TECHNICAL EFFICIENCY OF SMALLHOLDER PEARL MILLET FARMERS IN THE SEMI-ARID FARMING SYSTEM OF DODOMA, TANZANIA

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ABSTRACT

The objective of this study was to examine the level of technical efficiency of smallholder pearl millet producers and identify its determinants in the semi-arid farming system of Dodoma, Tanzania. A Translog stochastic production function model was used in the analysis. To specify technical inefficiency effects of socioeconomic variables, Maximum Likelihood Estimation (MLE) technique using cross sectional data collected from 300 randomly selected sample farmers in 2016 was applied. The MLE results revealed that land size under pearl millet cultivation and squared labour man days are the major factors influencing positively changes in the pearl millet output. The effect of land area on the output is positive and the coefficient is found to be significant, implying the economies of scale. The test result indicates that there is inefficiency in the production of pearl millet in the study area. The relative deviation from the frontier due to inefficiency is 67%. The average estimated technical efficiency for smallholder maize producers ranges from 0.18 to 0.91 with a mean technical efficiency of 0.78 (78%). The analysis also reveals that educational level of the farmer, experience of household head, and household size are the major socioeconomic factors significantly influenced farmers' technical efficiency and pearl millet output at 10%, 1% and 5% respectively. The implication of the study is that technical efficiency in pearl millet production in the study area could be increased by 22 percent through better use of available resources, given the current state of technology.

DECLARATION

I Nyamete Mgosi, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor concurrently being submitted in any other institution.

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Confirmation of the above declaration by;

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Dr. Khamaldini Mutabazi (PhD) Date

(Supervisor)

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DEDICATION

This work is dedicated to my beloved family (Nyamete Family) for their true heartfelt love and care they shown to me throughout my study period.

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LIST OF ABBREVIATIONS AND SYMBOLS

AE	Allocative Efficiency
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CD	Cobb-Douglas
DEA	Data Envelopment Analysis
DFID	Department for International development
ECA	East and Central Africa
ECOWAS	Economic Community of West African States
EE	Economic Efficiency
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical
ICRISTAT	International Crops Research Institute for the Semi-Arid Tropics
IFOAM	International Federation of Organic Agriculture Movements,
Kgs	Kilograms
Ln	Log Likelihood Function
LR	Log Likelihood Ratio
MAFC	Ministry of Agriculture, Food Security and Cooperatives
ML	Maximum-Likelihood
MLE	Maximum Likelihood Estimates
NAAS	National Academy of Agricultural Sciences
OLS	Ordinary Least Square
RSA	Republic of South Africa
SFA	Stochastic Frontier Analysis

TE	Technical Efficiency
TEI	Technical Efficiency Index
UA	Urban Agriculture
URT	United Republic of Tanzania
USD	United State Dollar
WCA	West and Central African

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet in Africa and the India subcontinent since prehistoric time (FAO, 2010). Pearl millet is the seventh most important cereal crop globally and an important coarse grain food crop in Africa and South Asia (ICRISAT, 2005).

Pearl millet, which is the seventh most important cereal crop in the world originated from central tropical Africa and is cultivated annually as a rain fed crop which is widely distributed across the drier or semiarid tropics of Africa and Asia (Lonewood Trust, 2013). The plant was domesticated as a food crop from 4 000 to 5 000 years ago along the southern margins of the central highlands of the Sahara (Lu *et al.*, 2009). Primarily a tropical plant, pearl millet is often referred to as the "Camel", because of its exceptional ability to tolerate drought; it can be grown where other cereals such as maize or wheat would not survive (ICRISAT, 2014a).

The crop is critically important particularly for food security in some of the world's hottest, driest cultivated areas; thus, it is a staple grain for about 90 million people living in the Semi-Arid Tropical Regions of Africa and the Indian subcontinent (Gulia *et al.*, 2007). There are estimated 24.2 million ha of pearl millet worldwide with approximately 45% of the world's production in Africa where pearl millet is of major importance in 17 countries (FAO, 2014).

