SOURCES OF TECHNICAL EFFICIENCY OF THE SMALLHOLDER MAIZE FARMERS AT ETUNDA IRRIGATION PROJECT IN OMUSATI REGION, NAMIBIA

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MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS

In the

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DECLARATION

I, Matheus Nangolo Ndjodhi, hereby declare that this dissertation submitted by me for the degree of Master of Science (M.Sc. Agric) in Agricultural Economics, at the University of the Free State, is my own independent work and has not previously been submitted by me to any other university. I further cede copyright of the dissertation in favour of the University of the Free State.

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Matheus Ndjodhi Date

Bloemfontein

January 2016

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"Though the mountains be shaken and the hills be removed, yet my unfailing love for you will not be shaken nor my covenant of peace be removed," says the LORD, who has compassion on you".

Isaiah 54:10

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ABSTRACT

In an effort to increase food production and improve food security in the country, government of the Republic of Namibia established green scheme projects in various parts of the country. This Endeavour aims to achieve increased food production where comparative advantages exist. Strengthening of agricultural productivity through increased production is critical in eradication of poverty, increased food security and betterment of the livelihoods of the smallholder farmers in the rural areas. Maize is one of the staple food crops in the country and is predominantly produced by smallholder farmers, both under irrigation and rain-fed conditions.

Low productivity in agriculture particularly in the crop sector has been observed over time. This has raised a concern about food insecurity among communities whose livelihoods are heavily dependent on agriculture. Therefore, increasing the technical efficiency levels of the farmers through enhancing support services, as well as facilitating easy access to basic inputs, would be among the best appropriate approaches to achieving increased productivity. There is no information currently available about the sources of technical efficiency of the smallholder maize farmers in Namibia; hence the need for this study.

This study sought to explore the potentials for improving production efficiencies among the smallholder maize farmers at the Etunda Irrigation Scheme in Omusati region of Namibia. The primary objectives of the study were to quantify the levels of technical efficiencies and to identify factors affecting the technical efficiency levels of smallholder maize farmers in the study area, using the Data Envelopment Analysis (DEA) double bootstrap approach in a Principal Component (PC) regression. Primary data was used to produce the estimates and determinants of technical efficiency. Since the population of the smallholder farmers at Etunda Irrigation Project is small, all the farmers were interviewed using a structured questionnaire.

The empirical results revealed that the technical efficiency of smallholder maize farmers is relatively high with an average score of 72 %. However, the efficiency levels vary and range between 36 % and 100 %. This suggests that, high levels of production inefficiency exist among farmers and there is a potential for the inefficient farmers to increase the efficiencies by 32 % when utilizing the existing resources better. The factors that were found to contribute positively to the high levels of technical efficiency included age of the farmers, plot size, livestock manure, planting in summer, market access and training. The study recommended policy interventions to promote farmer- to- farmer skills transfer, improve extension services, increase farming plots, and encourage the use of livestock manure and regular training for the farmers.

Keywords: Productivity, Technical efficiency, Smallholder Farmers, Data Envelopment Analysis, Double Bootstrap Approach.

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NPC	National Planning Commission
GDP	Gross Domestic Product
NSA	Namibia Statistics Agency
MAWRD	Ministry of Agriculture, Water and Rural Development
NAP	National Agricultural Policy
NDPs	National Development Plans
DCPP	Dry land Crop Production Program
MAWF	Ministry of Agriculture, Water and Forestry
NAB	Namibian Agronomic Board
SACU	Southern Africa Custom Union
FAO	Food and Agriculture Organisation
DEA	Data Envelopment Analysis
PCR	Principal Component Regression
SADC	Southern Africa Development Community
OPV	Open Pollinated Variety
TE	Technical Efficiency
AE	Allocative Efficiency
EE	Economic Efficiency
TPP	Total Physical Product
MPP	Marginal Physical Product
SFA	Stochastic Frontier Analysis
OLS	Ordinary Least Squares
AGRIBANK	Agricultural Bank
NCSS	National Council of Statistics Software
N	Nitrogen
P	Phosphorus

K	Potassium
CDF	Cumulative Probability Distribution Function

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

Maize is the most produced grain in the world and staple food to many people, particularly in the sub-Saharan Africa. Maize is used directly or indirectly as food, livestock feeds and raw materials for industrial purpose and is an essential commodity in the global food market. It is a great source of carbohydrates, protein, iron, vitamins and minerals, as well as being used for ethanol (Business Insider, 2011). More than half of global maize production is concentrated in the United States of America and China (AMIS, 2014). About 6.5% of the global maize production is produced in Africa, with Nigeria being the biggest producer, followed by South Africa (IITA, 2012).

The production of maize in Africa is diverse and it varies from subsistence to commercial farming systems. Subsistence farming system is mainly small scale production intended for owner's consumption and sometimes for selling surplus. The subsistence farming system is characterised by low productivity attributable to not using modern technology, low levels of education and poor access to finance. A commercial farming system, on the other hand, constitutes large-scale production destined for the market and is branded by high levels of farm mechanisation, high productivity and access to finance to fund the production. Maize is grown widely all over the world in a range of various agro-ecological environments. There are about 50 varieties, in which the grains vary in colours, texture, shapes and sizes (IITA, 2012). White, yellow and red maize varieties are the most common types cultivated. As a member of *gramineae* or grass family to which all major cereals belong, maize (*Zeamays*) is believed to have originated from North America. Maize is said to have spread gradually throughout the world from its centre of origin in Mexico and Central America. According to IITA (2012) maize production has spread to Latin America, the Caribbean, the United States and Canada, and was later distributed by European seamen to Europe, Africa and Asia. Since it was introduced in Africa in the 1500 century, maize became one of Africa's major food crops. Given its ability to adapt to various climatic conditions with the highest grain yield potential, maize is currently the world's most commonly grown cereal (Butler & Huybers, 2000).

Namibian agriculture plays a crucial role in the economy and the livelihoods of the majority of the citizens. According to the National Planning Commission (NPC, 2011) more than 70 % of the Namibian population is heavily dependent on agriculture for their livelihood. The Namibia Statistics Agency (NSA, 2012) reported that the agricultural sector's direct contribution to the total Gross Domestic Product (GDP) is estimated at 7.4% which is relatively low compared with other sectors of the economy. The relatively poor performance of the agricultural sector is predominantly attributable to climate variability of arid to semi-arid conditions with an annual rainfall range between 50 – 600 mm per annum (NSA, 2013). The scarcity of agricultural land and delicate soils, together with scarce water resources and erratic rainfall condition are the principal features of Namibia's agriculture (MAWRD, 1995). Despite the challenges confronting the agricultural sector and its relatively small contribution to the national economy its overall importance remains crucial in the context of food production, employment creation and foreign exchange earnings.

Immediately after Namibia's independence in 1990, the advancement of the agricultural sector was hampered by the lack of an explicit and sound National Agricultural Policy (NAP) framework (MAWRD, 1995). Since then, developmental activities have been steered by a transitional Development Plan which endeavors to sustain national economic stability and growth by minimizing disruptive changes. Within a time space of five years after Namibia's independence, government developed the NAP to guide the development and advancements of the agricultural sector with the policy being launched in October 1995. The principal goal of the NAP is to increase and maintain the desired levels of agricultural productivity, real farm incomes, and national and household food security to the extent possible and within the context of Namibia's fragile ecosystem (MAWRD, 1995). The policy further addresses issues which resulted from colonial administration by creating an enabling environment for increased food production, with a particular emphasis on smallholder producers who comprise the majority of farmers in Namibia. NAP also sought to continue to support and strengthen the commercial farming sector which contributes significantly to the country's agricultural exports, national food security and employment creation for a considerable number of the Namibian population. By so doing, NAP will serve as a mechanism of convalescing employment opportunities, incomes, household food security and the nutritional status of all Namibians

(MAWRD, 1995). As part of agrarian reforms, the Namibian government has put in place several initiatives and programmes to supplement the National Development Programmes (NDPs). These initiatives and programmes aimed at among other things, uplifting the livelihood of the previously marginalised farmers so that both large and small-scale farmers can compete, locally and on international markets. Some of these initiatives are the Green Scheme Policy, National Horticulture Development Initiatives and the Dry land Crop Production Programme (DCPP) (MAWF, 2012).

Notwithstanding government efforts to increase agricultural production, Namibia remains a net importer of maize to meet its domestic requirements and import approximately 60% of its national maize requirement (NAB, 2012). Namibia also has a very fast growing feed industry, for which the large source of raw materials is maize and maize milling residuals. According to Hoffmann (2012), most maize milled in Namibia comes from South Africa and some from other Member States of Southern Africa Custom Union (SACU), which is an advantage where no trade barriers exist within the custom union.

Despite the fact that Namibia is known as one of the driest countries in Africa, maize production remains a priority in the country (MAWF, 2012). Four major cereals are produced in Namibia, which are pearl millet (mahangu), white maize, wheat and sorghum. Most of these crops are grown under rain fed condition particularly by the smallholder farmers. The crop farming system is encountered in both commercial and communal areas. Crop production in the commercial areas is aimed for market, while production in the communal areas is mainly for household consumption. Maize is produced in both communal (under rain-fed conditions) and commercial (irrigation and rain-fed conditions) areas. The major communal crop producing regions are found in the northern part of Namibia and include: Zambezi, Kavango East, Kavango West, Omusati, Ohangwena, Oshana and Oshikoto regions.

Increasing demand for food as a result of the rising population and low level of agricultural productivity has been a major cause for concern in sub-Sahara Africa and not only in Namibia. These challenges have worsened the food security situation by widening the gap between demand and supply of food (Geta *et al*. 2011). Sienso (2013) has, argued that the presence of these shortfalls in efficiency suggests that output could be increased without increasing production inputs and by using the existing technology set. For this concept to hold there is a need to ascertain empirical measures of efficiency in order to determine the extent of the gain that could be obtained by improving productivity and efficiency of smallholder maize producers within the scope of existing technology (Sienso, 2013).

Therefore, in order to improve production efficiency of smallholder maize irrigation producers, farmers need to be taught how to use their production inputs efficiently. Geta *et al*. (2011) advised that there is a need to understand the relationships between productivity, efficient use of the production inputs, policy indicators and farm-specific practices. These features provide important information to policy makers which are needed for the design of programmes and policies aimed at increasing the crop productivity of smallholder producers.

1.2 PROBLEM STATEMENT

Despite the various government efforts to improve food security in the country, food insecurity remains a challenge in Namibia. This is because of low and stagnating agricultural productivity, particularly in the crop sector where major crops such as maize is predominantly produced by small-scale farmers, usually under the rain-fed conditions. For example maize yields fluctuated between 1100 kg / ha in 2004 and 1400 kg /ha in 2013, with no clear upward trend (FAOSTAT, 2013). Similar trends and fluctuations were also observed in total maize production, with a minimum total production of 28 200 metric tons recorded in 2004 and a maximum of 40 000 metric tons in 2013 (FAOSTAT, 2013). Musaba and Bwacha (2014) argued that the wider fluctuations in maize yields and total production suggest persistent food insecurity over time, especially in the years of low production.

Many researchers have attributed various factors to low maize productivity and production among smallholder farmers. These included human capital, income level, lack of access to credit and poor extension services. This has increased pressure on farmers to use their inputs more efficiently in order to maximise outputs with available resources and inputs to produce optimally at minimum cost. Mulinga (2013) observed that increased productivity is directly linked to production efficiency. It is therefore imperative to raise productivity of the farmers by reducing their technical inefficiencies. In order to achieve this, there is a need for a study to determine and investigate factors responsible for variations in productivity and technical efficiency, as well as to examine the levels of access to basic inputs and finance among the smallholder farmers. The results from the study may have implications for farm management and policy formulations, which is important in providing guidelines on the efficient use of resources (Musaba & Bwacha, 2014).

This topic on technical efficiency among the smallholder maize farmers has received much attention by researchers internationally. For example Chirwa (2007) in his study found out that many smallholder maize farmers are technically inefficient, with a mean score of 46.23 % and some scoring as low as 8.12 %. The author further indicated that, the use of hybrid seeds, club membership, bigger plot size and regular extension contacts are some of the variables found to contribute to high levels of technical efficiencies of the farmers in the study area. Oyewo (2011) did a study on technical efficiency of maize production in Oyo State in Nigeria. The study found that farm size and seed quality were statistically significant at 10 % and 1 % respectively. This study therefore concluded that, with the current level of input used and existing technology set, more land could still be available for maize production in the area and more quality seeds should be provided to farmers.

Gunda (2013) carried out a study on the productivity of smallholder maize farmers at Towkane–Ngundu Irrigation Scheme in Masvingo District in Zimbabwe, using the Data Envelope Analysis (DEA) Double Bootstrap Approach in a Principle Component Regression framework. The findings of this study indicated that, the mean technical efficiency score of the farmers in question was relatively high, at 77 %. The study noted that high technical efficiency is associated with increased formal education, farming experience, household size, English proficiency, arithmetic abilities, extension visit and compliance with best management practices. The study suggested that there is a need for policy interventions in terms of incentive schemes to promote farmer-to-farmer skills transfer to uplift the technical efficiency levels of inefficient farmers. Dlamini (2012) investigated the technical efficiency of maize production in Swaziland, using a Stochastic Frontier approach. The findings of this study were that, technical efficiency was found to be positively related with farmer's age, having off-farm income, farmer's experience, intercropping and the use of hybrid seeds. The study recommended that farmers need support in terms of input subsidies so that they can use more inputs to improve their technical efficiency.

No study was found within Namibia on sources of technical efficiency of small-scale maize farmers, hence there is no information available to guide the efforts to reduce technical inefficiency of small-scale maize farmers. Thus, this study provides information on the sources of technical efficiency of the smallholder maize farmers at Etunda Irrigation Project in Omusati region in the northern Namibia.

1.3 RESEARCH OBJECTIVES

The main objective of this study is to explore factors that influence the production efficiency of smallholder maize farmers at Etunda Irrigation Project in the Omusati region. The main objective of this study will be achieved through the completion of the following sub-objectives.

- The first sub-objective is to quantify the levels of technical efficiency among smallholder farmers in the study area in order to get an understanding of the levels of efficiency with which these farmers use their production inputs. Data Envelopment Analysis (DEA) will be used to compute the technical efficiency scores because of its flexibility and applicability to varieties of production settings that include agriculture (Gunda, 2013)
- The second sub-objective is to explore factors which are hypothesised to affect technical efficiency among the smallholder maize farmers in the study area. This will be achieved by following Gunda (2013) and Jordaan (2012), who used the double bootstrap approach of Simar and Wilson (2007). The approach will be applied within the Principal Component Regression (PCR) framework to ensure the reliability of information generated about the farmers in the study area. This will enable a better understanding on the determinants of production efficiency and such information could be used to inform decisions on how these farmers can be assisted to increase their production efficiency.

1.4 CHAPTER OUTLINE

This thesis is organised into five Chapters: Chapter 1 (Introduction) as already covered, Chapter 2 (literature review), Chapter 3 (data and procedure), Chapter 4 (results and discussions) and Chapter 5 (summary, conclusion and recommendations). Chapter 2 provides a review of relevant literature on the technical efficiency of the smallholder farmers. Specifically, the chapter covers the relevant subtopics of maize production with reference to the global maize market, maize production in Africa, maize production and usage in southern Africa, and Namibian agriculture and maize production as well as smallholder maize farmers in Namibia. Additionally, the chapter encompasses complementary topics such as production efficiency, methods used to assess efficiency, and factors which are hypothesised to affect technical efficiency. Chapter 3 provides details of geographic information of the study area, the method used in data collection, the questionnaire design, field work procedures, and characteristics of the respondents, as well as the model used to analyse data. Lastly, the results and discussions are presented in Chapter 4, followed by a summary, conclusions and recommendations in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to present a review of relevant literature on the technical efficiency of small-scale maize farmers. The chapter begins by providing information on the global maize production market, the African perspective, the southern Africa context, and the Namibian situation. This chapter further discusses the factors affecting technical efficiency among smallholder farmers. Accordingly, this chapter is aimed at enhancing the understanding of factors that influence maize productivity and how these factors impact on the levels of technical efficiencies among the smallholder farmers in the study area.

2.2 GLOBAL MAIZE MARKET

Throughout the world, the diet of the majority of people, particularly in developing countries is based on the consumption of cereals, usually maize, pearl millet, sorghum or rice. Maize is the most widely distributed crop and is cultivated in tropic, sub-tropic and temperate regions. Maize is also grown in semi-arid areas, especially under irrigation. According to Corn India (2009), maize production ranks third in the world, following wheat and rice. Worldwide, maize production is estimated at about 980 million metric tons (International Grain Council, 2014). Figure 2.1 below shows the major maize producing countries in the world. According to the graph, the top five major maize producing countries are the United States of America, topping the list and contributing 37 %, followed by China with 28 %, Brazil with 10 %, and Argentina and India, each contributing 3 % to the world total maize production (FAO, 2014). In terms of production in monetary values, the trend is similar to the quantity, again the United States of America topping the list with over $22 billion, followed by China with $10 billion, and Brazil, Argentina and India, each valued less than $3 billion (FAO, 2014).

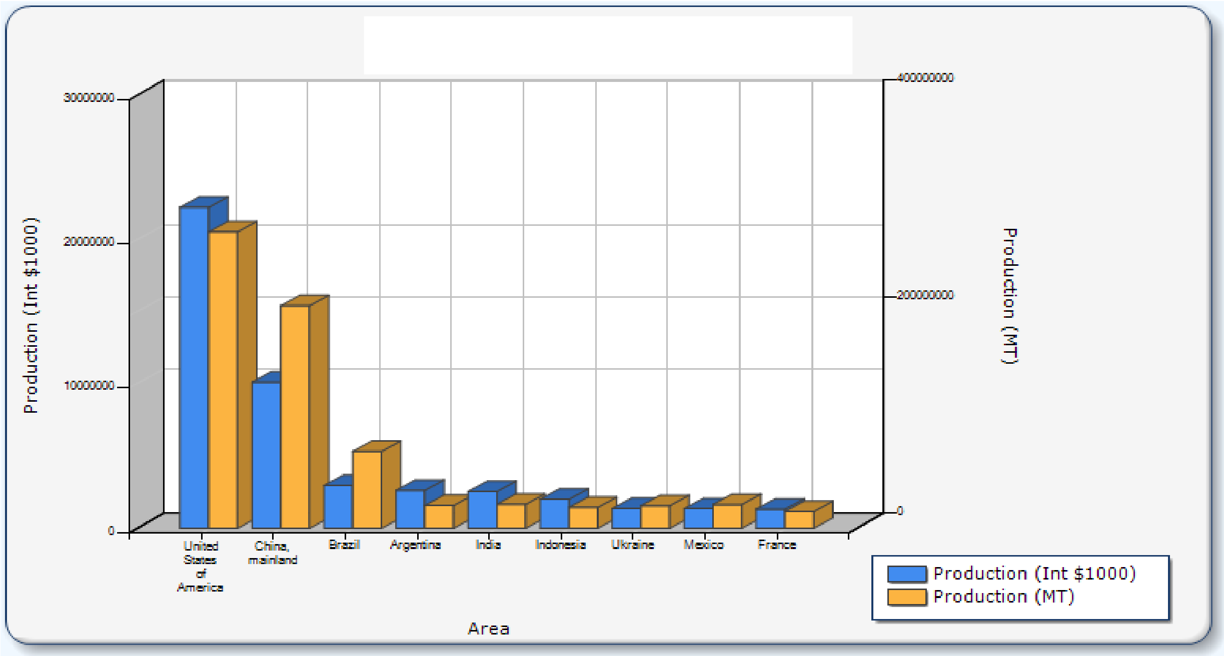

Figure 2.1: Top major maize producing countries in the world

Source: FAOSTAT

According to FAO (2014), over 90 % of the world's white maize total is produced in the developing countries where it accounts for around one quarter of total maize output and just fewer than 40 percent of the total maize area. Argentina, Brazil and China account for over 60 % of total maize output in the developing world, of which 45 % of this total is produced in China alone (FAO, 2014). In the developing world, a larger area is planted to white maize than to yellow maize in tropical highland and sub-tropical/mid-altitude environments, and it occupies about 40 % of the lowland tropical maize area (FAO, 1997). According to FAO (2014), about 158 million hectares of land is under cultivation of maize worldwide.

