. While age and cooperative participation were negatively related to economic inefficiency, they were however significant at one percent level of probability for only rain-fed Irish potato farmers. The coefficients for extension visits were negative and statistically significant at 10 percent and 5 percent levels of probability for irrigated and rain-fed Irish potato farmers respectively. This means that economic inefficiency reduced with increase in extension contact. The coefficient for memberships of cooperative was negative and statistically significant at one percent level of probability for irrigated Irish potato farmers.

The major constraints faced by the Irish potato farmers included high cost of fertilizer; limited water supply (for the irrigated potato farmers); Poor market prices; high cost of potato seeds; poor and inadequate network of rural roads; poor storage facilities; high cost of labour and inadequate farm size.

## **5.2 Conclusion**

It is evident from the results of profitability analysis that Irish potato farming enterprise is a profitable venture, considering the rate of return on investment (return per Naira invested) of ₦1.41 and N1.36 for irrigated and rain-fed Irish potato farmers respectively. However, in spite of the profitability incentive of the Irish potato farming enterprise, the farmers were yet to operate on their production frontiers. The inability of the farmers to achieve their best in the efficiency of production has been due to the presence of technical, allocative and economic inefficiency effects. Besides, there were over twelve constraints identified in the study. This implies that there is room for improvement in the technical, allocative and economic efficiencies, if the significant factors associated with the inefficiencies are improved upon and the constraints mitigated appropriately.

## **5.3 Recommendations**

In order to improve on the Irish potato farming enterprise in Plateau, all hindrances that cause inefficiencies in resource-use in its production need to be removed so as to warrant the attainment of the optimal levels of technical, allocative and economic efficiency.

- i. One of the results of this study showed that the farmers of Irish potato were constrained by inadequate farm size (average of 1.90ha and 2.67 ha were recorded for irrigated and rain-fed farmers respectively) therefore, unable to expand the scope of their

production. Therefore government should put in place legal framework and concrete policy measures to ensure that farmers have easy access to land for cultivation.

ii. This research established that the over-utilization of Irish potato seeds by farmers was attributed to heavy reliance on the use of old stock from the previous harvest, most of which rotted due to poor storage as a result of inadequate storage facilities. In view of this a scale of production of new and improve varieties of Irish potato seeds should be expanded by the National Root Crops Research Institute (Irish Potato Research Programme, Kuru) and made available to farmers at subsidize rates.

iii. Moreover, it is further recommended that government (at the various level) should subsidize the cost of key Irish potato farming inputs, such as new improved seeds varieties, fertilizer and water pumping machines for those interested in irrigated potato farming enterprise.

iv. The many benefits derivable from being members of agricultural cooperative societies were identified in this research. Therefore, it is recommended that Irish potato farmers should form cooperative societies to enable them reap maximally from the advantages associated with membership, especially in the area of purchasing inputs in bulk and at wholesale rates (which are usually cheaper).

v. The role of extension officers in the transfer of modern farming technologies and relevant information cannot be over emphasized. It was established in this study that the number of extension visits by extension agents (an average of twice per farming season) was not adequate. It is therefore recommended that agricultural institutions, such as NRCRI, PADP,

Federal and State Ministries of Agriculture, as well as local government departments of agriculture should step-up and improve their extension services so as to train and educate farmers on the use and benefits of new and improved technologies, especially the use of “True Potato Seeds” (TPS).

vi. In this respect, the services of extension officers should be enhanced by motivating them through improve conditions of service, including better and higher remunerations, constant training, among other measures.

vii. Labour was identified as one of the important inputs in Irish potato farming enterprise, but unfortunately it was one of the expensive factors. Farmers should be encouraged to make more use of “communal labour” (referred to as ‘Gayya’ in Housa), in addition to family labour. Furthermore, the farmers could employ the services of tractors, which have the advantage of not only being cheaper, but can cultivate more hectares of farmland and in lesser time than labour services. Given the above, it is further recommended that government and other agricultural agencies should purchase and render tractor-hire services to the farmers at affordable rates.

viii. In order to enhance farmers efficiencies in crop production, government (especially at state and local government levels) should embark on massive provision of rural infrastructure, such as network of rural roads, electricity, market stalls and construction of mini-dams and bore-holes.

ix. The problem of persistent low prices of agricultural produce can be tackled by the establishment of agricultural commodity boards by government. The boards should be charged with the responsibility of stabilizing farmers' income and prices of farm produce. This will enable farmers to remain in the farming enterprise.