According to FAO (2012), pearl millet is the fourth most grown cereal in Africa, with about 20.1 million tons produced annually in the arid and semi-arid tropical regions. India is the largest producer of pearl millet in Asia, both in terms of area of about 9 million hectares and production of 8.3 million tons with an average productivity of 930 kg/ha (Mula, *et al.,* 2010). West and Central African (WCA) regions have the largest area under millet (16.8 million ha) in Africa with the grain yield of 880 kg/ha, of which more than 95% is pearl millet and finger millet.

In Eastern and Southern Africa, pearl millet is cultivated on about 2 million ha and whose productivity increased from 800 kg/ha in 1970 to 920 kg/ha in 2006 (Mula, *et al.,* 2010). Despite limited investments in improved crop management, Tanzania's average pearl millet yields are among the highest in Eastern and southern Africa (Rohrbach and Kiriwaggulu, 2001). The country produced about 243 729 tons of pearl millet on about 293 554ha of land in 2011/2012 (MAFC, 2012). This reflects the relatively long growing season and favourable soils which are found in the country's pearl millet production zones (Rohrbach and Kiriwaggulu, 2001).

Pearl millet production in Tanzania is concentrated in the drought-prone areas of Dodoma, Singida, and Shinyanga as it can withstand periods of heat stress better than sorghum (Rohrbach and Kiriwaggulu, 2007). In Tanzania particularly in areas where rainfall is scarce, small household farmers are engaged in pearl millet production. They produce over 200 000 tons of pearl millet per year. The crop is the fourth most widely grown cereal grain crops in the Tanzania (Rohrback and Kiriwaggulu, 2007). Pearl millet is important for food security in the central high plateau of Singida and Dodoma regions of Tanzania (Monyo *et al.,* 2002).

Despite that pearl millet is among the drought resistance crops grown in arid and semi-arid areas such as Dodoma and Singida, and apart from its significant role in food security, national production quantity has been declining in thousands of tons in Tanzania (FAOSTAT, 2016). Productivity is a function of the differences in the scales of operation, production technologies, operating environment and operating efficiency (Mussa *et al.*, 2015). An increase in production depends mainly on the efficient use of available appropriate technologies and not necessarily on the adoption rates of new technologies. To achieve higher productivity, technological innovations though necessary are not sufficient; efficient use of old technologies are also necessary (Chiona, 2011).

If farmers are not using the existing technologies efficiently, then the ways of improving efficiency will in a short run be more cost effective than introducing other technologies. Technical inefficiency may be a result of managerial incompetence and therefore efficiency differences can be explained in the context of the presence of absence of management characteristics such as training, experience, and motivation (Ahmed *et al.*, 2005).

Therefore, improving efficiency in production allows farmers to also increase productivity. It should be noted that variation in production among smallholder farmers may be caused by various factors, which include regional and farm specific socio-economic factors.

1.2 Problem Statement and Justification

The future of pearl millet enterprise is linked to its contribution to food security, income growth, and poverty alleviation. Attaining these outcomes is more relevant in developing countries in the African continent than in developed nations (Chepng'etich *et al.*, 2014).

According to FAO data based on input methodology national production quantity of millet has been decreasing from 397,069 tons in 2011 to 312,352tons in 2016 which is a bad sign to food security and income of pearl millet farmers (FAOSTAT, 2016).The decreasing trend in the production of this vital cereal crop in food security is of great concern to planners and policy makers in the county.

Despite that the drought tolerant pearl millet crop has the ability of thriving well in arid and semi-arid regions and with lower input requirements compared with most staple cereals such as maize, there are limited studies that aimed at quantifying the current level of technical efficiency so as to estimate losses in pearl millet production: Such losses which could be attributed to inefficiency resulting from differences in socioeconomic characteristics and management practices.