In a report by the FAO (2007), it was noted that, 65 % of the global maize production is used as feed while about 15 % is used for food, and the remaining part is mainly destined for various industrial uses. Therefore, the variation in usage of maize stems from its manifold nutritional qualities which underscore its importance.

2.3 MAIZE PRODUCTION IN AFRICA

Maize is the most important cereal crop in Africa, particularly in the sub-Sahara regions where it is regarded as the most important staple food for over 1.2 billion people (FAO, 2014). All parts of the crop can be used for food and non-food products. According to IITA (2012), maize consumption accounts for 30−50 % of low-income household expenditures in the eastern and southern Africa regions. Maize production in Africa represents about 7 % of the world total, of which the largest producer is Nigeria with nearly 8 million tons, followed by South Africa and Tanzania. Area under cultivation of maize in Africa constitutes about 18 % (about 29 million hectares) of the global total (FAO, 2014). Most maize production in Africa is rain fed and as a result it is vulnerable to droughts, floods and other unpredictable weather patterns.

Byerlee and Heisey (1997) noted that Africa was known to be self-sufficient in food production, as well as being a leading exporter of agricultural produce at the beginning of the era of the independence movement in the 1960s. In contrast, Asia was at the epicentre of a world food crisis and thereafter launched the green scheme revolution in the mid-1960s, which presently adds about 50 million metric tons of grain to the world food supply each year (Byerlee and Heisey 1997). Byerlee and Heisey (1997) further noted that the food crisis in the early 1970s began shifting to Africa and as a result, the continent’s food balance sheet changed from positive to negative. For example, Byerlee and Heisey (1997) observed that between 1970 and 1985, annual food production grew at half (1.5 %) the rate of population growth of 3 % per year. Since then, the situation continues to deteriorate and consequently leads to a significant decline in per capita food consumption.

IBP (2014) has noted that climate change, diminishing soil fertility and other environmental stresses affect crop production especially in the developing countries. The author argued that crop productions in developing countries is mainly rain-fed and is vulnerable to low productivity thereby threatening the food security of millions of people, especially in sub-Saharan Africa. In addition, poor access to improved seeds and fertilisers, poor market development and low investment in research and extension services have exacerbated the situation.

According to IITA (2009), Africa imports 28 % of its maize requirements from countries outside the continent. The author further noted that maize imports into the sub-Sahara Africa alone, account for thousands of metric tons annually in years of good crop harvests to far higher amounts than this after droughts. This altogether suggests that more still needs to be done by governments in Africa in terms of policy and programme interventions in order to mechanise agriculture and provide the much-needed support to their respective farmers.

2.4 MAIZE PRODUCTION AND USAGE IN SOUTHERN AFRICA

Maize is one of the most crucial cereals and basic food crops for most people in the southern African region, accounting for at least 36 % of total caloric intake from cereals across the region (Grant *et al*., 2012). In a study by CIMMYT (2012), it was noted that maize stands out as the primary crop, both in terms of acreage and absolute yield levels. This study corroborated data from FAOSTAT (2010), which showed an increasing trend in proportion of area allocated to maize. In the poor rural areas, maize consumption accounts for much higher percentages as a major staple food. Grant *et al*., (2012) noted that maize is also a primary input for animal feeds and intermediary products for industrial use. Therefore, maize plays a vital role in both food security and systems requiring raw materials from agriculture to make up goods and services necessary for trade in the southern African region. Additionally, maize is also known to provide the market with important value adding services, such as storage, extension, equipments supply, agricultural finance and commodity exchanges needed for the fabric of the commercial agricultural system (Grant *et al*., 2012).

According to FAO (2012), the southern African region produces on average, 18 to 24 million tons of maize per annum, with 55 % produced by South Africa. It is further noted that, the region consume about 17 million tons of maize per annum and is a net surplus producer in most years (FAO, 2012). However, according to SADC (2011), several member states such as Mozambique, Namibia, Zimbabwe, Angola and Botswana are usually in net deficit while other member states such as South Africa, Zambia and Malawi, have a steady surplus. The food deficits/surpluses within the region are often balanced by international and regional trade and long-term storage. SADC (2011) further noted that, most maize produced in the region is directly used for home consumption, particularly by the poor members of society.

Despite the importance of maize in the region in general, and in the low-income countries in particular, maize productivity has not been moving in tandem with the rising human population in the region. According to the FAO (2012), there have been no net increases in maize productivity in the region over the last 30 years, excluding South Africa. Figure 2.2 below shows comparative maize yields in Malawi, Namibia and South Africa. From Figure 2.2 it can be seen that maize yields are relatively lower in Namibia and Malawi, when compared with South Africa.

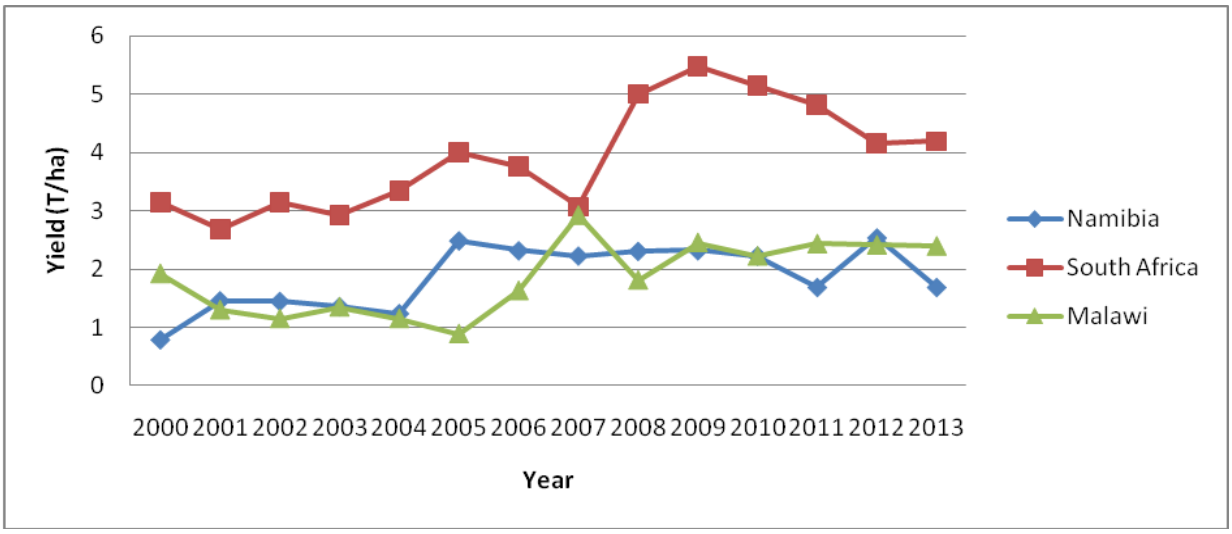

Figure 2.2: Average maize yields in selected countries in southern Africa

Source: FAOSTAT

CIMMYT (2013) noted that maize yields of smallholder farmers in the southern African region are a fraction of those in the developed world because of the region's poor soils and limited access to basic inputs such as fertiliser and improved maize seeds. Maize productivity in the region is generally confronted by a vast array of challenges, ranging from insufficient investments in agriculture, inadequate funding on research, insufficient use of yield-enhancing technology, and low land and labour productivity. Murungu (2010) observed that low productivity among smallholder farmers is attributable to low application of external inputs caused by lack of financial resources and lack of access to credit. Such farmers, according to Murungu (2010) commonly rely heavily on family labour and there is also a shortage of hired labour during peak periods. It is also imperative to note that even for the small-scale irrigation farmers the sustainability of irrigation schemes has always been a cause of concern because of the farmer's heavily reliance on government grants for their operations. Boosting crop yields, in general, does not always result from doing just one thing right, but often from a combination of many key management decisions (Murungu, 2010). Thus, while holding other things constant, maize productivity over time can be achieved through the efficient use of production inputs, the use of modern technology, and improved farming practices.

Given the importance of maize in the southern African region, there is a need to understand the relationships between productivity, efficiency, policy indicators and farm-specific practices, in order to advise policy makers on appropriate programmes that will enhance maize productivity among smallholder farmers.

2.5 NAMIBIAN AGRICULTURE AND MAIZE PRODUCTION

Namibia's climate varies from arid to semi-arid conditions with an annual rainfall range between 50 to 600 mm per annum (NSA, 2013).The country is characterised by hot and dry conditions with sparse and erratic rainfall, and the risk of agricultural production under rain-fed conditions is very high. The rain falls during summer and the country is prone to occurrences of frequent droughts and to some extent floods in the north and north-east. Low and variable rainfall and poor soil conditions are major constraints on optimal agricultural production. However, five perennial rivers are found along the borders with neighbouring countries while all the other rivers are ephemeral. In view of the perennial rivers which the country has, government realised the need to promote farming based on a technical and economic framework which is intended to stabilise yields and farm incomes where comparative advantages exist (MAWRD, 1995). Such approach has been promoted through appropriate agricultural support services in partnership with the private sector as part of a long-term agricultural development initiative. Specifically, government has established green scheme projects in the north-central, north-east and southern parts of the country along its perennial rivers. The aim of these projects is to increase food production in the country using irrigation systems thereby contributing toward the national agenda for food self-sufficiency, food security and job creation (MAWRD, 1995). These projects included the Hardap Irrigation Project near Mariental in the Hardap region and Haakiesdoorn at the Oranje River in the Karas region, both situated in the southern part of the country. In the north-central part, the Etunda Irrigation Project was established in the Omusati region. For the north-eastern part of the country, irrigation projects included Katima farm in the Zambezi region, Shadikongoro, Ndonga Linena, Mashare, and Vungu-Vungu Irrigation Projects in the Kavango East region, as well as Sikondo, Shitemo and Muses in the Kavango West region (MAWF, 2012).

Maize production as is the case with many other countries in southern Africa remains the most important staple crop to many communities in Namibia. Maize production in Namibia is confined in the northern part of the country and is produced by both commercial and subsistence agricultural systems. Although there are some emerging areas with limited maize production activities, most maize is produced in the north-east and north-central part of the country. According to the NAB (2013), maize and wheat are the largest commercial grain crops in the country. Maize is produced both communally (dry-land condition) and commercially (irrigation and dry-land conditions). According to MAWF (2009), both irrigation and dry-land maize farming systems make up the total national maize production.

Dry-land white maize is produced mainly on the private commercially owned farms in the maize triangle (Otavi, Tsumeb and Grootfontein areas) (NAB, 2013). Furthermore, MAWF (2012) indicated that a significant amount of maize is also produced under rain-fed condition by smallholder subsistence farmers in the Zambezi, Kavango East, Kavango West, Otjozondjupa, Omaheke and Kunene regions. White maize production under irrigation is produced in the government green scheme projects, as well as on privately owned irrigation farms (MAWF, 2009). Since yellow maize is normally produced for animal feed purposes, there is no yellow maize production in Namibia and the country only produces white maize.

2.6 SMALLHOLDER MAIZE FARMERS IN NAMIBIA

Most maize producers in Namibia are smallholder subsistence farmers, with an average crop field size of less than 4 hectares (MAWF, 2009). The majority of these farms are rain fed and characterised by low input use and low yields. The smallholder subsistence farmers use their own traditional seed varieties, kept from previous season's harvest, which are typically open-pollinated varieties (OPV), strong and able to yield reasonable production under poor rainfall conditions (ARC, 2002). The author further argued that, since most varieties used are open-pollinated, the re-use of these varieties does not reduce yields significantly as is the case with hybrid seeds.

Although the use and development of OPVs is not advisable or supported by research institutions, these varieties are important in providing low-priced seeds and acceptable yield levels, especially to smallholder farmers. OPVs are said to yield less than well-adapted hybrid varieties do. However, Kutka (2011) advised that in lower yielding agro-ecosystems where hybrid varieties appear to be more expensive, farmers need to recognise the importance of seeds selection and seed production methods and adopt it, in order to realise acceptable outcomes. IITA (2009) observed that scientists have made efforts in the development of high yielding OPVs of maize with resistance to drought and the prevailing major diseases in the humid forest and moist savannah. Average maize yields for the smallholder farmers under rain-fed conditions range from 0.45 tons/ha in the Zambezi region, to about 0.35 tons/ha in the Kavango East and Kavango West regions, while for those in the green scheme projects it is estimated at about 4.6 tons/ha (MAWF 2009).

2.7 PRODUCTION EFFICIENCY THEORY

Efficiency is one of the most critical factors in the production process of any project, particularly in agro-business enterprises. Efficiency is measured by comparing the actually attained outputs, against what is attainable at the frontier (Alene, 2003). In a broader context, production efficiency occurs when the economy is utilising all of its resources efficiently, that is producing a high level of output from the least input cost (Wetzstein, 2005). Greene (1993) noted that the level of technical efficiency of a particular firm is characterised by the relationship between observed and some ideal production levels. The measurement of firm-specific technical efficiency is based upon deviations of observed outputs from the efficient production frontier. If a firm's actual production point lies on the frontier, then it is said to be perfectly efficient. In contrast, if the firm's actual production point lies below the frontier, then this is regarded as technically inefficient (Wetzstein, 2005). Therefore, efficiency is the act of attaining good results with less waste of efforts. It is also the act of hooking up materials and human resources together and coordinating these resources to attain better management goals (Wetzstein, 2005).

Farrell (1957) observed that there are three types of efficiency, namely Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE). Farrell (1957) distinguished these types efficiency where TE is described as a measure of the firm's ability to produce the maximum outputs from a given set of inputs. TE also refers to the capacity of the firm to operate on the production frontier (Effiong & Onyenweaku, 2006). AE refers to 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 factor cost (Farrell, 1957). Musaba and Bwacha (2014) indicated that AE reflects the ability of the firm to use inputs optimally, given their relevant prices and technology set. According to Musaba and Bwacha (2014:105), EE is defined as the ability of the firm to produce a predetermined quantity of output at minimum cost for a given level of technology. It is concerned with the realization of maximum output in monetary terms with the minimum available resources (Farrell 1957). Technical and allocative efficiencies are components of economic efficiency (Abdulai and Huffman, 2000). Farrell (1957) indicated that farm efficiency can be measured in terms of all these types of efficiency. It is also relevant to define production as a process of transforming goods and services into finished products. This is referred to as an input-output relationship and is applicable to every production process, maize included. Olayide and Heady (1982) defined production as a process in which inputs are transformed into outputs.

Although not all producers are technically efficient, it is important to note that some producers are able to utilise the minimum quantity of required inputs in order to produce the desired quantity of output given the available technology (Rivera Rivera *et al*., 2009). In the same way, not all producers are able to minimise costs for the intended production of outputs. This observation, from theoretical point of view suggests that producers do not always optimise their production functions. The production frontier characterises the minimum number of necessary combinations of inputs for the production of diverse product or the maximum output with various input combinations and a given technology (Rivera Rivera *et al*., 2009).

In order to do economic modeling, factors of production (inputs) are generally aggregated into three groups, namely capital, labour and land. This is part of microeconomic theory that deals with the production of goods using sets of inputs. A production function is a model used to formalise this relationship and according to Hisnanick (2014), the general specification of the production function model can be specified as follow:

$$Q=f\{L, S, F\ldots\} \quad (1)$$

Where *Q* represents an output of the firms, *L* represents the amount of labour and *S* represents quantity of seeds used in the production of *Q,* while *F* represent the amount of fertilisers applied. The objective of the producer is to maximise profit, either by increasing the quantity of *Q* produced or by reducing the cost of producing *Q*. Kamau and Otieno (2013) explained that the production function shows the maximum amount of the good that can be produced using alternative combinations of labour (L), seed (S) and fertiliser (F). *Q* is also referred to as the total physical product (TPP). The authors further noted that the production relationship can be expressed in several forms such as linear functional forms, polynomial functional forms and the Cobb-Douglas functional form. The latter is modified into the transcendental and trans-log functional forms. The marginal physical product (MPP) of an input is the additional output that can be produced by employing one more unit of that input, while holding all other inputs constant (Kamau and Otieno, 2013).

2.8 METHODS USED TO ASSESS EFFICIENCY

An understanding of the relevant concepts and methodological framework regarding production efficiency is of utmost importance in order to determine data requirements and develop analytical tools. Peacock *et al*. (2001) noted that developing an appropriate efficiency analytical framework requires a sound theoretical basis, adjusted to the specific discipline under study. Farrell (1957) proposed a measure of efficiency of the firm based on two concepts, namely technical efficiency and allocative efficiency. The former reflects the capacity of the firm to obtain maximum output at a given set of input, while the latter reflects the ability of the firm to use inputs optimally, given their respective prices (Farrell, 1957). These two measures when combined provide a measure of total economic efficiency, thereby assuming that the production function of the firm is known. However, since in practice the production function is never known, Farrell (1957) suggested that the function be estimated from the sample data using a non-parametric price-wise linear technology or parametric form, such as Cobb-Douglas production functions. Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) were the two traditional alternative methods used to measure efficiency of production. However, these methods were criticised because of their weaknesses, which may have tremendous impact on inferences made from studies using these approaches (Simar and Wilson, 2007).

SFA is an alternative approach to measure technical efficiency. This was independently proposed by Aigner *et al*., (1977) and is a parametric analytical method which is different from DEA. This approach uses econometric techniques wherein models of production take into considerations technical inefficiency and the fact that random shocks beyond producers' control may affect the yield (Aigner *et al*. 1977). SFA is different from non-parametric approaches that assume deterministic frontiers. This means that SFA makes allowance for deviations from the frontier, whose error can be decomposed for adequate distinction between technical efficiency and random shocks, e.g. capital or labour performance variations (Aigner *et al*., 1977). Jacobs (2000) observed that the SFA constructs a smooth parametric frontier which may as a result have an inappropriate technology, but accounts for stochastic noise in the data. Many researchers, including Baten *et al*. (2013), Khaile (2012), and Maseatile (2010) have noted that the advantage of SFA is that it accounts for random errors related to data and also permits statistical testing of hypothesis with regard to the structure of production and the extent of inefficiency. However, the main weakness of this approach is that it requires an explicit imposition of a particular parametric functional form representing the underlying technology and an explicit distributional assumption for the inefficiency terms (Hossain *et al*., 2013; Khaile 2012; Maseatile 2010). Nevertheless, the SFA approach will not be used in this study.

DEA, on the other hand, is a non-parametric method adapted from multiple input-output production functions and is applied in many industries (Peacock *et al*., 2001). DEA is used in operational research and economics for the estimation of production frontiers and is used to empirically measure production efficiency of a decision-making unit. This method is different from an Ordinary Least Square (OLS) statistical technique, which bases evaluation relative to average production (Peacock *et al*., 2001). DEA benchmarks firms against the best producers and is characterised by an extreme point method that assumes that if a firm can produce a certain level of output utilising specific input levels, another firm of equal scale should be capable of doing the same (Peacock *et al*., 2001). According to Jacobs (2000), the advantage of DEA is that this approach constructs a piecewise, linear, segmented efficiency frontier, based on the best practice and is capable of handling complex production data with multiple input and output technologies, such as production efficiency in agribusiness and research environments. Furthermore, DEA gives the benefit of the doubt to companies that do not have suitable comparable sister organisations so that they are considered efficient by default (Commonwealth of Australia, 1997). However, there are weaknesses related to this approach. One is that this approach does not produce diagnostic tools which enable judgment of the goodness of fit of the model specification created (Jacobs, 2000). Moreover, the author further noted that, the approach does not consider errors or random fluctuations that may exist within production inputs, thus making it more vulnerable to data error.