#### **5.4 Contributions to Knowledge**

1. The study revealed that Irish potato farming enterprise in the study area was profitable. The net farm income were ₦214,979.82 and ₦165,547.70 per hectare for irrigated and rain-fed Irish potato farming respectively, and the rate of return on investment (returns per naira invested were ₦1.41 and ₦1.36 for irrigated and rain-fed Irish potato farming respectively.

2. The study showed that technical inefficiency effects were present in the Irish potato farming enterprise. The findings revealed that 48.3 percent and 10.2 percent of the changes in the output of Irish potato under irrigated and rain-fed enterprises respectively, were attributed to farmers' inefficiency factors.

3. It was revealed that, while production of Irish potato under irrigated farming in the study area was in stage one – the stage of increasing returns to scale, the rain-fed Irish potato production was in stage two – the stage of decreasing returns to scale. The sum of the coefficients of the estimated inputs elasticities of the Cobb-Douglas stochastic frontier production function were 1.808 and 0.157 for irrigated and rain-fed Irish potato respectively.

4. The study showed that potato seeds were over-utilized, most likely due to impotency, as most of the seeds were from the old stock. The findings (-0.228 and -0.135 for irrigated and rain-fed Irish potato) obtained for seeds were negative and significant at one percent and five percent levels of probability respectively.

5. The Irish potato farmers experienced a lot of constraints which limited their level of productivity and efficiency. The study showed that some of the major constraints were: high cost of fertilizer (29 percent); insecurity; high cost of potato seeds (16 percent); poor storage facilities (13 percent); high cost of labour (12 percent); poor and inadequate network of rural roads (15 percent) for both irrigated and rain-fed farming enterprises.

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## APPENDIX I: QUESTIONNAIRE FOR RAIN-FED IRISH POTATO FARMERS

### SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

- 1 Name:\_\_\_\_\_ District:\_\_\_\_\_
- Village:\_\_\_\_\_ LGA:\_\_\_\_\_
- 2 Sex: Male [ ] Female [ ]
- 3 Marital Status: Single [ ] Married [ ]; Widow/widower [ ]
- 4 Age (years):\_\_\_\_\_
- 5 Educational level (a) Primary school [ ] (b) Secondary School [ ]  
Tertiary School Level: (a) OND/ND [ ] (b) HND [ ] (c) University degree [ ]
- 6 Family size (NO. Of people in the family, including dependents)  
(a) Number of wives\_\_\_\_\_ (b) No. Of children under 10 years \_\_\_\_\_  
(c) No. Of children above 10 years\_\_\_\_\_ (d) No. Of dependents\_\_\_\_\_
- 7 Total farm size (for all crops)\_\_\_\_\_
- 8 How long have you been farming Irish potato? (years)\_\_\_\_\_
- 9 Do you belong to any farm cooperative society? Yes [ ] No [ ]
- 10 If yes, how long have you been a member of the cooperative society?  
(years)\_\_\_\_\_
- 11 If no, why are you not a member?\_\_\_\_\_
- 12 Kindly indicate the sources of income (capital) for your Irish potato farming last Season?