However, previous studies on pearl millet focused on other aspects such as increasing utilization of sorghum and pearl millet based food in Tanzania (DFID, 2010), adoption of improved technologies for sorghum and pearl millet production in Dodoma central part of Tanzania (Mwanga, 2002), pearl millet marketing and value chain: the value chain approach (Charles, 2013), determinants for local pearl millet consumption (Abdallah, 2013), and commercialization prospects of sorghum and pearl millet in Tanzania (Rohrbach and Kiriwaggulu, 2007). None of these studies however concentrated on assessing pearl millet technical efficiency and thus little is known about technical efficiency of smallholder pearl millet producers in Tanzania.

Understanding the levels of inefficiency or efficiency can help address productivity gains if there are opportunities to improve socio-economic characteristics and management of the available resources (Kikuchi *et al.,* 2017).

Therefore, the aim of this study is primarily to provide insights into technical efficiency of pearl millet production in two villages in Chamwino District in the semi-arid region of

Dodoma in Central Tanzania. This information would help in identifying avenues for possible policy interventions towards improving pearl millet production in Tanzania. Increasing pearl millet productivity would have a profound positive affect to the household food security and income of the majority of smallholder farmers growing pearl millet.

1.3 Research Objectives

1.3.1 General objective

The main objective of the study was to assess the technical efficiency of smallholder pearl millet farmers in semi-arid farming system of Dodoma, Tanzania.

1.3.2 Specific objectives

i. To analyse the level of technical efficiency of smallholder pearl millet farmers in Chamwino, Tanzania.

ii. To analyse the factors affecting technical efficiency of smallholder pearl millet farmers in Chamwino, Tanzania.

1.4 Research Hypotheses

i.The level of technical efficiency of smallholder pearl millet farmers in Chamwino, Tanzania is low.

ii. Social-economic factors have no significant influence on technical efficiency of smallholder pearl millet farmers.

1.5 Significance of the Study

The present study generates information that would be useful in increasing pearl millet production in the study area and in other areas with similar conditions. This would be possible through the identification of factors that determine the production of pearl millet and in designing strategies that would help in promoting pearl millet production, which would ultimately improve the livelihood of the farmers in semi-arid areas of the country. The potential users of this information are farmers, traders, food and feed processors, consumers, policy makers, and government and non-government organizations with a stake in pearl millet production. Furthermore, this study enriches the background information for further studies on pearl millet subsector.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Area under Pearl Millet Cultivation in Tanzania

Pearl millet covers about half of the land under cereal cultivation in semi-arid areas of Tanzania. Apart from sorghum; it is a crop on which farmers depend for their food (Letayo *et al.,* 1996). About 293 554 ha were under pearl millet production in different parts of the country in the year 2011/202 (MAFC, 2012).

Pearl millet is widely grown in three of the country's agro-ecological zones, which are the Central, Western, and Lake Zones. The major production areas are Dodoma and Singida in the Central Zone; Tabora in the Western Zone; Shinyanga, Mwanza, and Mara in the Lake Zone; and Lindi and Mtwara regions in the Southern Zone. Dodoma, Singida, and Shinyanga account for a large proportion of pearl millet planted area in Tanzania's agriculture sector (Monyo *et al.,* 2004).

Dodoma has about 22% of the total area under pearl millet production, Singida accounts for 10% and Shinyanga accounts for 7% of the total area under pearl millet production. Farmers have been growing the local pearl millet varieties and the most common variety is local landraces (Letayo *et al.*, 1996).