Many sources in the literature have shown that a two stage approach is commonly used, where DEA efficiency scores are estimated in the first stage. This will then be followed by Tobit regression analysis in the second stage in order to explain the inefficiency. However, Jordaan (2012), McDonald (2009), Simar and Wilson (2007), and Xue and Harker (1999) pointed out that this approach is invalid because one of the assumptions underlying regression analysis (no serial correlation) is being violated. Jordaan (2012) further argued that efficiency scores are censored due to the existence of number of efficiency scores of one. However, Simar and Wilson (2007) observed that no study had yet provided any explanation as to how the censoring of efficiency arises. Simar and Wilson (2007) have further argued that such a two stage, semi parametric approach fails to articulate a coherent data gathering procedure and is invalid due to a complicated nature of serial correlation among the estimated efficiencies. Thus, inferences made from researchers that used the two-stage approach (for example, Khaile 2012, Van der Merwe 2012; Speelman *et al*., 2007) may be invalid and unreliable (Jordaan, 2012).

In an effort to overcome the severe predicament associated with a two-stage approach, Simar and Wilson (2007) noted that a double bootstrap approach could be used to scrutinise efficiency levels and determinants of technical efficiency of the farmers. This procedure has been found to be suitable for analysing determinants of technical efficiency accurately in the second stage of regression of DEA efficiency scores on some of the covariates (Jordaan, 2012). Alexander *et al*., (2007), Gunda (2013), and Jordaan (2012) concur with this procedure and have since realised that the approach permits valid inferences and such information may contribute toward improving technical efficiency levels of the principal decision makers. Therefore, this study will use DEA double bootstrap procedures as proposed by Simar and Wilson (2007) to analyse technical efficiency and its determinants by performing Algorithm # 2. These procedures involved regression analysis based on Algorithm # 2 of Simar and Wilson (2007) within the principal component framework in order to reduce the number of independent variables vis-à-vis the number of observations. This approach which is an input oriented was selected for this study since the efficient use of production inputs is the primary decision over which the principal decision makers have most control.

2.9 FACTORS DETERMINING TECHNICAL EFFICIENCY

Concurring with Gunda's (2013) arguments, and as articulated by Obwona (2006) technical efficiency is determined by certain attributes of individual farms and farmers' specific characteristics. These characteristics in this study are classified into demographic, human capital, socio economic, support services and farm characteristics. Knowledge of these characteristics is hypothesised to have a crucial influence on agricultural productivity among farmers. This entails determining these factors and examining why some farmers are more efficient in the way they utilise their production inputs than others are. The analysis takes into account the environment in which farmers are operating, access to the necessary technology, and inputs and prices thereof. Therefore, understanding the fundamental issues responsible for variations in the use of production inputs among farmers is very important. This understanding may help policy-makers to design appropriate policy and programme interventions to raise agricultural productivity of farmers by improving on factor productivity and on-farm and crop-specific efficiencies.

Studies on TE among smallholder farmers are emerging around the globe in general and in Africa in particular. However, no studies on TE of smallholder maize farmers were found in Namibia, despite decades of policy efforts to improve agricultural productivity in the national economy. Nevertheless, studies on TE especially from Africa associated various factors to have an influence on technical efficiency among small-scale maize farmers as discussed below.

2.9.1 DEMOGRAPHIC CHARACTERISTICS

Age

Age is among the factors which are said to have an influence on the production efficiency of a farmer. According to Mulinga (2013), younger farmers are more efficient than older ones are, possibly because the age variable picks up the influence of physical strength. Younger farmers are also likely to have attained higher levels of education and tend to be innovative, and hence are more efficient. Mulinga (2013) argued that although farmers become more skilled and more experienced as they grow older, the 'learning by doing' effect may be weakened as they approach middle age, when their physical strength begins to diminish. This conclusion was also made by Abdulai and Huffman (2000).

On the contrary, some scholars have argued that older farmers are more efficient than younger farmers because farmers become more skilful as they grow older. Mignouna *et al*. (2010) noted that the older farmers become the more experience they have and have lower technical inefficiency. This observation was also made by Rahman (2002) who found a similar relationship in rice farming in Bangladesh. Therefore, it is imperative to note that the age of the farmer is interlinked with farming experience.

Gender

Simonyan *et al*. (2011) examine gender-based technical efficiency in Essienudim local government area, using descriptive tools and a Stochastic Frontier production function approach. The authors found that the technical efficiencies for male and female were 93 % and 98 % respectively. This study concluded that marital status and other variables, such as extension contact, educational status, and access to credit were found to be positive and significantly linked to technical efficiency of the male farmers. In a case study by Kibirige (2014) in Masindi District of Uganda, using a Stochastic Frontier and Cobb-Douglas production function, it was found that gender and other factors, such as membership to farmer organisations, have positive relationships with technical efficiency of the farmers.

2.9.2 HUMAN CAPITAL

Many studies cited various socio-economic factors as having a significant influence on technical efficiency. This includes the level of education, farming experience, income sources, and membership to farmer's organisation. The correlations of these factors to technical efficiency are discussed in detail as follow:

Education Level

According to Rakipova *et al*. (2003), farmers who have high levels of education have high levels of commitment to farming activities and work long hours on their farms. The study further noted that these farmers are likely to be more technically efficient than those with opposite characteristics. The high level of education helps the farmer in the use of production information which may increase the productivity potential and subsequently achieve increased yield. Pudasaini (1983) noted that high levels of education contributed to agricultural production in Nepal through both worker and allocative effects. The writer also established that although education improves agricultural production, mostly by enhancing farmers' decision-making capacities, the way in which this is done varies from environment to environment. Hence, in a situation with changing agricultural technology, education advances farmers' allocative ability by enabling them to choose improved inputs and to optimally allocate existing and new inputs among competing uses.

Tshilambilu (2011) conducted a study on technical efficiency of small-scale maize farmers in Ga-Mothiba area in Limpopo Province, South Africa. The results revealed that the farmers in question are technically inefficiency due to the decreasing return to scale, meaning that they were over-utilising factors of production, resulting in inefficiency. This situation was attributed to ignorance as a result of poor educational level of the farmers. Therefore, there is a need to educate farmers, specifically on the optimal use of inputs, without reducing the desired maximum output level.

Farming Experience

Farming experience is one of the most important factors with a positive impact on the technical efficiency of farmers. The more experienced a farmer is the higher are the chances of the farmer being efficient. Addai and Owusu (2014), Wilson *et al*. (1998) and Rahman (2003) found a positive relationship between the technical efficiency and farming experience of the farmers under study. The authors noted that farming is carried out in a risky environment, affected by adverse circumstances such as pests, diseases, erratic rainfall and other risk factors which are beyond farmers' control. Farmers who have been planting the same crop over a period of time are likely to make more accurate predictions and use effective control measures, such as plant timing, the type and quantity of input to use, pesticides and so on; hence they are more efficient in their input use as compared with inexperienced farmers.

Gunda (2013) and Maseatile (2011) have also found a positive contribution of farming experience to the level of technical efficiency of the farmers. Maseatile (2011) noted that, her findings were in agreement with Omonona *et al*. (2010) who argued that a unit increase in farming experience may result in a better decision-making ability which consequently suggests efficiency in the use of inputs. A well-experienced farmer tends to have good managerial skills which were acquired over a period of time and as such are likely to use production inputs optimally.

2.9.3 SOCIO-ECONOMIC

Off-farm Income

Farmers with off-farm income are likely to be more able to afford sufficient appropriate inputs and services than those who are only dependent on farm income alone. The positive effect of off-farm income on farmer's technical efficiency is that, multiple sources of income may enable farmers to afford the necessary inputs and technology, thereby increasing their crop yields (Diiro, 2013). This is particularly the case when farmers do not have sufficient resources to afford basic inputs and services, causing farmers to compromise on the supply of essential inputs thereby adversely affecting the quality and quantity of the output.

However, Abede (2014) argued that, participation in off-farm activities might be at the expense of owner-farm activities in terms of providing less labour, resources and time causing a negative relationship between technical efficiency and participation in off-farm activities. Therefore, off-farm income may have a positive or negative effect on the levels of technical efficiency of the farmer.

Membership to Farmers' Organisation

Membership of a farmers' organisation is also one of the important factors which plays a critical role in the technical efficiency levels of a farmer. Active farmers' organisations facilitate farmer access to essential information, such as new production techniques, market, credit facilities, and also provide training to their members. Olowa (2010) found a positive relationship between membership of a farmer's organisation and the technical efficiency level of a farmer. The author noted that inefficiency declined on plots planted with hybrid seeds and controlled by farmers who belong to a household with membership in a farmers' organisation. Therefore, it is imperative to note that membership of an active farmer's organisation enables a farmer to access crucial and updated information with regard to input, new technology and market, thus enhancing their ability to apply innovation and thereby improving their efficiency.

2.9.4 SUPPORT SERVICES

ACCESS TO CREDIT AND EXTENSION CONTACT

Msuya (2007) noted that the lack of access to credit, coupled with a low level of education, lack of extension services, and the unavailability or high prices of agricultural inputs have a negative effect on the technical efficiency of a farmer. This observation was supported by Haji (2007) who argued that most subsistence farmers are poor and experience credit limitations from the financial institutions and subsequently may not be in a better position to increase agricultural productivity significantly.

Olarinde (2011) and Chikamai (2008) also noted that credit accessibility and other variables such as farming experience, number of extension visits and farm distance to extension office, were found to be significant in determining technical efficiency of smallholder maize farmers in Oyo State of Nigeria. Results from these studies suggested that maize productivity has enormous potential to improve the general welfare gains by creating an enabling environment for the farmers through technological interventions as well as enhancing farmer's capacity to afford the required quantity of basic inputs that will optimise the production. The studies further pointed out that farmers who were in the category of having adequate access to credit were found to operate within and above the efficiency frontiers than those in the opposite category.

2.9.5 FARM CHARACTERISTICS

Land Size

The size of the farming plot can also affect the productivity of a farmer. Chirwa (2003) carried out a study on sources of TE of smallholder maize farmers in southern Malawi, using a Stochastic Production Frontier approach. The findings indicated that smallholder maize farmers in Malawi are inefficient, with an average efficiency score of 53 %. This inefficiency according to the study is attributed to small plot size, limited used of hired labour and hybrid seeds, and non-membership to a farmer organisation. In another related study, Byiringiro and Reardon (1996) examined the impacts of land size, soil erosion, and soil conservation investments on land and labour productivity and allocative efficiency in Rwanda. Results of this study showed that there is a significant inverse relationship between farm size and land productivity. The study further revealed that, there has been an indication of inefficiency in the use of land and labour for small farms, the cause of which was attributed to the factor of market access constraint. The average technical efficiency was computed as 83 %. Studies by Amos (2007), Barnes (2008) and Jha *et al*. (2005) found a positive relationship between the bigger land size and technical efficiency. Tadesse and Krishnamurthy (1997) suggested that for small farmers to pursue the patterns of efficient use of resources there is a need to provide them with adequate land and sufficient extension services.

To the contrary, some researchers have argued that bigger farming plots become more difficult to manage and this will render the farmer inefficient. Chiona (2011) and Pender *et al*. (2004) found that farm size was negatively related to productivity. The same views were also echoed by Frisvold and Ingram (1994) who noted that for small fields, the proportion is normally small but in terms of productivity, they perform better than large fields.

Use of Livestock Manure

Regular use of livestock manure in addition to inorganic fertilisers is said to increase technical efficiency of a farmer. Tchale and Sauer (2007) noted that farmers who use both livestock and chemical fertilisers are more technically efficient than those using chemical fertilisers alone.

The result is also in support of a Weight and Kelly (1998) study which noted that the poor productivity of smallholder farmers in the sub-Sahara Africa can be improved by applying both chemical and organic fertilisers.

2.30 CONCLUSION

The importance of maize worldwide cannot be overemphasised, since it is one of the most important food crop commodities, particularly in the livelihood of many people in the sub-Sahara African region. Literature highlighted the main approaches used to measure the technical efficiency of the farmers, which include SFA, DEA and DEA Double Bootstrap approach. The first two methods have been heavily criticised because of their significant weakness which may have significant impacts on the inferences of the studies which used these procedures. The SFA approach has been criticised because some of its weaknesses include the imposition of explicit functional form and the distribution of the error term. The DEA two-stage semi-parametric approach has also been criticised, inter alia, for failing to explicate a coherent data gathering process. The DEA Double Bootstrap approach has been suggested and used in order to overcome the severe limitations which exist with the DEA two-stage approach. This procedure has been found to be suitable for accurately analysing determinants of technical efficiency in the second stage of regression of DEA efficiency scores on some of the covariates. Based on the strength associated with DEA Double Bootstrap approach in the exploration of the determinants of technical efficiency of the farmers, this study is aligned with this approach and will follow the procedure in order to achieve the second sub-objective of the study.

Many studies found that maize productivity is low among smallholder farmers because of various challenges confronting the producers. Many scholars referred to various factors related to certain attributes of individual farms and farmer’s specific characteristics. These characteristics are classified into demographic, human capital, socio-economic characteristics, support services, and farm characteristics. Based on the findings from the relevant studies, it is concluded that technical efficiency can be increased when improvements are made on the abovementioned factors which are hypothesised to have an influence on the technical efficiency of the smallholder farmers.

CHAPTER 3

DATA AND PROCEDURES

3.1 INTRODUCTION

The purpose of this chapter is to present and discuss the data and procedures used to achieve the objectives of this study. The first part of this chapter provides information with respect to the geographic location and the background of the area, as well as the data collection plan. The second part presents and discusses the questionnaire design, the survey and actual data collection procedures, the characteristics of the respondents, and the data limitations. The third and the last part of this chapter presents and discusses the analytical framework and model specification using the Data Envelopment Analysis, double bootstrap procedure which was implemented in order to achieve the objectives of the study.

3.2 STUDY AREA

3.2.1 THE REGION

The Etunda Irrigation Project is one of the government's Green Scheme Projects, situated approximately 150 km west of Oshakati, in the Omusati region. Figure 3.1 below depicts the location of the Etunda Irrigation Project within the Omusati region of Namibia.

Figure 3 .1: Map of Etunda Irrigation Project in the Omusati region of Namibia

Sources: Republic of Namibia, Omusati Regional Council

The Omusati region in one of the northern regions of Namibia, with an area estimated at 26 551 km^2 and population size of 228 842 people (NSA, 2011). The area has a high population density of 9.1 persons per km^2 when compared to the national population density of 2.6 persons per km^2 (NSA, 2011). The region is dominated by Mopani tree species and a few Makalani palm trees with some acacia species, and has clay to sandy loamy types of soil, suitable for crop production. The region has a warm climate similar to Oshana, Oshikoto and Ohangwena regions with a mean annual temperature of between 26-30 degree Celsius and the mean annual rainfall of 270 mm (MHSS, 2012). A canal system which carries water from the Kunene River, through the Ruacana waterfall to Oshakati, passes through the region and supplies water to the Etunda Irrigation Project for crop production purposes. According to NSA (2011), nearly 50 % of the population is economically active with agriculture forestry and fishing sectors making up the large employment groups in the region. About 85 % of the population resides in the traditional dwellings with wood being the main sources of energy for cooking and candles for lightings (NSA, 2011). In addition, about 48 % of the rural population use unsafe water for drinking and cooking and 78 % of these households have no toilet facilities. As noted by NSA (2011), the region borders the Kunene Province in Angola and domestically shares borders with the Ohangwena, Oshana and Kunene regions of Namibia. The Etunda Irrigation Project has an area of about 600 hectares and is split into half, for both commercial and small-scale farming systems (AGRIBANK of Namibia, 2004). Maize is the main crop both for commercial and small-scale farming systems, followed by wheat. Other crops, such as potatoes, cabbage, onions, melons and bananas are cultivated throughout the year by small-scale farmers. According to the AGRIBANK of Namibia (2014), the farm workforce at the time of the study consisted of 126 people, of whom 45 were male and 81 female.

3.2.2 BACKGROUND OF ETUNDA IRRIGATION PROJECT

Etunda Irrigation Project was established by the government of the Republic of Namibia in 1994 some two years after the country attained its independence. Government saw the need for establishing green scheme projects with the aim to increase food production under irrigation. At the time of this study, there were about 65 small-scale farmers, each of whom is allocated a plot of about 3ha. However, 19 farmers were given an additional 3ha or 6ha in total, because of their outstanding, high levels of production and also because of the way they maintain and manage their crops. According to the project management, this serves as motivation and an encouragement to other small-scale farmers to follow suit. The Agricultural Bank of Namibia has provided loans of about N$3 million to the small-scale farmers since 2008 through a voucher system. The loan is from the Ministry of Agriculture, water and Forestry, and AGRIBANK is administering it. The farmers are given vouchers to purchase inputs and pay for services rendered. AGRIBANK invests N$7 million for production loans to both the small-scale farmers and the service providers. This has created about 100 permanent jobs and 500 seasonal jobs per season (AGRIBANK of Namibia, 2014).

3.2.3 DATA COLLECTION PLAN

Primary data was used in this study and was collected using a structured questionnaire through a field survey covering all the 65 small-scale maize farmers. Data collection was set to take two weeks and started from 10 to 21 September 2012. The questionnaire was structured in thematic areas including household demographic information, human capital, maize production activities, input use and yield, labour, marketing, financial records, extension contact and training and access to credit. Pertinent issues related to the captioned thematic areas were covered within that section.

3.3. QUESTIONNAIRE DESIGN AND SURVEY

Questionnaire templates from Khaile (2012), Tshilambilu (2011), Maseatile (2011), and Van der Merwe (2012) were used to guide the formulation of questions for this study. The researcher has consulted relevant literature on determinants of technical efficiency and the best management practices regarding maize production. Consultations were held with extension officials for advice and to ascertain the relevance of the questions included in the questionnaire to elicit information from the smallholder maize farmers in Etunda Irrigation Project. The questionnaire was designed to collect information which would enable the quantification of technical efficiency levels (Sub-objective 1) and exploration of the determinants of technical efficiency (Sub-objective 2) of the farmers in the study area. Further consultations were also held with the study leaders to peruse the questionnaire and obtain best advice on the relevance and adequacy of data to be collected.

The questionnaire consisted of eight sections which are designated in alphabetical order (A to H).The first section (A) of the questionnaire covers household demographic information such as gender, marital status and age of the principal decision maker. Section B covers human capital issues which included education, arithmetical abilities, maize farming experience and membership of farmer’s organisation. These variables were measured through the allocations various scores such as yes or no for membership to a farmers’ organisation; excellent, good or poor for arithmetic ability; number of years for farming experience; primary, secondary or tertiary for education variable. For example, the arithmetic ability variable was measured by asking the respondents a simple question that requires applying mental arithmetic (without using a calculator). Such question could be for instance, a farmer selling maize grain at N$ 20 per 2 kilogram bag and a client gave N$ 200 for 4 bags, how much would be the change. The score was allocated as “excellent” if the respondent gave a correct answer within one minute, “good” if the respondent gave a correct answer after a minute or “poor” if the respondent gave a wrong answer. For the membership to a farmer’s organisation, a yes or no response was obtained from the farmers whereby if “yes” it is noted that the respondent is a member to a farmer’s organisation and non-member for otherwise.

Information related to maize production activities, such as farming plot size, area planted to maize, month planted, inter and intra row plant spacing, planting depth and soil analysis, were covered in section C. Input use and yield issues were captured in section D and this included amounts of water, fertilisers, seeds, manure, compost, pesticides and other relevant inputs used for the season under study. Section D also covered the quantity of labour used (in man days) during the course of the crop season, as well as the quantity of maize harvested and the method used in harvesting maize for the season in question. Section E captured marketing-related information which included type of market access, method of selling, unsold maize, access to other markets, awarded additional plot and sources of incomes. Financial record-keeping information was captured in section F, while information on extension contacts and training were covered in section G. The last section of the questionnaire (section H) covered issues related to credit access by the farmers.