	Source	Amount	Interest rate (%)
(a)	Own savings		
(b)	Borrowed from friends/ relations		
(c)	Borrowed from money lenders		
(d)	Borrowed from banks		
(e)	Others specify		

- 13 Are you engaged in any non-farm activities for which you earn income?  
Yes [ ] No [ ]
- 14 If yes, indicate the activities and the total amount earned in the last 12 months:

	Non-farming activity	Income in the year (₦)
(a)	Teaching	
(b)	Tailoring	
(c)	Barbing/hair-dressing	
(d)	Public services	
(e)	Skill trades (carpentry, masons etc	
(f)	Others specify	

- 15 Were you ever visited by an extension officer/agent from any of the organizations below for the purpose of advising you on how to improve your potato farming in the last farming seasons?

	Organization	Response
(a)	Local government Agriculture Department	
(b)	State Agricultural Ministry?	
(c)	Federal Agricultural Ministry?	
(d)	Plateau Agricultural Development Programme?	
(e)	National Root Crop Research Institute Vom?	
(f)	Agricultural Services of Training Company?	
(g)	Others specify	

Code: Yes = 1, No = 0

- 16 If you answer is yes to any of the above, how many times were you visited?

- (a) Less than once a month \_\_\_\_\_  
 (b) Between one to four times a month \_\_\_\_\_  
 (c) Between five to nine times a month \_\_\_\_\_

## SECTION B: FARM INPUT

- 1 What were the number of plots under Rain-fed irish potato cultivation last farming seasons? \_\_\_\_\_

- 2 What were the sizes of plots (hectares) under Rain-fed irish potato last farming Season?

- (a) Plot 1: \_\_\_\_\_  
 (b) Plot 2: \_\_\_\_\_  
 (c) Plot 3: \_\_\_\_\_

- 3 Kindly indicate the sources and cost of farmland allocated to Rain-fed Irish potato production in the last farming season:

Rain-Fed			
Plot	Source of Farm	Size (ha)	Current value (₦)
I	1		
	2		
	3		

II	1		
	2		
	3		
III	1		
	2		
	3		
	Total		

Code for source: 1 = Purchase 2 = rented 3 = Inherited

- 4 Indicate the quantity and cost of Irish potato seeds cultivated in the last farming period.

Plot	Unit measure used	Variety	No. Of unit measures used	Weight per unit measure (kg)	Cost per measure used (₹)
1					
2					
3					

Code for unit of measures: 1 = bag 2 = basket 3 = others

Code for variety: 1 = improved 2 = local

- 5 Indicate the type, quantity source and cost of fertilizer used in the Irish potato production in the last farming period

<b>RAIN-FED</b>					
Plot	Type	Source	Unit of Measure (No of bags)	No. Of unit of measure	Cost/Unit measure
I	1				
	2				
	3				
II	1				
	2				
	3				
III	1				
	2				
	3				
	Total				

Code for type: 1 = NPK 2 = Urea 3 = SSP

Code for unit of measure 1 = bag 2 = mudu 3 = kg

Code for source: 1 = Open market 2 = co-operative society 3 = government

- 6 Indicate the type, quantity and cost of agro-chemical applied on the Irish potato farm in the last farming season.

<b>RAIN-FED</b>				
Plot	Type	Unit of Measure	Quantity of measure	Rate/cost per unit (₦)
I	1			
	2			
	3			
II	1			
	2			
	3			
III	1			
	2			
	3			
	Total			

Code of type: 1 = Herbicide 2 = pesticide  
 Code of unit of measure 1 = Liters 2 = tin 3 = gallon

- 7 what was the mode of cultivating your potato farmland?  
 (a) Traditional simple implement [ ] (b) Tractor [ ] (c) Both [ ]

- 8 If you used tractor, kindly give the details below:

	Tractor operation	Plot 1		Plot 2		Plot 3	
		Farm size (ha)	Cost (₦)	Farm size (ha)	Cost (₦)	Farm size (ha)	Cost (₦)
(a)	Ploughing						
(b)	Harrowing						
(c)	Ridging						
	Other (specify)						
	Total						

- 9 If you used traditional simple implement, kindly give details below:

	Types of tool	Quantity (No.)	Year of purchase	Purchase price/unit	Residual value
(a)	Small hoes				
(b)	Big hoes				
(c)	Cutlasses				
(d)	Water pump (machine)				
(e)	Wheel barrow				
(f)	Empty hose				

(g)	Empty bags				
(h)	Baskets				
	Others (specify)				
(i)					
(j)					
(k)					
(l)					

10 Kindly indicate the number of people whose labour were utilized, number of days and cost per day in the last Irish potato farming season.