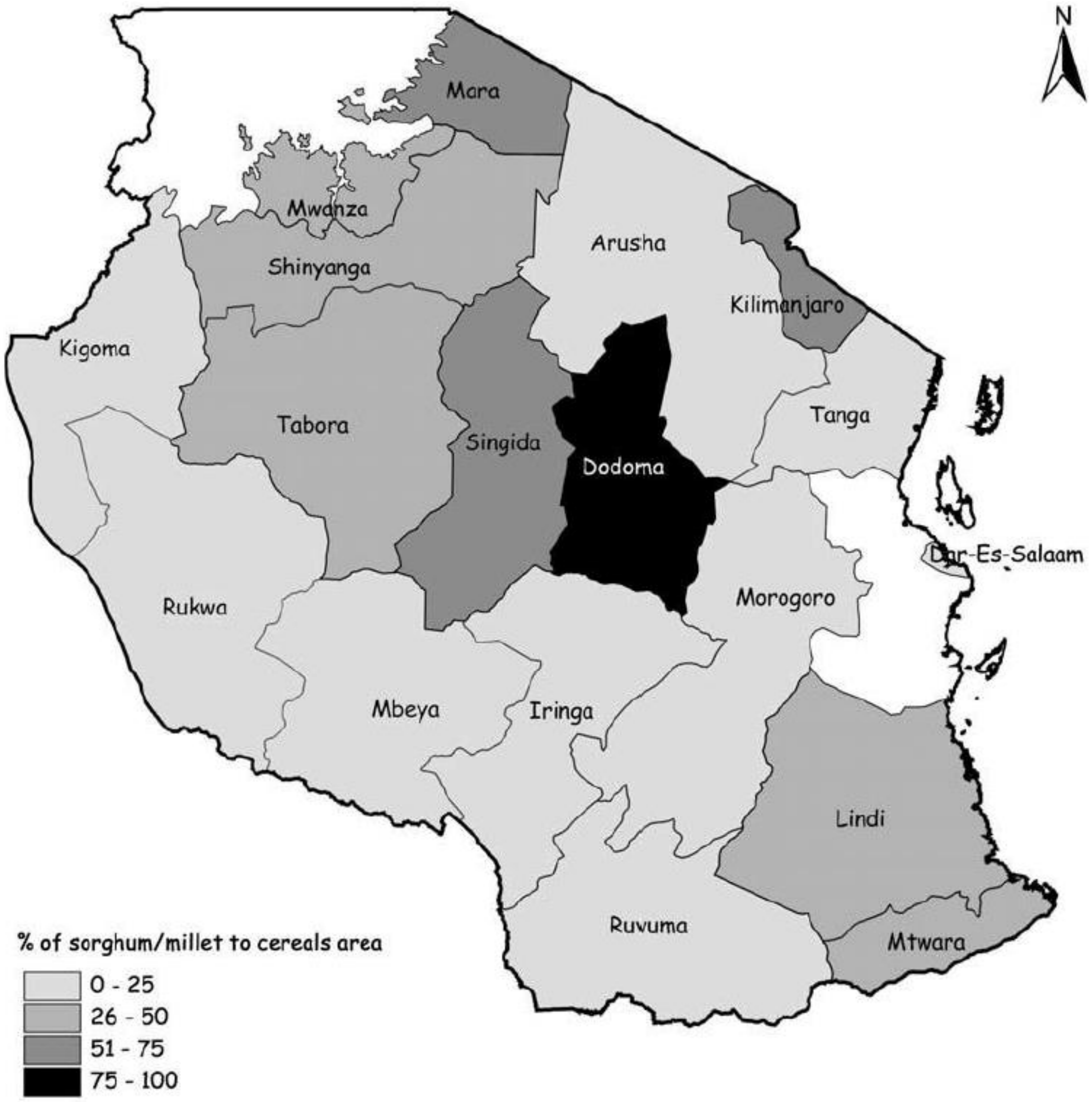

Figure 1: Map of Tanzania, showing regions and major cities.

Source: Monyo *et al.* (2004)

2.1 Pearl Millet Production Trend

India, Niger, Nigeria, Sudan, Mali, Burkina Faso, and Senegal are the major countries contributing to world pearl millet value chain covering 28 million ha of area under production with an output of 21.8 million tonnes (Murty *et al.*, 2007). Pearl millet value chain in the United State of America has been historically centered for forage and cattle grazing (FAO, 2000). In Brazil, it is estimated that over 2 million ha are committed into pearl millet value chain under "no till systems" (Murty *et al.*, 2007). Moreover, pearl millet is an important alternative crop in the Cerrado areas of the Central part of Brazil (Reddy *et al.,* 2000). Recent statistics reveal that there is a decline in millet area, production, and consumption in the primary millet growing regions of India during the rainy season largely due to competition from other high-value crops such as maize, cotton, and soybean (Nagarajan *et al.,* 2006).