The input and output data were necessary for the calculation of the farmer’s technical efficiencies and also to determine the factors that affect their technical efficiency. Efforts were made to elicit information on the amount of water applied in cubic metres per hectare, but this proved futile since such information is not communicated to the farmers by the project management. Nonetheless, the rest of the variables serve as the basis for physical inputs used for producing maize for the 2012 production season in the study area.

Prior to the actual commencement of the survey, a pretesting of the questionnaire was done to determine the appropriateness and suitability of the data collection instruments. The pretesting of the questionnaire was done in the second last week of August 2012 in the study area, which also helped the researcher to get the feel for the practical field situation of the smallholder irrigation maize farmers in the study area. Five respondents were randomly selected from the population to pre-test the questionnaire. The selected participants were asked to peruse the questionnaire and be critical about the questions used and provide constructive comments. The respondents were further asked to provide their candid observations with respect to the wording and sequencing of the questions, possible redundant questions, and missing and convoluting questions. This helped the researcher to make the necessary adjustments and changes to the questionnaire. The pretesting of the questionnaire was followed by the necessary adjustment, corrections and refining of the data collection instruments. A final structured questionnaire (see Annex A) was then completed which was then used to collect the primary data for this study. Respondents to the household survey were the principal decision makers of the household, who were either the owner of the households or their spouses. At the time of the study, there were some 65 smallholder maize farmers in the Etunda Irrigation Project. This number is relatively low, hence there was no need for sampling, and as such all the 65 farmers were interviewed.

3.4. FIELDWORK

Before the start of the survey, the project officials were contacted and informed about the planned survey in order for them to sensitise the small scale maize farmers in the project. Upon arrival at the Etunda Irrigation Project, the researcher held a meeting with the Project Management to inform them of his arrival and to request the assistance of officials to facilitate the farmer interviews. The meeting also discussed the modus operandi on how data could be collected to achieve the research goal and objectives. The researcher worked closely with the project extension officials who are well known by the farmers and know the 'ins and outs' of the farmers under study. The actual data collection survey was conducted from the 10th to the 21st September, 2012.

3.5 CHARACTERISTICS OF THE RESPONDENTS

3.5.1 DEMOGRAPHICS AND SOCIO-ECONOMICS

The distribution of the respondents by age group and gender is presented in Figure 3.2 below.

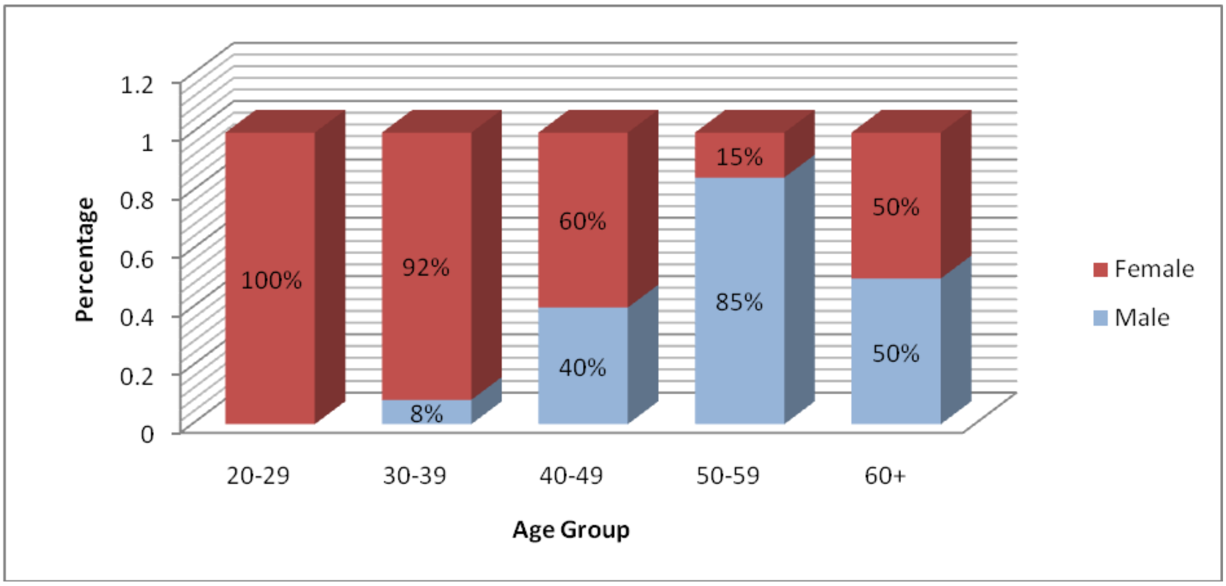

Figure 3 .2: Distribution of the respondents by age and gender

Based on Figure 3.2, the majority of the respondents are female in the first three age categories of 20-29, 30-39 and 40-49. Accordingly, most of the farmers in the first three (relatively young) age categories are female constituting about 69 % of the smallholder farmers in these categories. This clearly indicates that young males are reluctant to participate in the farming activities. Moreover, the results further indicated that over 76 % of the smallholder farmers in the elderly categories (50-59 and 60+) are male. Therefore, this demonstrates the fact that, many male farmers are only found in the elderly age categories as opposed to the many female farmers in the younger age categories.

The marital status of the household head by gender is presented in Figure 3.3 below.

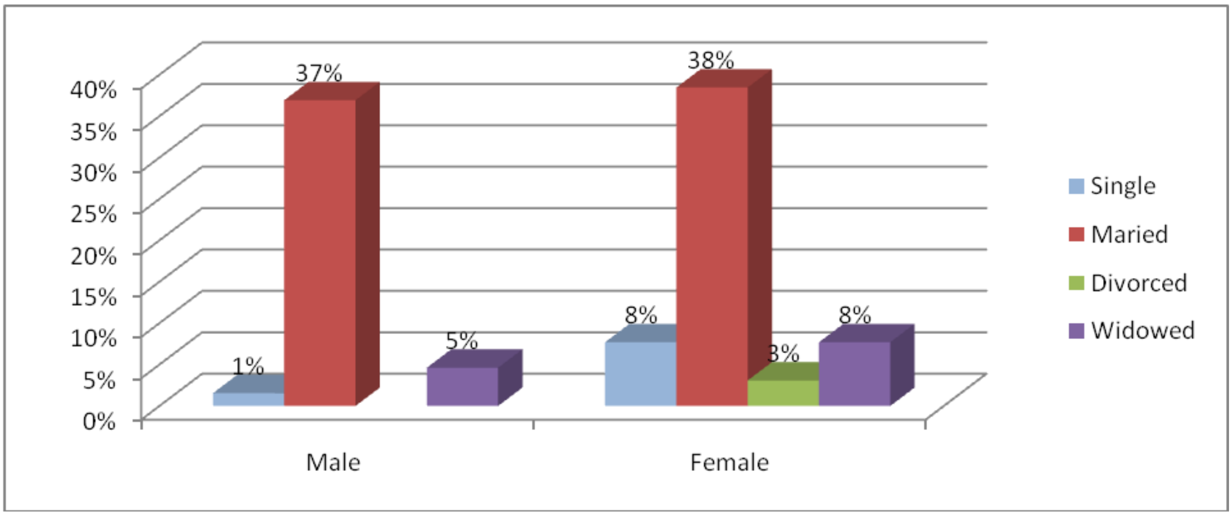

Figure 3.3: Marital status of the household head by gender

Figure 3.3 shows the marital status of the household head by gender. The marital status is represented by four designations, namely, single, married, divorced and widowed. The results indicated that most of the respondents are married with very few household heads that are being single, divorced or widowed. The results further indicated that at the time of the study, most of the smallholder maize farmers in Etunda Irrigation Project were female, constituting about 57 % of the respondents.

4.2.2 HUMAN CAPITAL

The levels of education of the household heads by gender are presented in Figure 3.4 below.

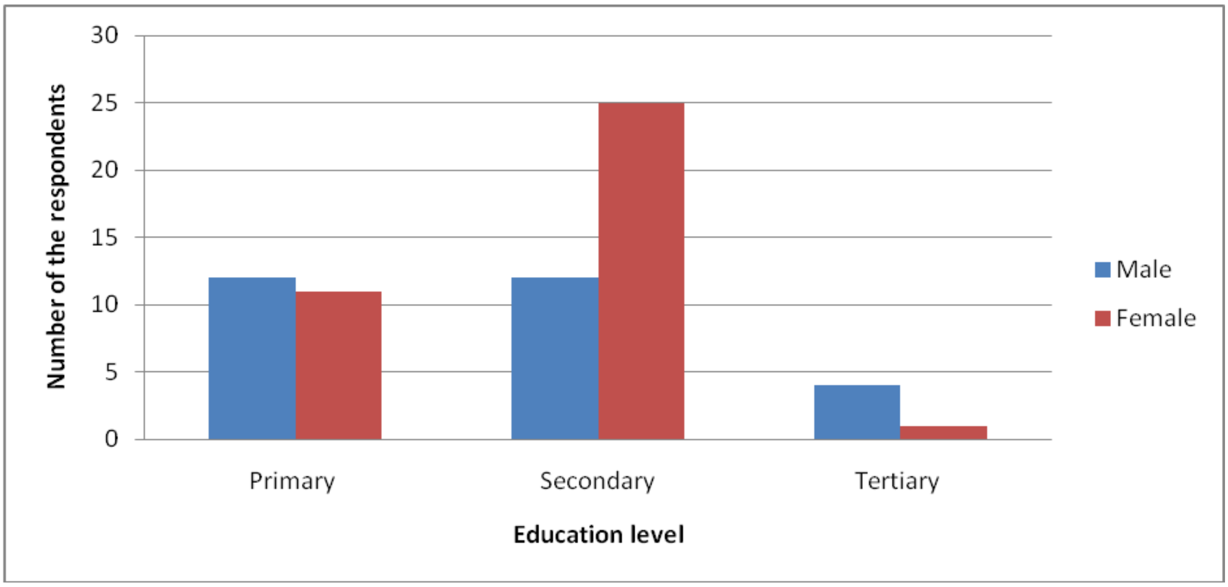

Figure 3.4: Education levels of the household heads by gender

The results indicate that the majority of the respondents (about 57 %) have attained at least secondary education, with females being in the majority. This was followed by the primary education category, with constituted 35 % with the number of males and females being nearly equal. On the other hand, only four male and one female out of the total of 65 smallholder maize farmers in Etunda Irrigation project have undergone tertiary education.

Figure 3.5 provides a summary of membership of the smallholder maize farmers to farmers' organisations.

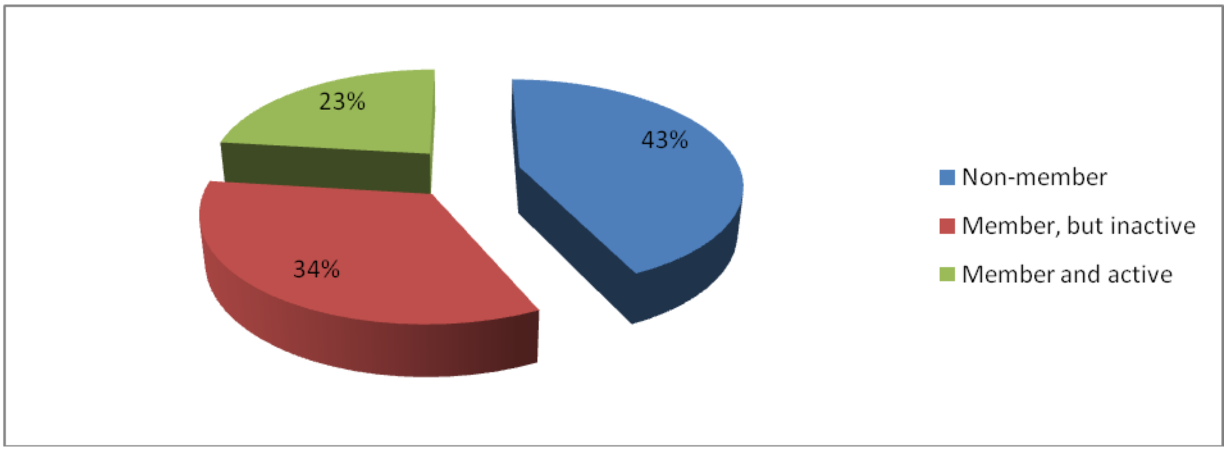

Figure 3.5: Farmer's membership to farmer's organisation.

According to Figure 3.5, the majority of the respondents (about 43 %) indicated that they are not a member of any farmer's organisation. However, 23 % of the household heads indicated that they are active members of a farmer's organisation, while 34 % of the household heads indicated that they are inactive members of a farmer's organisation. There are three major farmers' organisations in the area with Othithiya being the most popular with most members, followed by the Etuveko and Omupapa farmers' organisations.

Figure 3.6 shows income sources of the smallholder maize farmers in the study area.

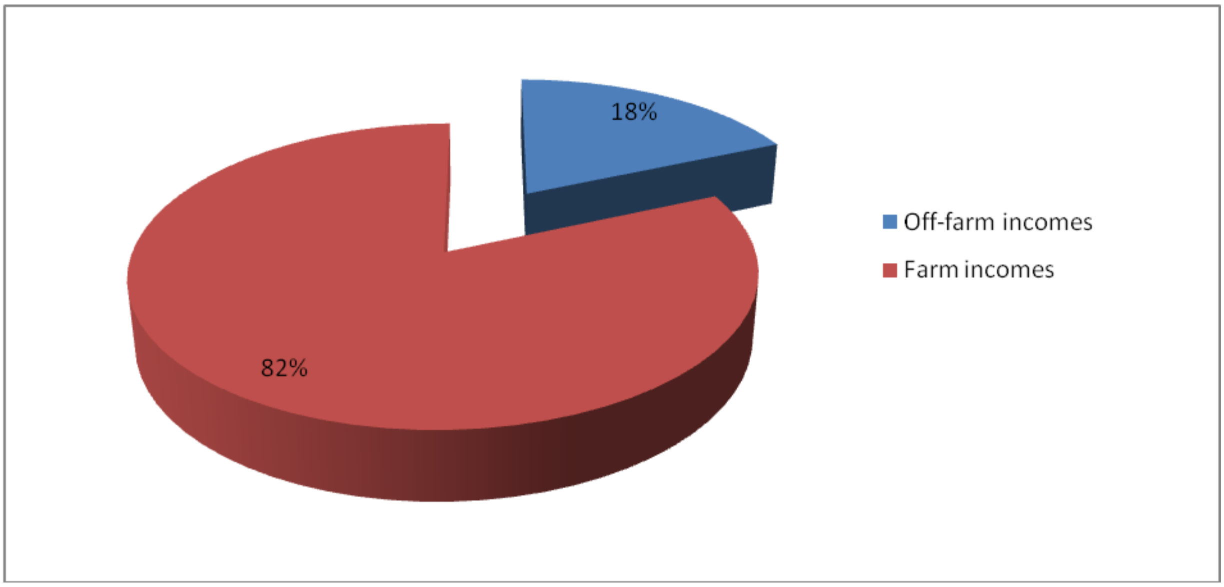

Figure 3.6: Income sources for the smallholder maize farmer in Etunda Irrigation Project

The results presented in Figure 3.6 indicate that 82 % of the smallholder maize farmers in the study area are dependent on their farming activities as a source of income. These farmers are involved only in crop farming activities and derive their livelihoods from the harvest of their produce. However, the results also show that 18 % of the farmers are engaging in non-farming activities and as such are receiving off-farm incomes. Farmers receiving off-farm incomes other than from farming are likely to have the financial resources to enable them to purchase the necessary inputs and obtain easy access to labour. However, one may argue that these same farmers are also likely to face some financial difficulties in reviving other business that are facing financial crises. According to the respondents, sources of off-farm income range from old-age or disability grant from the government to small retailing business.

Figure 3.7 presents a summary of the record-keeping levels of the smallholder maize farmers in the study area.

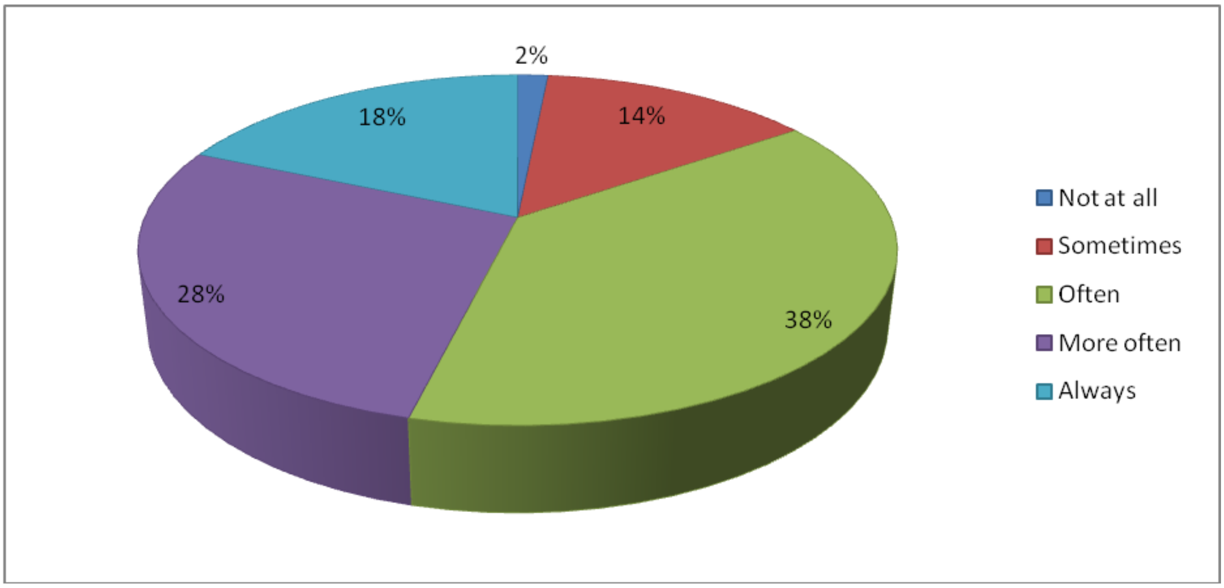

Figure 3.7: Summary of record-keeping levels of the farmers.

The majority of the respondents (38 %) indicated that they often keep their financial records up to date and use these when making decisions. Twenty-eight per cent of the respondents indicated that they use financial records more often, while 18 % said they use financial records always when making decisions related to maize production. Fourteen per cent of the respondents indicated that they use financial records sometimes, while 2 % do not use financial records at all when taking decisions on maize production.

Figure 3.8 show a summary of number of respondents in various socio-economic variables.