**PLOT 1**

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₦)	No. Of people	Days spent	Cost/day (₦)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						
(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

**PLOT 2**

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₦)	No. Of people	Days spent	Cost/day (₦)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						

(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

### PLOT 3

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₦)	No. Of people	Days spent	Cost/day (₦)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						
(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

11 What is time taken and amount spent in pumping water to irrigate your potato farm?

	Plot 1			Plot 2			Plot 3		
	Time (Hrs/day)	Number of days	Rate (₹)	Time (hrs/day)	Number of days	Rate (₹)	Time (hrs/day)	Number of days	Rate (₹)
(a)									
(b)									
(c)									
(d)									
(e)									
(f)									
	Total								

### SECTION C: OUTPUT OF POTATO

1 Kindly indicate the quantity of Irish potatoes harvested from the different plots cultivated in the farming season.

RAIN-FED				
Plot	Description of unit	No. Of units (quantity)	Weight per unit (kg)	Price per unit (₹)
I				
II				
III				
	Total			

Code: 1 = Pick-up load    2 = Bags    3 = Baskets

2 What was the quantity of Irish potato consumed at home in the last farming season? (bags or baskets) \_\_\_\_\_

3 What was the quantity of Irish potato given out as gifts in the last farming period? (bags or baskets) \_\_\_\_\_

4 Indicate the quantity and value of Irish potatoes sold in the last farming period

Rain-Fed		
Description of unit	No. Of Units (quantity)	Price per unit (₹)
1		
2		
3		
1		
2		
3		
1		
2		
3		
Total		

Code for description of unit: 1 = Pick-up load    2 = Bags    3 = Baskets

## SECTION D: CONSTRAINTS, COPING STRATEGIES AND SUGGESTIONS

- 1 What were the problems encountered and the coping strategies adopted in the Irish potato farming enterprise in the last farming season?

	Constraints	Coping strategies
(a)		
(b)		
(c)		
(d)		
(e)		
(f)		
(g)		
(h)		
(i)		
(j)		

- 2 Kindly suggest ways of improving Irish potato farming.

- (a) \_\_\_\_\_
- (b) \_\_\_\_\_
- (c) \_\_\_\_\_
- (d) \_\_\_\_\_
- (e) \_\_\_\_\_
- (f) \_\_\_\_\_
- (g) \_\_\_\_\_
- (h) \_\_\_\_\_
- (i) \_\_\_\_\_
- (j) \_\_\_\_\_

Thank you very much

## APPENDIX II: QUESTIONNAIRE FOR IRRIGATED IRISH POTATO FARMERS

### SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1 Name: \_\_\_\_\_ District: \_\_\_\_\_

Village: \_\_\_\_\_ LGA: \_\_\_\_\_

2 Sex: Male [ ] Female [ ]

3 Marital Status: Single [ ] Married [ ]; Widow/widower [ ]

4 Age (years): \_\_\_\_\_

5 Educational level (a) Primary school [ ] (b) Secondary School [ ]  
Tertiary School Level: (a) OND/ND [ ] (b) HND [ ] (c) University degree [ ]

6 Family size (NO. Of people in the family, including dependents)  
(a) Number of wives \_\_\_\_\_ (b) No. Of children under 10 years \_\_\_\_\_  
(c) No. Of children above 10 years \_\_\_\_\_ (d) No. Of dependents \_\_\_\_\_