Sub-Saharan Africa annually produces about 13 million tons to the world millet value chain (FAO, 2003). However, less than 5% of Africa annual production of pearl millet is commercially processed by industry (Rohrback, 2004). The area where pearl millet is important in East and Central Africa (ECA) falls within low agricultural potential, low market access, and low population density (Omamo *et al.,* 2006). But the precise figures on pearl millet production in African developing countries are normally not easy to obtain, because few statistics distinguish pearl millet from other millet botanical species (FAO and ICRISAT, 1996).

In addition, pearl millet is the second most important cereal crop in Eritrea cereal crop value chain, which is practiced mainly by small farmers in low lands and mid lands (Paul *et al.,* 2006). Pearl millet is grown commercially in South Africa as a forage grass but none of this grain is commercially processed while Zimbabwe produces about 45 000 tons of pearl millet annually but only small quantities of this is used for beer malt and animal feed (Rohrbach, 2004).

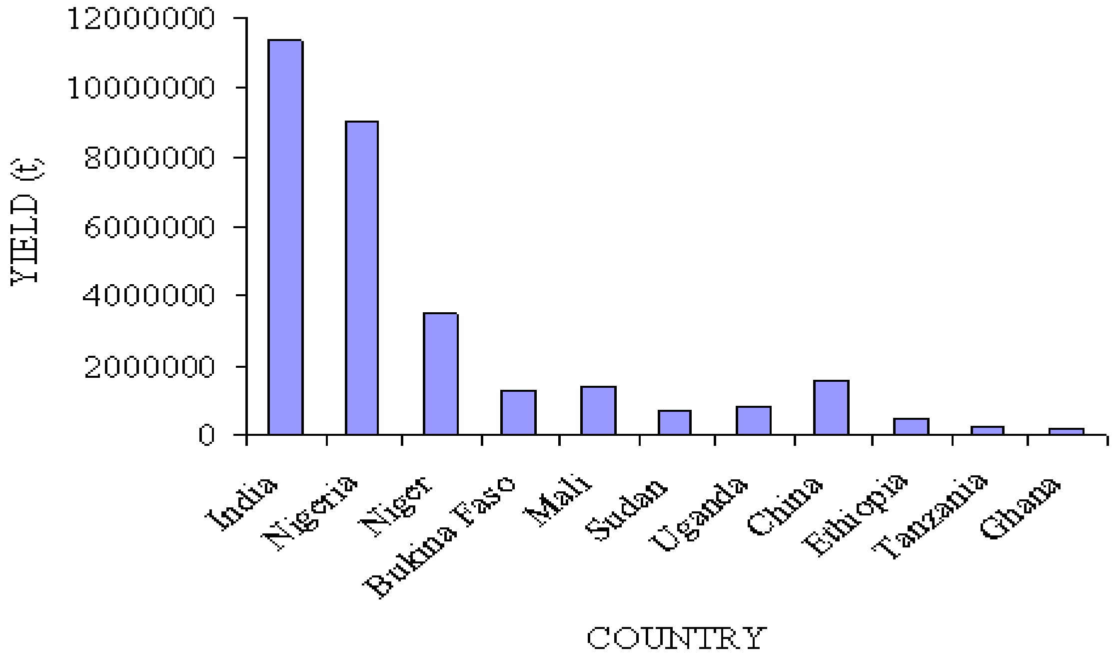

Figure 2: Production of millet in different countries during 2008 Source: Hays (2011)

In Tanzania particularly in areas where rainfall is scarce, small household farmers are engaged in pearl millet production and produce over 200 000 tons of pearl millet per year (Rohrback and Kiriwaggulu, 2007). The crop is the fourth most widely grown cereal grain crops after maize, rice and sorghum in the Tanzania's agricultural economy (URT, 2012). However, according to the United Republic of Tanzania (URT, 2009), the production of millet and sorghum decreased substantially by 80.9 percent in the year 2009 compared to an increase of 8.7 % in previous year of 2008.