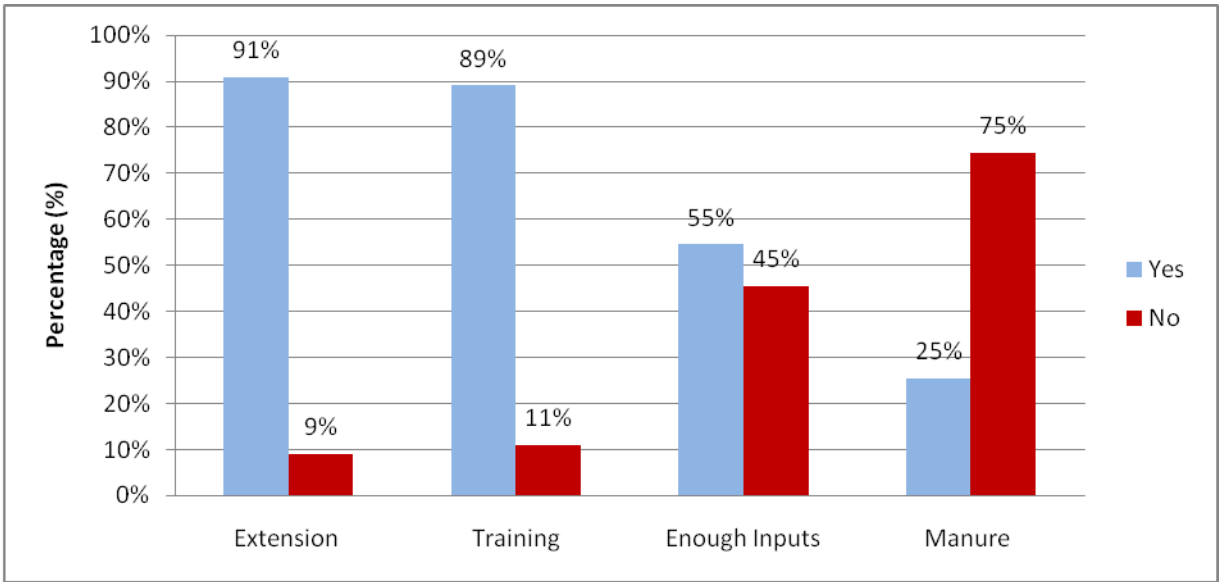

Figure 3.8: Summary of various socio-economic variables of the farmers

With regard to the use of services of project extension officials that are put at the disposal of the farmers, the majority of the respondents (91 %) indicated that they do contact extension officials for advice, while very few farmers indicated that they do not consult the extension officials for advice. Farmers who do not consult extension officials indicated that they would rather consult their fellow farmers than use the extension officials, whom they accuse of not bringing any new knowledge to them. Respondents were also asked to indicate whether they do attend regular training on maize production. In this regard, most of the respondents indicated that they had attended all the training sessions, while only 11 % of the respondents indicated that they had not attended all the training sessions due to various reasons. The reasons according to farmers were: not available at the time of the training or already knowing the content of the training, hence no need to attend.

As to whether farmer had applied enough inputs to ensure optimal production during the crop season under study, most of the respondents (55 %) indicated that they had applied sufficient inputs. Those that could not apply sufficient inputs cited insufficient inputs availability in the project and a lack of funds to purchase inputs. On the use of livestock manure, the results indicated that majority of farmers (75 %) do not use livestock manure to supplement the chemical fertilisers which are used every cropping season. Farmers perceived that the use of livestock manure does not come cheap, since there is cost involved when acquiring the manure.

Figure 3.9 shows the three seasons used by smallholder maize farmers to plant maize during the 2012 production season.

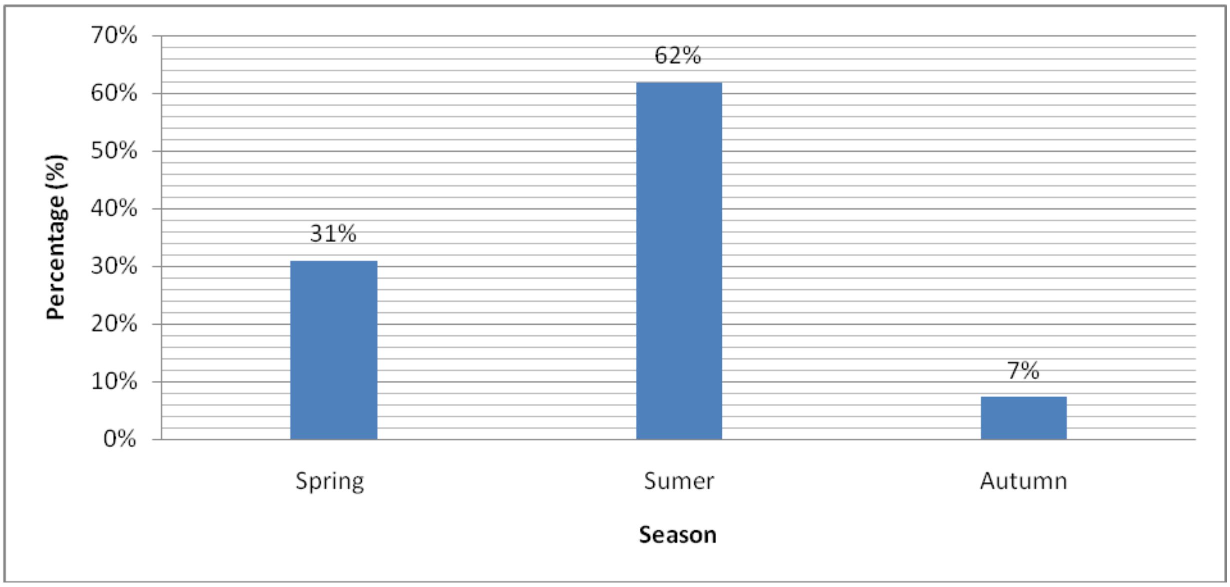

Figure 3.9: Season used to plant maize for the 2012 production season

As shown in Figure 3.9, the majority of the respondents (62 %) planted their maize during summer, 31% planted during spring, and 8 % of the respondents indicated that they planted during autumn. Summer coincides with the time of rainfall, and so irrigation will be limited as most water for crop production comes from the rainfall. However, crop production during the spring and autumn seasons are entirely dependent on irrigation, and accordingly, the cost of irrigation will be high.

Figure 3.10 shows a summary of the soil analysis status for the farming plots of the smallholder farmers.

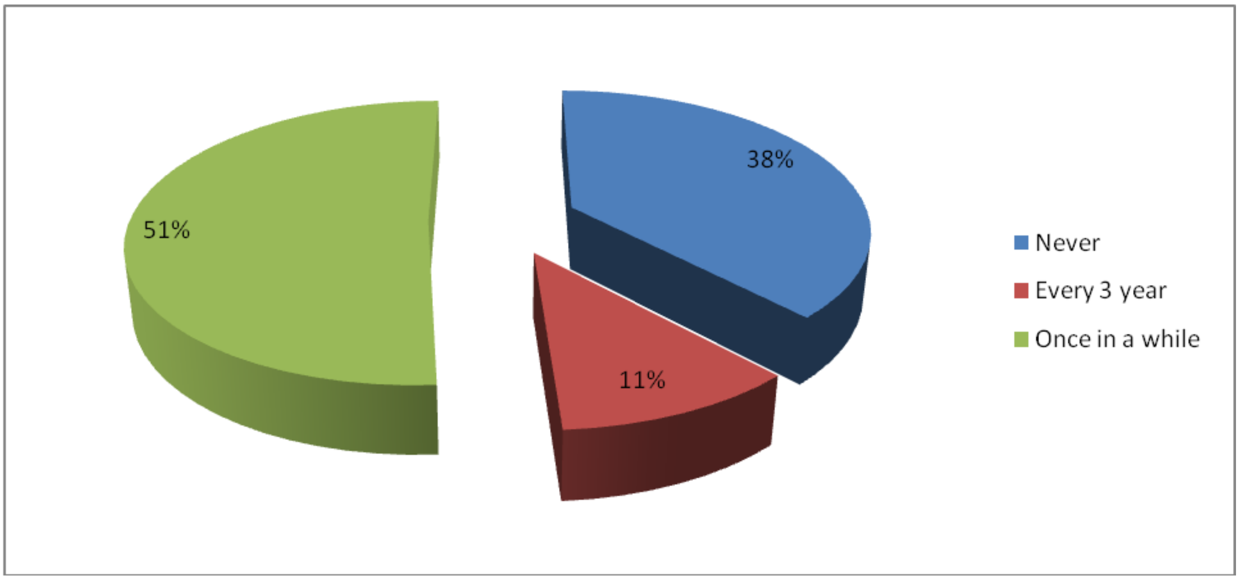

Figure 3.10: Summary on the soil analysis status of the farming plots

The results indicate that the majority of the farmers (51 %) do send soil samples from their farming plots to the laboratory for analysis, once in a while. Thirty-eight per cent of the respondents indicated that they had never sent soil samples of their farming plots for analysis. Furthermore, few farmers indicated that they do send soil samples of their farming plots for analysis every 3 years. Farmers who sent soil samples from their farming plots for analysis indicated that they had not yet received the results of the analysis and would like to know the nutritional status of their plots in order for them to apply the correct types and quantities of fertilisers.

Table 3.1 presents the arithmetic levels of abilities of the farmers in terms of number and percentage of the respondents.

Table 3.1: Summary of the arithmetic levels of the farmers

	Number of respondents (n=55)	**Percentage (%)**
Average	8	14
Good	9	17
Excellent	38	69
Total	**55**	**100**

As indicated in Table 3.1 above, the majority of the farmers (69 %) indicated having an excellent arithmetic ability. However, a few farmers showed good and average arithmetic levels, with respective percentages of 17 % and 14 %. Farmers with good to excellent arithmetic ability are likely to be more efficient in the way they use their production inputs.

Table 3.2 represents the types of market options used by farmers when selling maize.

Table 3.2: Types of market options used by the farmers to sell maize

	Number of respondents (n=55)	Percentage (%)
Formal market only	46	46
Formal and Informal market	54	54
Total	**55**	**100**

According to Table 3.2, the majority of the respondents (54 %) indicated that they use both formal (project) and informal (outside the project) markets to sell their maize. The rest of the farmers indicated that they only sell their maize to the project. Farmers who sold maize outside the project indicated that prices outside the project are much higher than those offered by the project.

Table 3.3 shows a summary of the statistics on the farming plot sizes used by the smallholder farmers.

Table 3.3: Size of farming plots used by the farmers

	Number of respondents (n=55)	Percentage (%)
3ha Plot	39	71
6ha plot	16	29
Total	**55**	**100**

With regard to the size of the farming plots given to farmers, the majority of the farmers (71 %) have a 3-hectare farming plot. The 3-ha plot is the standard farming area given to all new smallholder farmers in the project. The remainder of the farmers was given additional 3-hectare plot. It was noted that these farmers were given additional 3-hectare plots because of their high production levels and the way they are managing their crops.

Table 3.4 shows a summary of the maize farming experience levels and summary statistics of the farmers.

Table 3.4: Distribution of farming experience of the respondents

Maize farming experience (years)	Number of respondents (n=55)	Percentage (%)
1-5	3	5
6-10	9	17
11-15	35	65
16 & more	8	14
Total number of respondents	55	
Average farming experience (years)	12	
Minimum farming experience (years)	3	
Maximum farming experience (years)	18	

With regard to farming experience, the majority of the respondents (65 %) indicated that they had been farming maize for 11 to 15 years. About 17 % of the respondents indicated that they had been farming between 6 and 10 years. On the other hand, 14 % of the respondents indicated that they had been farming for 6 years or more, while very few farmers indicated a farming experience of 1-5 years.

3.5.2 FARM-SPECIFIC CHARACTERISTICS

Table 3.5 presents a summary of the physical inputs used and the yields of maize obtained by the smallholder farmers at Etunda Irrigation Project. The table provides descriptive statistics of inputs used and yields obtained.

Table 3.5: Descriptive statistics of the quantity of physical inputs used and yields

	Unit	Mean	Standard Deviation	Minimum	Maximum
Maize Yield	T/ha	4.7	1.8	0.6	9.3
Nitrogen	kg/h	247.3	116.3	20.1	495.2
Phosphorus	kg/ha	38.9	12.3	3.7	63.4
Potassium	kg/ha	38.0	19.1	3.7	109.8
Seed quantity	kg/ha	16.3	5.7	4.0	31.8
Pesticide	l/ha	5.0	4.8	0.5	25.0
Labour	Man-day/ha	77.1	79.8	21.0	238.8

The average maize yield for the smallholder maize farmers was 4.7 tons/ha, with 0.6 ton/ha as the minimum and 9.3 tons/ha as the maximum. This was achieved after having applied all the necessary inputs as indicated in Table 3.5. The fertiliser compounds used provided, on average, 247.3 kilograms of nitrogen, 38.9 kilograms of phosphorus and 38.0 kilograms of potassium. The lowest amount of nitrogen used was 20.1 kg/ha, while phosphorus and potassium uses were 3.7 kg/ha for each. The highest amount of nitrogen, phosphorus and potassium were 495.2 kg/ha, 63.4 kg/ha and 109.8 kg/ha respectively. Furthermore, on average, farmers used 16.3 kg/ha, whereby 5.0 kg/ha was the lowest and 31.8 kg/ha the highest. The average amount of pesticide used was 5.0 litres/ha, with 0.5 litres/ha being the lowest and 25 litres/ha being the highest. The mean number of man-days used for the production of maize under study was 77.1 man-days/ha, with 21 man-days/ha being the lowest, and 238.8 man-days/ha being the highest.

3.6. DATA LIMITATIONS

The challenges, as it was emphasised by many studies, were that some smallholder farmers do not keep comprehensive records of their farming activities. This came to light during the data cleaning and differencing exercise in which only 83 % of the questionnaires were found to be suitable for analysis and was included in the analysis. The remaining 17 % of the questionnaires were found to have contained too many instances of incomplete information and outliers, and hence were discarded. National Council of Statistics Software (NCSS), version 9, was used to clean data of outliers before running the analysis. NCSS data screening and scatter plots were used to detect the outliers. It is possible that information in this study may have suffered from limitations related to the adequacy of the survey coverage for the targeted population. Furthermore, the accuracy of data used in this study is dependent on the ability of a farmer to recall earlier season's information, which may have not necessarily been recorded. However, efforts to minimise such limitations were made by calling the farmers concerned over the phone, when inconsistencies were detected during data capturing exercise.

3.7 ANALYTICAL METHOD

3.7.1 DATA USED IN THE ANALYSIS OF TECHNICAL EFFICIENCY AND ITS DETERMINANTS

This study used data that was collected by the researcher through a field survey which took place from 10 to 21 September 2012 in the study area. The data was used to compute the technical efficiency levels and explore the determinants for the farmers in the study area. The same data was also used to produce information on the characteristics of the farmers. All the 65 smallholder farmers were interviewed during the abovementioned field survey and only 54 questionnaires were found to be acceptable for inclusion in the analysis.

The type of data that was used in the analysis included household demographic information such as the gender, marital status and age of the principal decision maker. Human capital information, such as the level of education, arithmetic ability, farming experience and membership of a farmer's organisation, were also used in the analysis. Other information used in the analysis for the maize production under study included month planted, soil analysis, pesticide use, number of time weeded, sufficient inputs applied, harvest method, extension contact and record-keeping.

Inputs that were considered for the analysis of the technical efficiency of the smallholder maize farmers in the study area included nitrogen, phosphorus, potassium and labour. Microsoft Excel was used to produce descriptive statistics about the characteristics of the respondents.

3.7.2 DATA USED IN ANALYSIS OF TECHNICAL EFFICIENCY AND ITS DETERMINANTS

According to Simar and Wilson (2007) and McDonald (2009), efficiency scores that are estimated with the non-parametric DEA approach are not censored but fractional. Jordaan

(2012), McDonald (2009) and Simar and Wilson (2007) have argued that for such cases of uncensored efficiency scores, the Tobit model is inappropriate and inconsistent to regress the estimated efficiency scores on hypothesised explanatory variables. However, the linear unit interval model is a suitable Data Generation Procedure (DGP) for efficiency scores and according to McDonald (2009) is presented as follows:

$$y_i = x_i\beta + u_i \qquad (2)$$

Where: u_i / x_i are independently distributed with zero means, $0 \leq y_i \leq 1$, with the limit point $y_i = 1$ possessing positive probability.

McDonald (2009) argues that, data generated by (1), are within the properties of Ordinary Least Square (OLS) and is in the linear probability binary discrete choice model. OLS estimates of β are consistent and asymptotically normal under general conditions.

Based on the discussions of McDonald (2009), this study used DGP (1) to explore the determinants of technical efficiency of smallholder maize farmers in the Etunda Irrigation Project. Factors hypothesised to influence the levels of technical efficiency of smallholder maize farmers in the Etunda Irrigation Project are summarised in Table 3.6 below.

Table 3.6: Factors hypothesised to influence the levels of technical efficiency of smallholder maize producers at Etunda Irrigation Project

Variable	Measurement scale	Expected sign
Human and social capital		
Age	Number of years	+/-
Level of education	Primary or Secondary	+
Extension contact	1 =Yes, 0 = No	+
Arithmetic ability	1= good, 0= poor	+
Maize farming experience	Number of years	+
Attended trainings on maize production	1 = Yes, 0 = No	+
Record keeping	1 = Yes, 0 = No	+
Applied enough inputs	1 = Yes, 0 = No	+
Farm characteristics		
Plot size	1=3ha, 2=6ha	+
Used manure	1=Yes, 0= No	+
Month planted	1= October, 2=December	+/-
Financial Characteristics		
Market access	1 =formal & informal, 0 = otherwise	+
Off-farm incomes	1 = Yes, 0 = No	+/-

Table 3.6 shows the variables that were considered and used in this study as they were hypothesised to have influence in the levels of technical efficiency of the smallholder maize farmers at Etunda Irrigation Project. Following Jordaan (2012), the variables were grouped into three categories, namely; human and social capital, farm characteristics and financial characteristics. Accordingly, the human and social capital factors hypothesised to affect

technical efficiency included; age, level of education, extension contact, arithmetic ability, maize farming experience, attending trainings on maize production, record-keeping and applying sufficient fertilisers. Farm characteristics included plot size, use of livestock manure and the month of planting. Financial characteristics included market access and off-farm incomes.

The likely signs of variables in the inefficiency model depend largely on their expected relationship with the use of improved inputs. For example, age of the farmer may have a positive or negative effect on the technical efficiency of the farmers; hence a positive or negative sign can be expected. Nsikak-Abasi and Okon (2013) argued that older farmers are more experienced and would be more technically efficient than the younger farmers are. However, with regard to new ideas and techniques of farming, older farmers are less likely to adopt innovations and thus would be technically more inefficient than the younger farmers are.

Access to extension services plays a crucial role in the level of technical efficiency of a farmer, thus, a positive sign is expected. Olarinde (2011) observed that, increased extension visits to or from the farmers improved maize productivity among smallholder maize farmers. The author noted that farmers who regularly access extension services and attend meetings, such as field days, demonstrations and so forth, are likely to be more efficient in the ways they use their production inputs. Such farmers have easy access to market information, best available practices and practice new ideas, and hence are likely to be more efficient than those in the opposite category. Similarly, a good arithmetic ability is expected to have positive effects on the technical efficiency of the farmer; hence a positive sign is expected. Farmers with high levels of arithmetic ability are in better position to estimate and use the optimal amount of inputs required per unit area, thereby minimising wastage without affecting the quality of the produce. Farmers with good arithmetic are therefore expected to be more efficient in the way they use their production inputs than those with poor arithmetic ability are.

The number of years in maize farming is also expected to have a positive influence on the technical efficiency of the farmers; hence a positive sign is expected. Farmers with many years of maize farming experience are expected to be efficient when it comes to the use of production inputs. Gunda (2013), Maseatile (2011), Khairo and Battese (2005) and Tijani (2006) found that, technical efficiency in maize production increases with many years of farming experience. This is may be because of the good management skills acquired over the years which enabled farmers to reduce their technical inefficiency. Khaile (2012) noted that farming experience is knowledge accumulated over the years and often assists farmers to understand the dynamics of the environment and the farming business, thereby increasing their efficiency.

The last three variables under human and socio-economic characteristics, namely attending training sessions on maize production, record-keeping and apply sufficient inputs are all expected to have a positive relationship with TE, hence positive signs are expected. Attending regular training on maize production is expected to increase farmers' ability to use their production inputs efficiently. Farmers who attend regular training, especially on maize production are likely to acquire the necessary skills in production, best available practices and market information, thereby improving their production efficiency.