7 Total farm size (for all crops) \_\_\_\_\_

8 How long have you been farming Irish potato? (years) \_\_\_\_\_

9 Do you belong to any farm cooperative society? Yes [ ] No [ ]

10 If yes, how long have you been a member of the cooperative society?  
(years) \_\_\_\_\_

11 If no, why are you not a member? \_\_\_\_\_

12 Kindly indicate the sources of income (capital) for your Irish potato farming last Season?

	Source	Amount	Interest rate (%)
(a)	Own savings		
(b)	Borrowed from friends/ relations		
(c)	Borrowed from money lenders		
(d)	Borrowed from banks		
(e)	Others specify		

13 Are you engaged in any non-farm activities for which you earn income?  
Yes [ ] No [ ]

14 If yes, indicate the activities and the total amount earned in the last 12 months:

	Non-farming activity	Income in the year (₦)
(a)	Teaching	
(b)	Tailoring	
(c)	Barbing/hair-dressing	
(d)	Public services	
(e)	Skill trades (carpentry, masons etc	
(f)	Others specify	

15 Were you ever visited by an extension officer/agent from any of the organizations below for the purpose of advising you on how to improve your potato farming in the last farming seasons?

	Organization	Response
(a)	Local government Agriculture Department	
(b)	State Agricultural Ministry?	
(c)	Federal Agricultural Ministry?	
(d)	Plateau Agricultural Development Programme?	
(e)	National Root Crop Research Institute Vom?	
(f)	Agricultural Services of Training Company?	
(g)	Others specify	

Code: Yes = 1, No = 0

16 If your answer is yes to any of the above, how many times were you visited?

Less than once a month \_\_\_\_\_

Between one to four times a month \_\_\_\_\_

Between five to nine times a month \_\_\_\_\_

## SECTION B: FARM INPUT

1 What were the number of plots under irrigated Irish potato cultivation last farming seasons? \_\_\_\_\_

\_\_\_\_\_

2 What were the sizes of plots (hectares) under irrigated Irish potato last farming? Season?

Plot 1: \_\_\_\_\_

Plot 2: \_\_\_\_\_

Plot 3: \_\_\_\_\_

3 Kindly indicate the sources and cost of farmland allocated to irrigate Irish potato production in the last farming season:

<b>IRRIGATED</b>			
Plot	Source of Farm	Size (ha)	Current value (₦)
I	1		
	2		
	3		
II	1		
	2		
	3		
III	1		
	2		
	3		
	Total		

Code for source: 1 = Purchase 2 = rented 3 = Inherited

4 Indicate the quantity and cost of Irish potato seeds cultivated in the last farming period.

Plot	Variety	No. Of unit measures used	Weight per unit measure (kg)	Cost per measure used (₦)
1				
2				
3				

Code for unit of measures: 1 = bag 2 = basket 3 = others

Code for variety: 1 = improved 2 = local

5 Indicate the type, quantity and cost of fertilizer used in the Irish potato production in the last farming period

<b>IRRIGATED</b>				
Plot	Type	Source	No. Of Unit Measure	Cost/Unit measure
I	1			
	2			
	3			
II	1			
	2			
	3			
III	1			
	2			
	3			
	Total			

Code for type: 1 = NPK 2 = Urea 3 = SSP

Code for unit of measure 1 = bag 2 = mudu 3 = kg

Code for source: 1 = Open market 2 = co-operative society 3 = government

6 Indicate the type, quantity and cost of agro-chemical applied on the Irish potato farm in the last farming season.

<b>RAIN-FED</b>					
Plot	Type	Unit of Measure	Quantity of measure	Rate per unit (₦)	Cost/unit measure (₦)
I	1				
	2				
	3				
II	1				
	2				
	3				
III	1				
	2				
	3				
	Total				

Code of type: 1 = Herbicide 2 = pesticide  
 Code of unit of measure 1 = Liters 2 = tin 3 = gallon

7 What was the mode of cultivating your potato farmland?  
 (a) Traditional simple implement [ ] (b) Tractor [ ] (c) Both [ ]