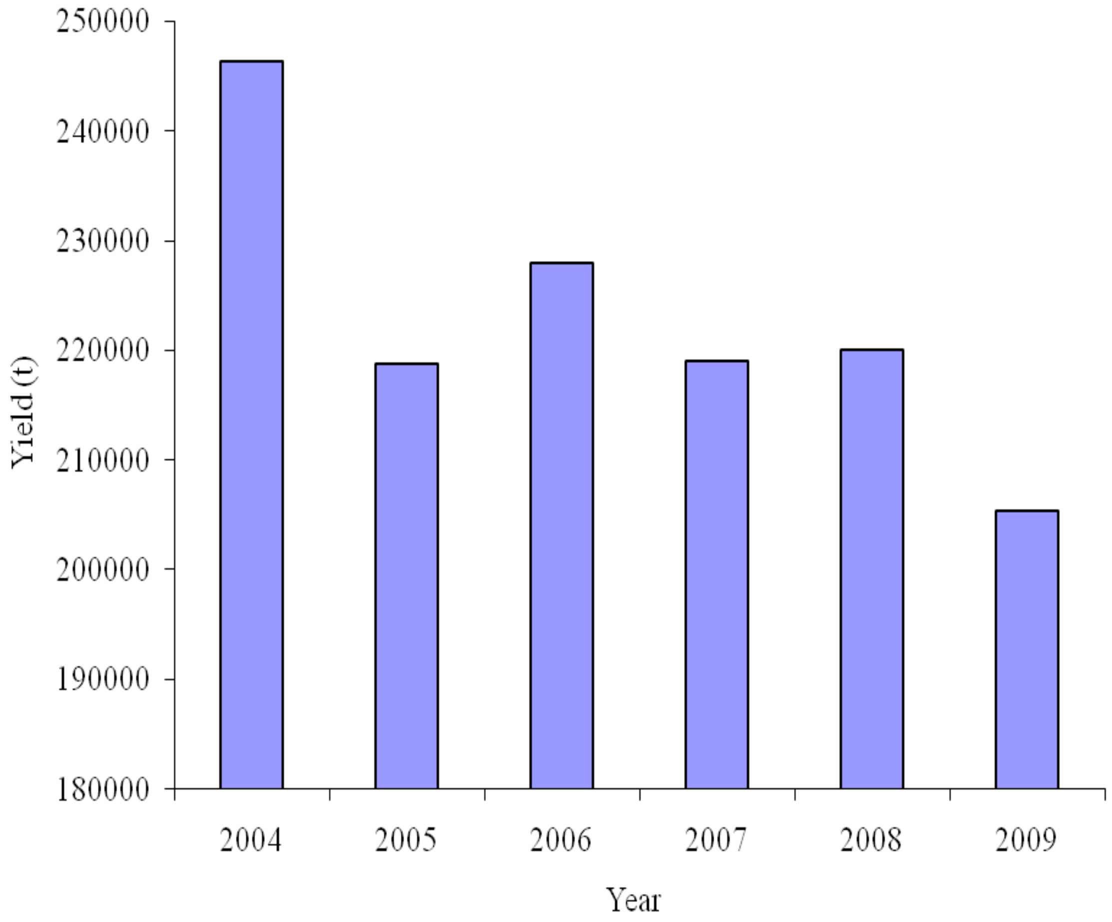

Figure 3: Millet production trend in Tanzania

Source: FAOSTAT (2009)

According to URT (2012), Dodoma was the leading pearl millet producing region in Tanzania during the 2007/8 cropping season. In general however, the level of commercial utilization of pearl millet appears to depend more on the size of the commercial food and feed economies than on the level of crop production (Rohrbach, 2004).