Record-keeping is an important practice in any business as it helps to keep control of resources, decision-making, and planning and monitors it the performance of the business (Mbatia, 2010). In line with the findings of Khaile (2012) and Wollni (2007), farm records can be used to determine the efficiency and inefficiencies of the farm, thereby assisting in determining progress, as well as planning for the future. Farmers who regularly keep records of their farming transactions are likely to be more efficient with the way they use their production inputs than those who do not keep records of their farming activities. With regards to the use of sufficient inputs, literature has suggested that making use of sufficient inputs will have positive effects on maize productivity, yields and net profit (World Bank, 2007). For example, maize producers who used sufficient improved seed varieties and applied fertiliser compounds containing the macro-nutrients of nitrogen, phosphorus and potassium obtained the highest maize yields and were more efficient in their input use, when compared with those farmers who used traditional seed varieties and never used fertilisers (Okoboi, 2011).

With regards to variables in the farm characteristics category, the size of the farming unit or plot is said to have a positive influence on the efficiency of a farmer, hence a positive sign is expected. Haji and Andersson (2006) found that larger plot sizes were positively related to high levels of technical efficiency. The significant positive relationship of plot size with the technical efficiency implies that better optimal combinations of factors of production are achieved on large plots, rather than on small plots (Chirwa, 2003). However, this observation contradicts the finding of Stifel and Minten (2008) who observed that an increase in area cultivated has negative impacts on yield, since this will increase plant density, as well as costs of production.

For the use of livestock manure as a proxy for physical and chemical soil improvement management systems, the expected sign is positive. This is so because, one of the advantages of organic fertilisers is that, they increase the organic matter content in the soil, thereby increasing water retention capacity, enhancing the exchange capacity of nutrients, and encouraging the growth of essential micro-organisms in the soil (Chen, 2006). Mutoko *et al*. (2015) noted that integrated soil fertility management practices in maize production led to a higher TE than the use of chemical fertilisers alone did. The finding of this study is in agreement with TE studies elsewhere that have advocated for a combination of organic and inorganic sources of nutrients in maize farming. For example, Seyoum *et al*. (1998) and Tchale (2005) made a similar conclusion in their studies among smallholder farmers in Ethiopia and Malawi respectively.

The timing of maize planting during the course of the cropping season may have an influence on the technical efficiency of a farmer; hence a positive or negative sign is expected. Farmers who plant their maize at the time for example in December when rainfall has been sufficiently established to supplement irrigation systems are likely to be more efficient than those are planted very early in the season (e.g. August, September or October). This suggests that, farmers who timed their planting to coincide with the rainfall season are likely to reduce the amount of water used for irrigation, as most of the required water will be coming from the rain. Planting early in the season may require much irrigation water since the rainfall has not established sufficiently and crops will be almost entirely dependent on the irrigation, hence there will be high spending on irrigation. Therefore, planting early in the season is likely to reduce the technical efficiency of the farmers.

On the financial characteristics category, sufficient access to various market options may have a positive effect on technical efficiency of the smallholder maize farmers; hence a positive sign is expected. Kibirige (2014) noted that confining farmers to a single market option where they could sell their produce had a negative relationship and a significant effect on technical efficiency. Such a market arrangement renders farmers less efficient than those with access to various markets, such as in towns and semi-urban areas. Off-farm incomes may have positive or negative effects on the maize yields of the farmers and subsequently on technical efficiency. Smallholder farmers who have other sources of incomes, other than maize farming alone, are said to be more efficient than their counterparts are who are solely dependent on maize farming income (Msuya, 2007). This is especially the case when farmers do not have sufficient resources to afford basic inputs and services. The positive effect of off-farm income on farmers' technical efficiency is that multiple sources of income, by and large, enable farmers to afford the necessary technology and inputs, thereby increasing their crop yields (Diiro, 2013). However, Abede (2014) has argued that participation in off-farm activities might be at the expense of own-farm activities in terms of providing less labour and time, causing a negative relationship between technical efficiency and participation in off-farm activities.

3.7.3 DOUBLE BOOTSTRAP METHOD TO ANALYSE TECHNICAL EFFICIENCY AND ITS DETERMINANTS

The approach used to analyse technical efficiency in this study is the Simar and Wilson (2007) DEA double bootstrap procedure, as followed by Gunda (2013) and Jordaan (2012). Regression analysis following this procedure produces technical efficiency scores in the first stage, which will then be used in the second stage on some covariates by performing algorithm #2 to explore the determinants of technical efficiency. This approach is a stepwise procedure along the principal component framework which reduces the number of independent variables vis-à-vis the number of observations (Jordaan, 2012). Gunda (2013) and Jordaan (2012) supported this approach, saying that the technique overcomes the severe limitations, which characterise the two-stage DEA procedure. Simar and Wilson (2007) formulated this procedure in seven steps, as follows.

Step1.

Estimate output-oriented DEA efficiency scores, $\hat{\delta}_i$, using the original data. The output-oriented DEA approach is defined as follows:

$$
\begin{aligned}
&\max \quad \hat{\delta}_i \\
&Subject\ to: \\
&x_{ijo} \geq \sum_{j=1}^{n} x_{ij}\lambda_j; \qquad (i = 1, \ldots\ldots, I) \\
&\delta_i y_{pjo} \leq \sum_{j=1}^{n} y_{pj}\lambda_j; \qquad (p = 1, \ldots\ldots, P) \\
&\sum_{j=1}^{n} \lambda_j \leq 1 \qquad (j = 1 \ldots\ldots, J) \\
&\lambda_j > 0;
\end{aligned}
$$

Where x_{ij} represent the amount of input, i, used by decision-making unit (DMU) *j*. Y_{pj} is the amount of output *p* produced by DMU *j* and j_0 refers to the reference DMU for which the efficiency is calculated. λ_j indicates the non-negative weights that are optimised for each DMU. The weights measure the location of an inefficient DMU if it was to become technically efficient. The restriction, $\sum_{j=1}^{n}\lambda_j \leq 1$, specifies variable returns to scale. δ_i is greater or equal to one and represents the efficiency score that measures the technical efficiency of the i-th DMU as the distance to the efficiency frontier. The efficiency frontier is a linear combination of best practice observations. DMUs with $\delta_i = 1$ are on the efficiency frontier and are considered to be technically efficient. DMUs with $\delta_i > 1$ are inside the efficiency frontier and are considered to be inefficient.

The production inputs that were used to estimate the DEA-technical efficiency scores (*X* (*i* x *j*)) include the amount of Nitrogen (N), Phosphorus (P), Potassium (K), and labour. N, P, and K were measured as the quantity in kilograms that was applied per hectare during the 2012 crop season. Labour was measured in man-day per hectare which represents the number of labour days that were used per hectare during the season to produce maize output.

Step 2

Use the maximum likelihood method to obtain an estimate $\hat{\beta}$ of β and also an estimate $\hat{\sigma}_\varepsilon$ of σ_ε from the truncated regression of the estimated efficiency scores ($\hat{\delta}_i$) on environmental variables (z_i) using the observations when $\delta_i > 1$.

The environmental variables (z_i) are principal components that were extracted from the original variables that were hypothesised to influence the technical efficiency levels of the smallholder maize irrigation farmers. The procedure to extract the principal components starts with the standardisation of the hypothesised explanatory variables. All of the standardised variables have averages of zero and standard deviations of one. The standardised explanatory variables then are used in a principal component analysis to calculate Eigen vectors that are used to construct the principal components. Following the

Kaiser-Gutman Rule only principal components with Eigen values greater than one are included in the regression analysis.

Table 3.7 below shows the Eigen values of the principal components of the variables that were initially hypothesised to influence the technical efficiency of the smallholder maize irrigation farmers at the Etunda Irrigation Project.

Table 3.7: Summary of Eigen values of principal components to identify the number of principal components to include in the analysis of the determinants of technical efficiency of smallholder maize farmers.

Principal component	**Eigen value**	**Individual percentage**	**Cumulative percentage**
1	**0.972272**	10.80	10.80
2	**1.003834**	11.15	21.95
3	**1.001786**	11.13	33.08
4	**1.002838**	11.14	44.22
5	**1.005231**	11.17	55.39
6	**1.002823**	11.14	66.53
7	**1.012381**	11.25	77.78
8	**1.004460**	11.17	88.95
9	**0.994375**	11.05	100.00

Table 3.7 shows that seven of the nine principal components have Eigen values greater than one. However, two of the principal components have Eigen value of at least 0.9, which is near one and each contributing about 11 % to explaining the variations within the explanatory variables included in the analysis. It was therefore decided to include these two variables in the analysis on the basis that their Eigen value is closer to 1. Cumulatively, the seven principal components, which have at least 1 Eigen value, explain 78 % of the variation in the explanatory variables that are included in the principal components. Based on the Eigen values in Table 2 of at most 1 and above, all nine principal components are included in the truncated regression analysis in Step 2 to obtain estimates $\hat{\beta}$ of β and $\hat{\sigma}_{\varepsilon}$ of σ_{ε}.

Step 3

Loop over the next four steps ([3.1]-[3.4]) L_1 times to obtain *n* sets of bootstrap estimates $\left\{\hat{\delta}^*_{ib}\right\}_{b=1}^{L_1}$:

3.1) For each *i* =1, ... ,*n*, draw ε_i from the *N*(0, $\hat{\sigma}^2_\varepsilon$) distribution with left truncation at (1- $z_i\hat{\beta}$).

3.2) Again for each *i* =1, ... ,*n*, compute $\delta^*_i = z_i\hat{\beta} + \varepsilon_i$

3.3) Set $x^*_i = x_i$ and $x^*_i = y_i\hat{\delta}_i / \delta^*_i$ for all *i* =1, ... ,*n*

3.4) Compute $\hat{\delta}^*_i$ using the bootstrap samples of x^*_i and y^*_i from step [3.3].

Simar and Wilson (2007) noted that 100 bootstrap replications prove to be sufficient to estimate the bias-corrected technical efficiency scores ($\hat{\hat{\delta}}_i$) in Step 4. L_1 in Step 3 and it's thus set to 100.

Step 4

Compute the bias-corrected efficiency scores, $\hat{\hat{\delta}}_i$, for each *i* = 1, ... , *n* using the bootstrap estimates in step [3.4] and the original estimate $\hat{\delta}_i$. The bias-corrected efficiency score is calculated as follows:

$$\hat{\hat{\delta}}_i = \hat{\delta}_i - bi\hat{a}s_i$$

Where $bi\hat{a}s_i$ is the bootstrap estimator of bias obtained by the formula (Simar and Wilson, 2000):

$$bi\hat{a}s_i = \left(\frac{1}{L_1}\sum_{b=1}^{L_1}\delta^*_{ib}\right) - \hat{\delta}_i$$

Step 5

Use the maximum likelihood method to estimate the truncated regression of $\hat{\hat{\delta}}_i$ on z_i to obtain estimates ($\hat{\hat{\beta}}, \hat{\hat{\sigma}}$) . Once again, the principal components of the explanatory variables are used as z_i in the truncated regression.

Step 6

Loop over the next three steps L_2 times to obtain a set of bootstrap estimates $\left\{(\hat{\beta}_b^*, \hat{\sigma}_b^*) \middle| b = 1, ..., L_2 \right\}$

6.1) For each *i* =1, ... ,*n*, draw ε_i from the *N*(0, $\hat{\hat{\sigma}}$) distribution with left truncation at (1- $z_i\hat{\hat{\beta}}$).

6.2) Again for each *i* =1, ... ,*n*, compute $\delta_i^{**} = z_i\hat{\hat{\beta}} + \varepsilon_i$.

6.3) Use the maximum likelihood method to estimate the truncated regression of δ_i^{**} on z_i to obtain ($\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*$) . The principal components of the explanatory variables are used as z_i in the truncated regression of δ_i^{**} on z_i to obtain ($\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*$) .

Jordaan (2012) concurred with Simar and Wilson (2007) who set L_2 to 2000 bootstrap replications with the aim of obtaining more accurate results. However, it was mentioned that, increasing the number of replications increases waiting time and diminishing returns arise slowly in the case of confidence interval estimation. Therefore, Jordaan (2012) followed the suggestion by Simar and Wilson (2007) that there is a need to balance the concern of higher number of replications and the increase in waiting period of the results. Below are the results from the truncated regression, as shown in Table 3.8.

Table 3.8: Truncated regression results of the bias-corrected technical efficiency scores on the nine principal components with Eigen values of at most or greater than one

Variable	Coefficient	Standard Error	z- statistic	Prob(z)
Intercept	-1.253	1.776	-0.705	5.099E-01
ZPC1	-2.918***	0.902	-10.988	3.375E-05
ZPC2	5.454***	0.889	6.130	8.609E-04
ZPC3	-3.697***	0.739	-5.002	2.446E-03
ZPC4	4.298*	2.103	2.043	8.707E-02
ZPC5	12.854***	1.059	12.127	1.909E-05
ZPC6	5.444***	0.360	15.086	5.346E-06
ZPC7	1.650	2.715	0.607	5.656E-01
ZPC8	14.240***	0.189	75.072	3.760E-10
ZPC9	-0.162**	0.055	-2.917	2.671E-02
ZPC10	-0.331**	0.104	-3.170	1.930E-02
ZPC11	0.175	0.106	1.640	1.520E-01
ZPC12	0.260**	0.103	2.517	4.542E-02
ZPC13	0.118	0.102	1.163	2.889E-01
ZPC14	-0.077**	0.030	-2.524	4.5001E-02

Note: ***, **, and * indicate statistical significance at 1 %, 5 % and 10 %, respectively.

The regression results in Table 3.8 indicated that six of the variables are statistically significant at 1 %, four variables at 5 % and one variable is significant at 10 %. This suggests that these principal components are significant in explaining the variation in the bias-corrected technical efficiency scores of the smallholder maize irrigation farmers at Etunda Irrigation Project. Three variables were found to be insignificant in explaining the variation in the bias-corrected technical efficiency scores of the smallholder farmers.

Following the procedures used by Jordaan (2012), as discussed by Khaile (2012) and Magingxa (2006), the coefficients ($\hat{\hat{\beta}}^*$) and standard errors ($\hat{\hat{\sigma}}^*$) from the truncated regression analysis are used to calculate the coefficients of the individual standardised variables that were included in the principal components and the standard errors of the coefficients of the standardised variables. In order to get un-standardised coefficients, the coefficients of the standardised variables are divided by the standard deviations of the original explanatory. In the same vein, un-standardised standard errors are also obtained by dividing the standard errors of the standardised coefficients by the standard deviations of the original explanatory variables. Jordaan (2012) noted that the un-standardised coefficients and standard errors are then used to calculate z-values and the probabilities of the z-values to determine the levels of significance of the respective un-standardised explanatory variables as determinants of technical efficiency.

Step 7

Using the bootstrap values ($\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*$) to construct (1- α) confidence intervals for each element of β and $\hat{\sigma}_\varepsilon$ as follows:

Prob $(Lower_{\alpha,j} \leq \beta_j \leq Upper_{\alpha,j}) = 1 - \alpha$

Where $Lower_{\alpha,j}$ and $Upper_{\alpha,j}$ are calculated using the empirical intervals obtained from the bootstrap values

Prob $(-\hat{b}_\alpha \leq \hat{\hat{\beta}}_j^* - \hat{\hat{\beta}}_j \leq -\hat{a}_\alpha) \approx 1 - \alpha$

And $Upper_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{b}_\alpha ; Lower_\alpha = \hat{\hat{\beta}}_j + \hat{a}_\alpha$

3.8 CONCLUSION

The objective of Chapter 3 was to discuss data collection procedures and analytical tools for the study. The data collection process was completed, all the smallholder maize farmers were interviewed, and data regarding their maize production activities was collected. The data collected included factors hypothesised to have an influence on technical efficiency of the farmers. This included variables in various categories, namely demographic, human capital, socio-economic, support services and farm-specific characteristics. Profiles of the respondents indicated that majority of farmers are young married females and have attained at least secondary education. Most of these farmers are members of farmers' organisations and are not involved in off-farm activities.

The DEA double bootstrap approach, along with the principal component framework, were found to be suitable and hence, chosen to be used in the analysis process for the study. The first stage of this procedure is to produce technical efficiency scores which will be followed by exploring determinants of technical efficiency by performing algorithm #2 in the second stage. The next section (Chapter 4) presents and discusses the results from the analysis of the technical efficiency for the smallholder maize farmers at the Etunda Irrigation Project.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The preceding chapter covered the data and procedures and set out the framework necessary for achieving the objectives of this study. Chapter 4 presents and discusses the results of the analysis on the technical efficiency scores, followed by a discussion on the determinants of` the technical efficiency of the smallholder maize farmers in the Etunda Irrigation Project. The last sub-section concludes the chapter by providing a summary of the findings of the study.

4.2 TECHNICAL EFFICIENCY ANALYSIS OF THE SMALLHOLDER MAIZE IRRIGATION FARMERS

4.2.1 TECHNICAL EFFICIENCY LEVELS OF THE SMALLHOLDER MAIZE IRRIGATION FARMERS

The bias-corrected technical efficiency scores of the smallholder maize irrigation farmers at Etunda Irrigation Project are shown as a Cumulative Probability Distribution Function (CDF) in Figure 4.1. It can be gathered that the estimated technical efficiencies for smallholder maize irrigation farmers varied from 36 % to 100 %. The mean technical efficiency score of the farmers under consideration is relatively high, at 76 %. This suggests that in general farmers are able to use their production inputs efficiently. The results further indicate that there is a potential in the short term for the maize farmers to increase their efficiency by 32 % through utilising existing farm resources better. The results for technical efficiencies found in this study are comparable to those of Gunda (2013), Maseatile (2011), Khaile (2012) and Jordaan (2012) who found mean technical efficiency scores of 77 %, 87 %, 81 % and 78 % respectively. The bias-corrected technical efficiency scores of the smallholder maize irrigation farmers are shown as a cumulative probability distribution in Figure 4.1.

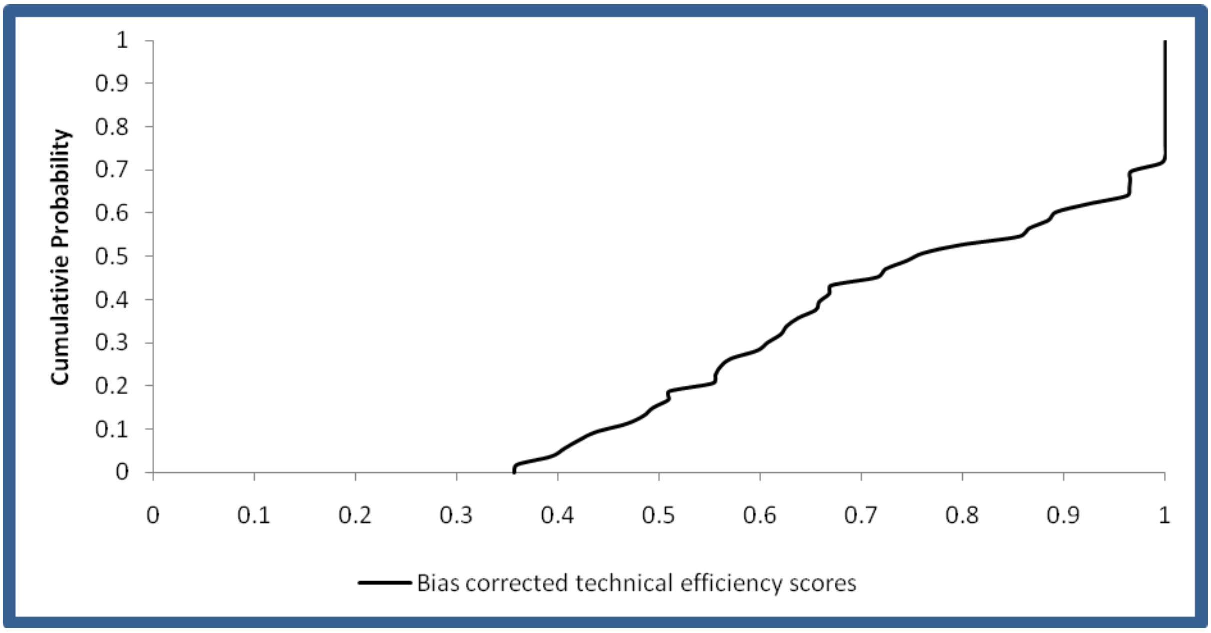

Figure 4.1: Cumulative probability distribution of the bias-corrected technical efficiency scores of the smallholder maize farmers at Etunda Irrigation Project

Results from the bias-corrected technical efficiency scores indicate that the small-scale maize producers in the Etunda Irrigation Project performed fairly well on the levels of technical efficiency. This demonstrates remarkable commitments made by farmers towards the maize farming business, particularly the manner in which they have used their production inputs. The average bias-corrected technical efficiency score is 0.76 and is quite high. Figure 4.1 further indicates that, 28 % of the respondents attained a technical efficiency score of one. Although there were very few farmers operating on the efficiency frontier, the results suggest that these farmers are efficient in the way they use their production inputs. This means that farmers with technical efficiency scores of one are operating on the efficiency frontier and are deemed to be efficient. A point can be made that, with the existing technology set and input levels, the technically efficient maize producers are unable to raise their outputs. However, these farmers may increase their current input levels and adapt new technology in order to increase their existing output levels.