8 If you used tractor, kindly give the details below:

	Tractor operation	Plot 1		Plot 2		Plot 3	
		Farm size (ha)	Cost (₦)	Farm size (ha)	Cost (₦)	Farm size (ha)	Cost (₦)
(a)	Ploughing						
(b)	Harrowing						
(c)	Ridging						
	Other (specify)						
	Total						

9 If you used traditional simple implement, kindly give details below:

	Types of tool	Quantity (No.)	Year of purchase	Purchase price/unit	Residual value
(a)	Small hoes				
(b)	Big hoes				
(c)	Cutlasses				
(d)	Water pump (machine)				
(e)	Wheel				

	barrow				
(f)	Empty hose				
(g)	Empty bags				
(h)	Baskets				
	Others (specify)				
(i)					
(j)					
(k)					
(l)					

10 Kindly indicate the number of people whose labour were utilized, number of days and cost per day in the last Irish potato farming season.

**PLOT 1**

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₦)	No. Of people	Days spent	Cost/day (₦)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						
(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

**PLOT 2**

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₱)	No. Of people	Days spent	Cost/day (₱)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						
(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

**PLOT 3**

	Operation	Hired labour			Family labour		
		No. Of people	Days spent	Cost/day (₱)	No. Of people	Days spent	Cost/day (₱)
(a)	Land clearing						
(b)	Ridging						
(c)	Planting						
(d)	1 <sup>st</sup> weeding						
(e)	2 <sup>nd</sup> weeding						
(f)	Fertilizing						
(g)	Earthing						
(h)	Herbicide application						
(i)	Water irrigation						
(j)	Harvesting						
(k)	Transporting						
(l)	Sorting and grading						
	Others (specify)						
(m)							
(n)							

11 What is time taken and amount spent in pumping water to irrigate your potato farm?

	Plot 1			Plot 2			Plot 3		
	Time (Hrs/day)	Number of days	Rate (₱)	Time (hrs/day)	Number of days	Rate (₱)	Time (hrs/day)	Number of days	Rate (₱)
(a)									
(b)									
(c)									
(d)									
(e)									
(f)									
	Total								

### SECTION C: OUTPUT OF POTATO

1 Kindly indicate the quantity of Irish potatoes harvested from the different plots cultivated in the farming season.

<b>IRRIGATED</b>				
Plot	Description of unit	No. Of units (quantity)	Weight per unit (kg)	Price per unit (₱)
I				
II				
III				
	Total			

Code: 1 = Pick-up load    2 = Bags    3 = Baskets

2 What was the quantity of Irish potato consumed at home in the last farming season? (bags or baskets) \_\_\_\_\_

3 What was the quantity of Irish potato given out as gifts in the last farming period? (bags or baskets) \_\_\_\_\_

4 Indicate the quantity and value of Irish potatoes sold in the last farming period

<b>IRRIGATED</b>		
Description of unit	No. Of Units (quantity)	Price per unit (₱)
1		
2		
3		
Total		

Code for description of unit: 1 = Pick-up load    2 = Bags    3 = Baskets

## SECTION D: CONSTRAINTS, COPING STRATEGIES AND SUGGESTIONS

1 What were the problems encountered and the coping strategies adopted in the Irish potato farming enterprise in the last farming season?

	Constraints	Coping strategies
(a)		
(b)		
(c)		
(d)		
(e)		
(f)		
(g)		
(h)		
(i)		
(j)		

2 Kindly suggest ways of improving Irish potato farming.

- (a) \_\_\_\_\_
- (b) \_\_\_\_\_
- (c) \_\_\_\_\_
- (d) \_\_\_\_\_
- (e) \_\_\_\_\_
- (f) \_\_\_\_\_
- (g) \_\_\_\_\_
- (h) \_\_\_\_\_
- (i) \_\_\_\_\_
- (j) \_\_\_\_\_

Thank you very much.