The remaining 72 % of the respondents had technical efficiency scores of less than one and are therefore said to be technically inefficient. This suggests that, with the current technology set and existing input levels, the technically inefficient farmers have the potential to increase their maize output. For example, the most technically inefficient farmer with a technical efficiency score of 0.36 has to increase his or her current output by 178 % [i.e. (((1/0.36)-1*100 %)] in order to raise the technical efficiency score to a desirable level of one. However, there is a possibility that the technically inefficient small-scale maize farmers at Etunda Irrigation Project can increase their production efficiency by learning from their technically efficient counterparts. Figure 4.1 also indicates that there were no significant variations in the distribution of the technical efficiency scores for the farmers who attained efficiency scores below one.

In an effort to gain a better perspective of the distribution of the technical efficiency levels, this study classified farmers into three distinctive groups, namely top (score =1), middle (score = 0.5-0.99) and bottom (score less than 0.5). This classification is based on the farmers' bias-corrected technical efficiency scores. The analysis indicated that the top third group constituted 28 % of the respondents who obtained technical efficiency scores of one, with the average score of one. This observation suggests that farmers in this group are unable to increase their outputs, given their existing input levels and current technology set. So, if these farmers were to raise their input levels and acquire new technology, it would be possible for them to increase their outputs (Jordaan, 2012). Results of the analysis further indicate that the middle category of the respondents constitute 56 % of the respondents, with a relatively high average technical efficiency score of 0.73. This average suggests that the middle third group of respondents could expand their output levels by 37 % if they were to improve their technical efficiency level to one. The bottom third group of farmers, on the other hand, constituted 16 % of the farmers who achieved an average technical efficiency score of 0.42. This means that these maize producers in the bottom third group, on average, could increase their output levels by 138 % if they were to enhance their technical efficiency levels to one.

However, Jordaan (2012) cautioned that, the increase should be made with diligence and with no additional costs being incurred. Jordaan (2012) advised that the possible extension should be viewed in the context of the existing input levels and current technology used. Therefore, mechanisms to improve the technical efficiency levels of the middle and bottom third groups of small-scale maize farmers at Etunda Irrigation Project may have significant impacts on their financial performance. Thus, there is a need to devise mechanisms to help the middle and bottom third groups to increase their output levels, as well as to use their production inputs efficiently using the existing technology, probably by learning from the top third group of maize farmers who have showed some levels of efficiency in converting the production inputs into maize.

4.2.2 EXPLORING THE DETERMINANTS OF TECHNICAL EFFICIENCY OF THE SMALLHOLDER MAIZE IRRIGATION FARMERS

The regression analysis results of the bias-corrected technical efficiency scores on the factors hypothesised to affect the levels of technical efficiency of the smallholder maize irrigation farmers in Etunda Irrigation Project are presented in Table 4.1.

Table 4.1: Results of the truncated regression of the bias-corrected technical inefficiency scores on its determinants in the double-bootstrap approach

Variable	Coefficient[1]		Standard error	z-statistic	Prob(z)
Human and Socio-Capital					
Age	-0.331	**	0.104	-3.170	0.019
Level of education	0.677		1.051	0.644	0.523
Extension contact	2.377	**	1.176	2.021	0.049
Arithmetic ability	0.175		0.106	1.640	0.152
Maize farming experience	0.654		1.450	0.451	0.654
Attended training on maize production	0.077**		0.030	-2.524	0.045
Record keeping	0.118		0.102	1.163	0.289
Applied enough inputs	0.260**		0.103	2.517	0.045
Farm characteristics					
Plot size	-3.847	***	0.542	-7.092	0.001
Used manure	-3.733	***	0.549	-6.803	0.001
Planted in October	20.615	***	0.783	26.329	0.001
Planted in December	-0.976		0.656	-1.488	0.144
Financial characteristics					
Market Access	-1.625	*	0.926	-1.756	0.086
Off-farm Income	2.051	**	0.881	2.328	0.025

Note: 1. The dependent variable is a reciprocal of the technical efficiency score; hence a negative sign of the coefficient implies a positive relationship between the explanatory variable and the level of technical efficiency of smallholder maize farmers in Etunda Irrigation Project.

2. ***, **, and * indicate statistical significance of 1 %, 5 % and 10 % respectively.

The results indicated that most variables in all three categories that were considered to have an effect on the levels of technical efficiency of smallholder maize producers in the study area do contribute significantly to high levels of technical efficiency. In the human and socio-capital group, age carries a negative sign and is significant ($p<0.05$). This suggests that the older the farmer is, the higher his or her technical efficiency levels are. This result is in agreement with the initial hypothesis that older farmers tend to be more efficient through learning experience and made efforts to put mechanisms in place in order to minimise production inefficiencies. The results concur with the findings of Maseatile (2011), Jirgi (2013) and Chiona (2011) who found a positive relationship between the technical efficiency and the older smallholder maize producers. The studies concluded that older farmers are more efficient than the young ones are. However, these results contradict the findings of Mulinga (2013) and Abdulai and Huffman (2000), who found that younger farmers were more efficient in maize production than the older ones were.

The coefficient of extension contact showed a positive sign and is significant ($p<0.05$). This suggests a negative relationship with technical efficiency. The result contradicts the earlier hypothesis which suggests that the more frequent the extension contacts with a farmer are, the higher the level of technical efficiency will be. These results contradict the findings of Amaza *et al*. (2006) and Seyoum *et al*. (1998) who both reported positive influences of extension contacts on productivity of maize farmers. The results might be suggestive of a possible weakness in or poor quality of the extension services being rendered to the smallholder farmers, which are supposed to help them improve the level of their technical efficiency. Accordingly, this calls for a review of the quality of extension services being offered to the farmers and subsequently making the necessary improvements in both quality and time of delivery of this service to the smallholder maize farmers in the Etunda Irrigation Project.

The attending of training sessions on maize production variable showed a negative sign and is significant ($p<0.05$). This suggests a positive association between training and high levels of technical efficiency of the maize producers in the study area. This result is in line with the hypothesis that regularly attending training sessions on maize production is likely to increase the efficiency of the farmers in the way they use their production input as compared with those who did not attend. Training improves the acquisition and utilisation of information on improved technology in agricultural production, which will in turn enhance the competence of the farmers in using production inputs efficiently. The result is consistent with the findings of Tefaye and Beshir (2014) who found a positive relationship between capacity development of a farmer and high levels of technical efficiency. Therefore, it is important to strengthen the training of farmers and to put mechanisms in place to encourage farmers to attend regular training sessions which will enhance their productivity.

In the farm characteristics category, the plot size and the use of livestock manure have a negative signs as expected. The negative sign, which is significant at 1 %, suggests a positive relationship of these variables with high levels of technical efficiency. This indicates that farmers who were given additional three hectares in addition to the standard three-hectare plots (totalling six hectares) are more efficient in maize production than their counterparts with only three hectare plots are. This result corroborates the findings by Amos (2007), Byiringiro and Reardon (1996), Chirwa (2003), Barnes (2008), Raghbendra *et al*. (2005), and Tadesse and Krishnamurthy (1997), who observed a positive association between plot size and the technical efficiency of the farmers. These studies concluded that there is a need to allocate more land and also to improve extension services to the farmers in their respective study areas.

Similarly, the findings on the use of livestock manure indicate a negative sign, which is significant ($p<0.01$). The negative sign suggests a positive relationship between the use of livestock manure and the high levels of technical efficiency of the maize producers. This is in accordance with the earlier hypothesis that farmers who use livestock manure more regularly in addition to chemical fertilisers are likely to be more efficient than those are who use chemical fertilisers only. The results concur with the findings of Mutoko *et al*. (2015) and Sauer and Tchale (2007), as well as those of Weight and Kelly (1998), who noted that farmers who use both livestock and chemical fertilisers are more efficient than those using chemical fertilisers alone. Livestock manure not only provides nutrients to crops, it also improves the microbial activity, aeration, and water holding capacity of the soil, thereby improving growing conditions for the crops (WASET, 1999).

The time of planting maize early in the season (October) carries a positive sign and is significant at 1 %. This suggests a negative relationship between early planting of maize and the technical efficiency levels of the producers at Etunda Irrigation Project. This result conforms to the earlier hypothesis that planting early in the season is likely to require much irrigation water, since the rainfall has not yet established and crops will be solely dependent on irrigation; hence there will be high spending on irrigation water. Moreover, at that time of year, ambient temperatures are relatively high, increased evaporation rate and crops will require more water, which will only be obtained from irrigation. This finding suggests that farmers who plant their maize from December are likely to spend less on irrigation water, as most of the water required will be supplied by the rain. Therefore, it can be concluded that the smallholder farmers in the study area who plant from December are likely to be more efficient in the use of their production inputs than those are who planted early in October.

With regard to variables under financial characteristics, market access carries a negative sign and is significant ($p<0.10$). The negative sign suggests a positive relationship with the technical efficiency of the smallholder maize producers in the study area. This positive relationship conforms to the prior expectation which suggested that farmers who use various market options, other than confining themselves to the formal market, are more efficient in the use of their production inputs. The results concur with those of Maseatile (2011), Mutoko *et al*. (2015) and Chiona (2011) who also observed a positive association between farmers who access various market options and high levels of technical efficiency. This could be because of the better price offered outside the project compared with the price offered by the project, which allows farmers to boost their revenue from the sale of maize.

The off-farm income showed a positive sign and is significant at 5 %. The positive sign implied a negative relationship between off-farm income and the technical efficiency levels of the maize producers. The result is in accordance with the earlier hypothesis, also as argued by Abebe (2014), that participation in off-farm activities might be at the expense of own-farm activities in terms of less labour and time being devoted on farms, causing a negative relationship between technical efficiency and participation in off-farm activities. This result contradicts the findings of Kibirige *et al*. (2014) and Dlamini *et al*. (2012) who found a positive connection between off-farm incomes and the high levels of technical efficiency. The negative relationship suggested in the earlier hypothesis could be that engaging in non-farming activities which generate additional incomes may compromise the full attention and commitments of farmers in maize production, thereby reducing their efficiency.

4.4 CONCLUSION

The key objective of Chapter 4 was to present and discuss the outcomes of the analysis of the technical efficiency scores in the first stage and to examine the determinants of technical efficiency of the farmers in the second stage. Specifically, this chapter sought to quantify and gain an insight into factors hypothesised to influence the technical efficiency of smallholder maize producers at the Etunda Irrigation Project.

In summary, the main results from Chapter 4 indicated that the smallholder maize irrigation farmers in the study area are reasonably competent and are doing relatively well, with an average technical efficiency score of 0.72 being noted. However, the result showed that only 26 % of the respondents were operating on the frontier, thus being efficient in terms of the way they used their production inputs. Nonetheless, the results suggest that there is a room for improvement for the smallholder maize producers who are lagging behind and to increase their production efficiency significantly by utilising their existing farm resources better. The farmers who scored less than one constituted 74 % of the smallholder maize irrigation farmers in Etunda Irrigations Project, and they might possibility increase their technical efficiency levels by learning from their technically efficient counterparts.

With regard to the determinants of the technical efficiency, the results indicated that technical efficiency is linked with high levels of human and socio-capital, farm, and financial characteristics. Although a positive relationship is expected between the high levels of technical efficiency and human and socio-capital, farm, and financial characteristics, most variables under these categories complied with this expectation.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

5.1.1 BACKGROUND AND MOTIVATION

The importance of maize worldwide cannot be overemphasised, particularly in sub-Saharan Africa where it is used as a main source of food. Maize production in Africa is diverse, ranging from subsistence to commercial farming systems. Due to limited use of modern technology, low levels of education and poor access to finance in the subsistence farming system, maize productivity is always low. In Namibia, agriculture in general plays a crucial role in the national economy and in the livelihoods of over 70 % of the population (NPC, 2011). However, the main challenge is its low contribution of 7.4 % to the GDP, as compared with other sectors of the national economy (NSA, 2013).

The Namibian Government, after attaining independence in 1990, developed the National Agricultural Policy to guide the development and advancement of the agricultural sector. Among other things, the policy provides an enabling environment for increased food production by smallholder producers, a means of improving employment opportunities and incomes, household food security, and the nutritional status of all Namibians (MAWRD, 1995). Maize is the largest grain crop produced in Namibia, by both subsistence and commercial farming systems, and remains the foremost staple food crop in the country. Despite efforts to increase maize production, Namibia remains a net importer of maize to meet its domestic requirements and imports approximately 60 % of its national maize requirements, most of which comes from South Africa (NAB, 2013).

The main cereal crops produced in Namibia include pearl millet (mahangu), white maize, wheat, and sorghum most of which are grown under rain fed conditions. The crop farming system carried out in both the commercial and communal areas. The major communal crop producing regions are found in the northern part of Namibia and include: Zambezi, Kavango East, Kavango West, Omusati, Ohangwena, Oshana and Oshikoto regions. Cereal crop production in the two farming systems under normal circumstances constitute about 60 % of the national total cereal requirements, while the remaining 40 % is obtained through commercial imports (MAWF, 2009). In order to improve the technical efficiency of the farmers, there is a need to teach farmers on how to use their production inputs efficiently. Geta *et al*. (2010) advised that an understanding of the relationships between productivity and farmer specific-practices can provide policy makers with information needed to design programmes that can assist in increasing the productivity potential of the farmers.

5.1.2 PROBLEM STATEMENT AND OBJECTIVES

Poor education, low income levels, inadequate access to credit, and poor extension services are some of the problems identified as contributing to low agricultural productivity among smallholder farmers. These problems have put pressure on farmers to use their inputs more efficiently, with the aim of maximising their outputs. In order to boost farmers' productivity, there is a need to raise productivity by helping farmers to minimise their technical inefficiencies. This topic concerning technical efficiency has received much attention from various scholars, internationally, who recommended various measures that would assist to enhance farmers' productivity.

Although no study was found on the technical efficiency of smallholder maize farmers in Namibia, this topic has been investigated over the years by many scholars. Among the scholars are Gunda (2013), Khaile (2012), Jordaan (2012), Maseatile (2011), and Mushunje *et al*. (2003). All these studies cited various factors related to certain attributes of individual farms and farmers' specific characteristics as having an impact on the levels of technical efficiency of the farmers. This study classified these characteristics into demographic, human capital, socio-economic, support services and farm characteristics categories. Currently, there is no information available on this topic detailing the situation Namibia which might be used to guide the efforts to reduce technical inefficiency of small-scale maize farmers.

Following Jordaan (2012) and Gunda 2013, this study used the double bootstrap DEA approach of Simar and Wilson (2007). This approach made considerations regarding bias correction of the technical efficiency estimates so that valid inferences could be made from the estimates to inform policy makers on appropriate interventions to increase farmers' productivity.

The main objective of this study was to explore factors that influence the technical efficiency of smallholder maize farmers in the Etunda Irrigation Project in the Omusati region. This objective was achieved by accomplishing the two sub-objectives. The first sub-objective was to quantify the technical efficiency and get an understanding of the various levels of technical efficiency among the smallholder farmers. The second sub-objective sought to explore the determinants of technical efficiency of the smallholder maize farmers in the study area using PCR and DEA double bootstrap approach of Simar and Wilson (2006).

5.2 LITERATURE REVIEW

A literature review was carried out to gain an insight on the importance of maize in the world. Literature revealed that, maize is one of the most widely produced crops in the world and is cultivated in the tropic, sub-tropic and temperate regions. The majority of people, particularly in developing countries use maize as their staple food crop. According to Corn India (2009), maize production is ranked third after wheat and rice. The top five major maize producing countries are the United States of America followed by China, Brazil, Argentina and India (FAO, 2010).

The literature noted that a large area is planted to white maize as compared with yellow maize in the developing countries. It was noted that an estimated 158 million hectares of land is under cultivation of maize worldwide FAO (2007). The literature further revealed that most maize in Africa is produced under rainfall conditions, mainly by smallholder farmers, and this renders the production vulnerable to the impacts of droughts, floods and other adverse impacts of weather patterns. The literature indicated that Africa was known to be self-sufficient in food production at the beginning of the independence movement, but subsequently experienced food crises between 1970 and 1985, and since then, the situation has not yet improved (Byerlee, 1997). Climate change, declining soil fertility, lack of access to inputs, low investment in research and extension and environmental factors are some of the major causes of low productivity, particularly in crop production in Africa (IBP, 2014). The literature suggests that there is a need to investigate and understand the relationships between productivity, technical efficiency and farm specific-practices in order to address the challenges faced by the farmers.

The concept of efficiency and its associated subjects needs to be pursued in order to achieve higher levels of productivity among the producers. The literature noted that there are two alternative models which are well documented and used to estimate technical efficiency. The one is Data Envelopment Analysis (DEA), which is a non-parametric model developed by Farrell (1957) and Charnes *et al*. (1978). The other is a parametric model, Stochastic Frontier Analysis (SFA), which was developed by Aigner *et al*. (1977), and Meeusen and Van den Broeck (1977). These approaches have been heavily criticised because of their weaknesses which may have significant impacts on inferences made from studies which used these approaches.

However, a double bootstrap approach developed by Simar and Wilson (2007) was introduced in the second stage of DEA in order to overcome the shortcomings. Therefore, based on this development, this study used the DEA double bootstrap approach in order to achieve its objectives. The study discussed various factors, such as demographic, human capital, socio-economic, support services, and farm characteristics, which were considered to have an influence on the technical efficiency levels of the farmers.

5.3 DATA AND PROCEDURES

5.3.1 STUDY AREA AND DATA COLLECTION PLAN

The study was carried out at the Etunda Irrigation Project which is located in the Omusati region in northern Namibia. The Etunda Irrigation Project is one of the government's green scheme projects established to increase food production in the country under irrigation. The project has a size of about 600 hectares and is split into two halves for commercial and smallholder farming systems. Maize is the main cereal crop produced by both commercial and smallholder farming systems. This study focused on the smallholder maize farmers in the project.

Data was collected through a field survey covering all the smallholder maize farmers in the study area at the time of the study. A structured questionnaire was used to collect data to be used in the study, covering the following thematic areas. These areas included household demographics, human capital, maize production activities, input use and yield, marketing, extension contacts and training, as well as access to credit. The areas covered made it possible for the study to achieve its objectives. Studies by Khaile (2012), Tshilambilu (2011), Maseatile (2011), and Van der Merwe (2012) provided the foundation for the design of the questionnaire used in this study. The extension officials in the project played a critical role in the facilitation of the farm interviews. After the data collection exercise has been completed, data entry, cleaning and analysis procedures were performed. However, due to some shortcomings which resulted from incomplete data received from some farmers, only 83 % of the questionnaires were analysed and used in the study.

5.3.2 CHARACTERISTICS OF THE RESPONDENTS

The study presented and discussed the characteristics of the respondents of the smallholder farmers in the Etunda Irrigation Project. According to the results, the majority of the smallholder maize farmers in the younger categories were female, which suggests that young males are reluctant to participate in the farming activities. However, in the older category, the majority of farmers (76 %) were male. The results further indicated that most of the smallholder maize farmers in the study area were married. It was further noted that the majority of the farmers attained at least secondary education level. Over 43 % of the smallholder maize farmers in the study area are not members of any farmers' organisations while only a few were active members to farmers' organisations. It was also noted that, the majority of farmers (82 %) are solely dependent on their farm income, while the remaining farmers received off-farm income.

As regards financial record-keeping, the analysis indicated that the majority of the farmers often keep their financial records up-to-date and use them in making decisions. The results have also indicated that over 91 % of the smallholder maize farmers usually contact their project extension officials for advice. About 89 % of the smallholder farmers indicated that they had attended all the trainings sessions concerning maize production. With regard to input use, 55 % of the farmers indicated that they had applied sufficient inputs for their maize production. The results also show that the majority of the farmers in the project do not use livestock manure and that only 24 % of the farmers indicated that they use livestock manure to supplement fertilisers. For the pesticide application, most farmers indicated that they have applied up to one litre of pesticides per hectare. The results have also indicated that most farmers do send soil samples for their crop fields, at least once in a while, for analysis. It was noted that the majority of farmers planted their maize during the summer season. Most farmers showed an excellent arithmetic ability which could suggest high levels of technical efficiency. On the marketing of maize, majority of farmers indicated that, they only sell their maize to the project, while about 46 % of farmers sold their maize to both the project and the market outside the project. The results further show that about 29 % of the smallholder farmers were given an additional 3 hectares to add to their farming plots because of their high crop production, as well as the way in which they manage their crops. With regard to farming experience, the results indicated that about 65 % of the farmers have been farming with maize for between 11 to 15 years.

5.3.3 DATA ANALYSIS AND ANALYTICAL TOOLS

Microsoft Excel was used to produce descriptive statistics on the characteristics of the respondents. The study presented and discussed the factors hypothesised to influence the technical efficiency levels of the smallholder farmers in the study area. The DEA double bootstrap approach of Simar and Wilson (2007), as supported and followed by Gunda (2013) and Jordaan (2012), was used to produce the technical efficiency scores. This was followed by performing algorithm #2 to explore determinants of technical efficiency. Detailed discussion about the procedures on the DEA double bootstrap algorithm #2 within the Principal Component Regression (PCR) framework, as discussed by Gunda (2013) and Jordaan (2012) was presented in the study. Based on the Kaiser-Gutman Rule as followed by Gunda (2013) and Jordaan (2012), only the principal components with Eigen values greater than one are supposed to be included in the regression analysis. However, for this study only seven of the nine principal components have Eigen values greater than one. Nevertheless, the other two principal components were included on the basis that their Eigen value of 0.9 each is near to one. Therefore, nine principal components were included in the analysis.

5.4 RESULTS AND DISCUSSIONS

5.4.1 TECHNICAL EFFICIENCY ANALYSIS ON THE SMALLHOLDER MAIZE IRRIGATION FARMERS

5.4.1.1 TECHNICAL EFFICIENCY LEVELS OF THE SMALLHOLDER MAIZE IRRIGATION FARMERS

Results from the DEA double bootstrap approach revealed that the mean technical efficiency score of smallholder maize farmers in the study area was 76 %. This mean technical efficiency level is relatively high and comparable with the findings from other researchers. The result suggests that in the short-term, there is a potential for the maize farmers to increase their efficiency level by 32 %, using the existing resources even better within their existing technology set. The results further noted that although the mean technical efficiency is relatively high, only about 28 % of the smallholder farmers are operating on the efficiency frontier. This suggests that technical inefficiency among the remaining 72 % is a cause for concern and needs to be addressed. The study noted that one of the approaches would be to come up with mechanisms to assist the underperforming farmers to learn from their technically efficient counterparts.

The study also made further analysis of the smallholder farmers by classifying them into tree distinctive groups, namely top, middle and bottom groups based on their efficiency scores. The results of this analysis revealed that the top third group forms 28 % of the farmers who achieved technical efficiency score of one and are efficient. The middle category constituted 56 % of farmers with an average technical efficiency score of 0.73. The bottom group category represents 16 % of the smallholder maize farmers with an average technical efficiency score of 0.42. The results further indicated that there is a need to devise means to assist the middle and bottom third groups on how to increase their output levels, as well as on how to use their production inputs efficiently within their existing technology set.

5.4.1.2 EXPLORING THE DETERMINANTS OF TECHNICAL EFFICIENCY OF THE SMALLHOLDER MAIZE IRRIGATION FARMERS

Results of the factors that were found to be the determinants of technical efficiency and have an influence on the technical efficiency levels of the farmers were presented and discussed in the study. The results indicated that the expectations were that high levels of technical efficiency are associated with high levels of variables in the categories of human and socio-capital, farm, and financial characteristics. It was further noted that most of the variables under the abovementioned categories complied with this expectation. However, the study revealed that education, arithmetic ability, maize farming experience, and extension contacts in the human and socio-capital category did not comply with this expectation, and it is noted that there is a need to review the quality of extension services and make the necessary improvements.

Nonetheless, the results indicated that older farmers in the human and socio-capital category are more efficient in the way they use their production inputs. The results further indicated that, plot size and the use of livestock manure were found to have a positive contribution to the high levels of technical efficiency. It was also noted that the project extension support services should provide more land to farmers and devise strategies to assist farmers to acquire manure. Moreover, the results indicated that attending training sessions on maize production showed a positive relationship with high levels of technical efficiency.

The results have also showed that, planting early in the season (October) has a negative effect on the levels of technical efficiency of the farmers. The study therefore advises that the smallholder farmers should synchronise their maize production activities with the rainfall season in order to reduce costs related to irrigation. The results also indicated that access to both formal and informal markets can increase the levels of technical efficiency of the farmers, noting that farmers should be encouraged to make use of both formal and informal markets when selling their maize. It was also found that engaging in activities outside the farm in order to receive off-farm income can compromise the technical efficiency of the farmers. For this reason, the study advises that farmers should avoid venturing into off-farm activities and should be encouraged to redouble their efforts and resources for their farming activities.

5.5 RECOMMENDATIONS AND IMPLICATIONS FOR POLICY AND FURTHER RESEARCH

The results of this study provided the basis for recommendations aimed at improving the production efficiency of the smallholder maize farmers at the Etunda Irrigation Project in Omusati region in the northern Namibia. The recommendations are directed to farmers and policy makers, as well as researchers for further research.

5.5.1 RECOMMENDATIONS FOR FARMERS

The results suggest that there is room for the smallholder maize farmers in the Etunda Irrigation Project to reduce their technical inefficiencies.

- It was noted that the older farmers are more technically efficient than the younger farmers are. It is important for the new and inexperienced farmers to learn the techniques and practices from their older counterparts which can ensure efficiency in farming.
- The use of livestock manure was found to contribute to high levels of technical efficiency of the farmers. Farmers are therefore advised to use livestock manure to complement chemical fertilisers in order to increase their productivity.
- Planting maize during early in the season was noted to be one of the factors increasing inefficiency. Farmers are therefore advised to synchronise maize production with the rainfall season and to avoid planting during the dry season.
- The use of both formal and informal markets for selling maize is also one of the factors noted to contribute to high levels of technical efficiency. It is recommended that the smallholder maize farmers should make use of all these options when selling their maize.
- Engaging in off-farming activities to obtain off-farm incomes may affect the level of production efficiency of the farmers. Farmers are therefore urged to redouble their efforts and resources in their farming activities and to avoid engaging in off-farm activities which might compromise their efficiency levels.
- Attending training sessions on maize production activities can increase the level of production efficiency of the farmers. Farmers are encouraged to attend all available

training sessions in order to enhance their capacity concerning new technology and good practices which can assist them to increase their production efficiency.

5.5.2 RECOMMENDATIONS FOR POLICY MAKERS

- Strategies and mechanisms should be devised to promote and encourage farmers-to-farmer skills transfer so that inefficient farmers can learn from their older counterparts.
- There is a need to review the quality and timeliness of the extension services provided to farmers and makes the necessary improvements that will assist farmers to increase their production efficiency.
- There is a need to increase a farmer’s plot size from the standard 3 hectare plot to at most 6 hectares, and to encourage farmers to put more efforts in to their farming activities.
- The study also recommends that the project extension support services should devise programmes to:
    - Encourage farmers to use livestock manure to complement fertiliser compounds,
    - Support farmers to synchronise their maize production with the rainfall season,
    - Encourage farmers to use both formal and informal market options when selling maize, and
    - Advise farmers to avoid engaging in off-farming income activities and to attend training sessions regularly.

5.5.3 RECOMMENDATIONS FOR FURTHER RESEARCH

- With regard to further research, the contributions of economic and allocative efficiency to the overall productivity of the farmers, as has been noted by Gunda (2013), could not be explored. Therefore, there is potential for further research to be undertaken to determine the impacts of economic and allocative efficiency on the productivity of smallholder maize farmers in Namibia.

- Due to some shortcomings in the research design process, the issue of compliance with the best management practices was not fully explored. Variables, such as timely applications of fertilisers, timely irrigation, prevention of leaching and soil compaction, weeds and pest control, and other variables relating to the management of maize production, were not investigated. Therefore, further studies to explore these variables and their respective contributions to technical efficiency of the smallholder maize farmers are recommended.

- As suggested by Gunda (2013), concerning the potential role which leading firms in the agricultural industry can play, further research is also necessary to investigate the nature of incentives and conditions required to attract firms to collaborate and support smallholder farmers in the marketing of their produce.

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APPENDIX: A QUESTIONNAIRE

QUESTIONNAIRE	
All information provided herein will be treated strictly confidential	
TECHNICAL EFFICIENCY OF WHITE MAIZE SMALL SCALE FARMERS IN ETUNDA IRRIGATION PROJECT	
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Instruction :

- This questionnaire should be completed by the interviewer/ researcher on behalf of the principal decision maker :
- Please Tick ☑ or otherwise where appropriate fill the information in the shaded area

A. HOUSEHOLD DEMOGRAPHIC INFORMATION		
A.1 Respondent number ……………………		
A. 2 Gender of the Principle Decision Maker	Male	1
	Female	2
A.3 Marital status of the principle decision maker	Single	1
	Married	2
	Divorced	3
	Widower	4
A. 4 Age of the principle decision maker		……….years

B. HUMAN CAPITAL						
Education						
B.1 Please indicate the number of years of formal education you have completed **(e.g. Grade 7= 7 years, Grade 12 = 12 years, 3 year tertiary = 15 years)**	……….years					
Knowledge and Farming Experience						
B.2 Please indicate your arithmetic abilities	**Very poor**					**Excellent**
	0	**1**	**2**	**3**	**4**	**5**
B. 3 How many years have you been farming as the main decision maker?	….……….. years					
B. 4 How many years have you been engaged in maize production?	……. ……years					
B.5 Are you a member of any farmers organisation?	No	Yes, but Inactive	Yes, active			
	1	2	3			
B.6 If "Yes" to B.5, Name the Organization	Name: ……………………………………………………					

C. MAIZE PRODUCTION ACTIVITIES					
Planted area					
C.1 How big is the plot or crop farming area in hectare (ha) allocated to you	………….ha				
C.2 How many hectares (ha) have you planted maize for the 2011/2012 crop season	………….ha				
C.3 When did you start planting maize in 2011/2012 cropping season?	August	September	October	November	December
	1	2	3	4	5
C.4 During the 2011/2012 crop season, what was the distance in cm between:	Rows ____cm Plant ____cm	Don't know Don't know			
C.5 What was the seed depth in cm	**____cm**	Don't know			

C. 6 How often do you do soil analysis?	**never**	**Every year**	**Every 3year**	**Once in a while**	**Other (specify)**
	0	**1**	**2**	**3**	**4**

D. INPUT USE & YIELD					
D.1 Where applicable, please indicates amount of input used in production of maize for the 2011/2012 crop season.					
INPUTS		**Don't know**	**Amount/ha**	**Amount total**	
D.1.1 Water			Irrigation	irrigation	
D.1.2 Fertilisers :	D.1.2.1 NPK (specify the ratio)……………………..		____kg/ha	____kg	
	D.1.2.2 LAN (specify the ratio)…………………….		____kg/ha	____kg	
	D.1.2.3 Others (name & specify ratio)………………		____kg/ha	____kg	
D.1.3 Maize seeds			____kg/ha	____kg	
D.1.4 Livestock manure			____kg/ha	____kg	
D.1.5 Compost			____kg/ha	____kg	
D.1.6 Pesticide			____l/ha		
D.1.7 Other (specify)………………………………………			____/ha		
D. 2 In your opinion, did you apply a sufficient amount of inputs to obtain optimal yield?				Yes	1
				No	2
LABOR					
D. 3 How many family members and relatives worked in maize production unpaid during the 2011/2012 crop season?				___people	
D. 4 Indicate the number of labourers you have employed and days they worked during the 2011/2012 crop season?		**Weeding:** Permanent : ____ people for ____ days Casual : ____ people for ____days			
		Harvesting: Permanent : ____ people for ____ days Casual : ____ people for ____days			
D. 5 Number of times you weeded (manual/mechanical/chemical)				____times	

YIELD			
D.6 Which month did you harvests your maize in 2011/2012 crop season?			
Green Maize		**Dry maize**	
Month	…………………………	Month	………………………………

D.7 How much maize have you harvested in the whole field during the 2011/2012 crop season?	
Green maize	____cobs
Dry maize	____kg
D.8 Please indicate method used to harvest dry maize in 2011/2012 crop season.	
Hand picking	1
Combined harvester	2

E. MARKETING		
E.1 Please indicate type of market you have access to for your maize produce		
Formal market		1
Informal market		2
Both formal and informal market		3
E.2 How did you sell your maize produce in 2011/2012 crop season?		
Cash		1
Credit		2
Other (specify)		3
E.3 During the 2011/2012 crop season, was there any maize that you could not sell?	Yes	1
	No	2
E.3.1 If yes to F3, what are the reasons?		
Too much maize and few buyers in the market		1

Maize quality is poor and not attractive to customers	2	
Other (specify) ……………………………………………………………………………………….	3	
E.4 Apart from you main market (Etunda Mills), are you selling your maize to other markets?	Yes	1
	No	2
E.4.1 If yes to F.4, name the markets :	Names: …………………………………………………………………………	
E.5 Are you one of the farmers who were given additional 3 ha because of high level of production obtained?	Yes	1
	No	2
E.5.1 If yes to F.5, For how long ago you were given this additional area?	……….Years	
E6. Please indicate the proportion of your total income (farm + off-farm) coming from the following activities:		
Income generating activities	**%**	
Off-farm economic activities		
Maize production		
Vegetables production		
Livestock production		
Others (specify)		
Total	**100 %**	

F. FINANCIAL RECORD					
F.1 On a scale from 1 – 5, please rate the following statements with regard to financial record keeping					
Statement	**Not at all**				**100 %**
F.1.1 I make sure that my financial statements are kep*t* up to date	1	2	3	4	5
F.1.2 I use my financial records in decision making	1	2	3	4	5

G. EXTENSION CONTACTS AND TARINING

G .1 Who do you consult when you need advice on maize production	
The project Extension officer	1
Fellow farmers	2
Others (specify)	3

G. 2 To what extend do you agree with the following statement?						
G.2.1 The extension officers are always available when you need them	Never					Always
	0	1	2	3	4	5

G. 3 Did the project extension officers provided you training on maize production?		
	Yes	1
	No	2

G. 4 How many times did you receive training on crop production in the last crop season (2010/2011)?		
	Yes	No
Daily	1	2
Weekly	1	2
Quarterly	1	2
Once in a while	1	2
Never	1	2
Other (specify)	1	2

G. 5 Did you attended all the training sessions you have indicated above?		
	Yes	1
	No	2

G. 5.1 If no to G.5 above, what were the reasons for not attending some of the training sessions?	
Was not around at the time of the training	1
I already know the content of that training	2
Others (specify)	3

G. 6 Do you think extension officers provided you with necessary skill needed for maize production?	
Yes	1

No	2

H. ACCESS TO CREDIT			
H. 1 Did you make use of external capital for maize production in 2011/2012 crop season?		Yes	1
		No	2
H. 1.1 If yes to H. 1, which source	Agribank loan	1	
	Other (specify)………………………………………	2	

APPENDIX B: PRINCIPAL COMPONENT REPORT OF EIGEN VALUE (FOR TECHNICAL EFFICIENCY)

Principal Components Report

Dataset Untitled

Eigenvalues after Varimax Rotation

No.	Eigen value	Individual Per cent	Cumulative Per cent	Scree Plot
1	0.972272	10.80	10.80	|||
2	1.003834	11.15	21.96	|||
3	1.001786	11.13	33.09	|||
4	1.002838	11.14	44.23	|||
5	1.005231	11.17	55.40	|||
6	1.002823	11.14	66.54	|||
7	1.012381	11.25	77.79	|||
8	1.004460	11.16	88.95	|||
9	0.994375	11.05	100.00	|||

Eigenvectors after Varimax Rotation

Variables	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9
Secondary	0.134534	-0.397927	0.500019	-0.40171	0.290717	-0.33736	0.302197	0.345754	0.054512
Exp	0.200163	-0.395816	0.178174	0.652813	-0.15363	0.371178	0.414075	0.085381	0.072329
Plotsise	-0.50626	-0.313806	-0.01878	0.007567	0.046757	-0.06161	0.198371	-0.2877	-0.71883
Manure	-0.51913	-0.088472	-0.17418	0.094328	-0.02921	-0.34687	0.333225	-0.24226	0.626533
mark access	-0.28339	0.234512	0.4763	-0.35849	-0.04192	0.634671	0.156962	-0.23315	0.160492
Off-income	0.227182	-0.390735	-0.34915	-0.15178	0.617702	0.306173	-0.08895	-0.3774	0.158533
Extension	0.085366	0.401138	0.437531	0.436867	0.506949	-0.26334	-0.02964	-0.34509	-0.05659
October	-0.41114	0.207387	-0.19907	0.164655	0.497727	0.240235	0.063856	0.641283	-0.0213
December	-0.32833	-0.408767	0.328203	0.184369	-0.02831	0.02627	-0.74116	0.067728	0.167321

Square of Eigenvectors after Varimax Rotation

Variables	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9
Secondary	0.0180994	0.1583459	0.250019	0.1613701	0.084516	0.113808	0.091323	0.119546	0.002971558
Exp	0.04006523	0.1566703	0.03174597	0.4261648	0.023601	0.137773	0.171458	0.00729	0.005231484
Plotsise	0.25630324	0.0984742	0.00035276	5.726E-05	0.002186	0.003796	0.039351	0.082768	0.516710818
Manure	0.2694918	0.0078273	0.03033867	0.0088978	0.000853	0.120321	0.111039	0.058688	0.3925436
market access	0.08030706	0.0549959	0.22686169	0.1285172	0.001757	0.402807	0.024637	0.054358	0.025757682
off income	0.05161166	0.1526738	0.12190433	0.0230378	0.381556	0.093742	0.007912	0.14243	0.025132712
Extension	0.00728735	0.1609117	0.19143338	0.1908528	0.256997	0.069348	0.000879	0.119087	0.003202768
October	0.16903199	0.0430094	0.03962687	0.0271113	0.247732	0.057713	0.004078	0.411244	0.00045352
December	0.10780256	0.1670905	0.10771721	0.0339919	0.000802	0.00069	0.549323	0.004587	0.027996317