**APPENDIX III: ANALYSIS OF RAIN-FED IRISH POTATO FARMING**

```

_____ (R)
/___ / ___/ / ___/
___ / / ___/ / /___/ 11.1 Copyright 2009 StataCorp LP
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Notes:

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1. (/m# option or -set memory-) 10.00 MB allocated to data
. *(8 variables, 198 observations pasted into data editor)
. regress tinf z1 z2 z3 z4 z5 z6

```

Source	SS	df	MS	Number of obs =	194
Model	13413.2662	6	2235.54437	F( 6, 187) =	1411.19
Residual	296.236714	187	1.58415355	Prob > F =	0.0000
				R-squared =	0.9784
				Adj R-squared =	0.9777
Total	13709.5029	193	71.0336939	Root MSE =	1.2586

tinf	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
z1	-1.762292	.2257176	-7.81	0.000	-2.207572	-1.317012
z2	-7.798881	.1862236	-41.88	0.000	-8.16625	-7.431512
z3	-.4359098	.0095861	-45.47	0.000	-.4548206	-.416999
z4	-1.082276	.0230778	-46.90	0.000	-1.127803	-1.03675
z5	-.7683795	.0192431	-39.93	0.000	-.8063408	-.7304181
z6	-.1485487	.0177931	-8.35	0.000	-.1836497	-.1134477
_cons	136.1047	.5927718	229.61	0.000	134.9353	137.2741

Economic inefficiency

```

_____ (R)
/___ / ___/ / ___/
___ / / ___/ / /___/ 11.1 Copyright 2009 StataCorp LP
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. drop \_all  
. \*(8 variables, 55 observations pasted into data editor)  
. drop \_all  
. \*(8 variables, 198 observations pasted into data editor)  
. regress eeineff z1 z2 z3 z4 z5 z6

Source		SS	df	MS	Number of obs =	194
-----+-----					F( 6, 187) =	5.78
Model		7254.3438	6	1209.0573	Prob > F =	0.0000
Residual		39128.5609	187	209.243641	R-squared =	0.1564
-----+-----					Adj R-squared =	0.1293
Total		46382.9047	193	240.325931	Root MSE =	14.465

-----						
eeineff		Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
-----						
z1		2.977516	2.594137	1.15	0.253	-2.140019 8.095052
z2		-6.871421	2.140238	-3.21	0.002	2.649307 11.09354
z3		-.3310912	.1101716	-3.01	0.003	.1137522 .5484301
z4		.5613345	.26523	2.12	0.036	.038107 1.084562
z5		-.4544411	.2211574	-2.05	0.041	.018157 .8907251
z6		-.0875885	.2044933	-0.43	0.669	-.4909987 .3158217
_cons		-1.918616	6.812633	-0.28	0.779	-15.35811 11.52088

## APPENDIX IV: ANALYSIS OF IRRIGATED IRISH POTATO FARMING

\_\_\_\_\_ (R)  
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1. (/m# option or -set memory-) 10.00 MB allocated to data  
 . \*(7 variables, 103 observations pasted into data editor)  
 . regress y2 z1 z2 z3 z4 z5 z6

Source	SS	df	MS	Number of obs =	103
-----+-----				F( 6, 96) =	1007.49
Model	41108.8259	6	6851.47099	Prob > F	= 0.0000
Residual	652.85301	96	6.80055219	R-squared	= 0.9844
-----+-----				Adj R-squared =	0.9834
Total	41761.6789	102	409.428225	Root MSE	= 2.6078

y2	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
-----+-----						
Educ	-.2985163	.0566759	-5.27	0.000	-.411017	-.1860156
HHsize	-.2856879	.0826963	-3.45	0.001	-.4498388	-.121537
Age	1.495593	.0235768	63.43	0.000	1.448794	1.542393
Exp	.3821666	.0350397	10.91	0.000	.3126132	.4517199
Ext	-8.910541	.533926	-16.69	0.000	-9.970376	-7.850706
Coop	3.090138	.5376403	5.75	0.000	2.022931	4.157346
cons	-25.70188	1.156824	-22.22	0.000	-27.99816	-23.4056
-----+-----						