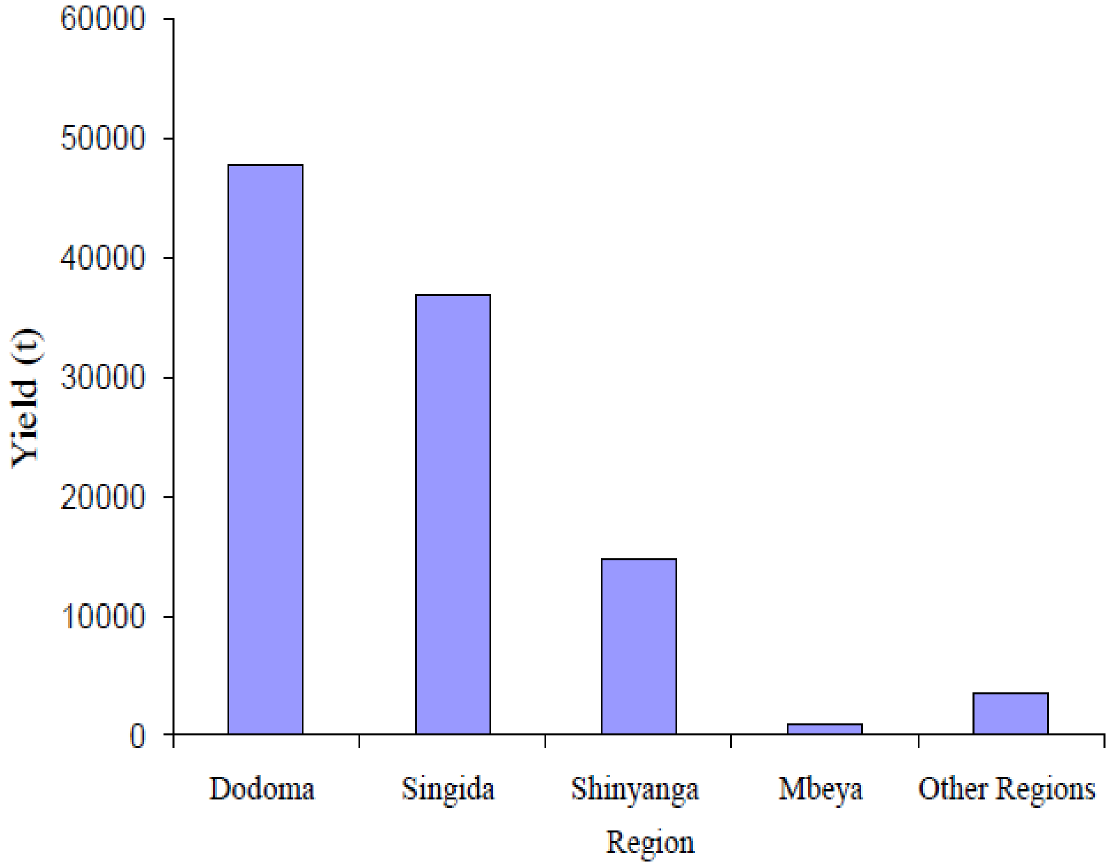

Figure 4: Pearl millet production by regions in Tanzania - 2007/8

Source: URT (2012).

2.2 Pearl Millet Price

The millet market is very difficult to plan because of its small size, the unknown volume of unrecorded trade and uncertainties regarding supply and demand (Kajuna, 2001). This is because the market of millet has not been fully established (UOG, 2012). However, the consistent price data for millets are missing in most of the African countries (FAO, 2004). In addition, the published data do not distinguish between the various species of millet and in Tanzania sometimes the data are combined with that of sorghum(Rohrbach, 2004). People in the villages are not directly sensitive to pearl millet market prices, since most of them assume that they have pearl millet for free (Leporrier *et al.*, 2002). Moreover, the prices received for the product vary according to the value perceived by the consumer

(UOG, 2012). For example, the opaque beer industry of Zambia tends to offer intake prices for pearl millet that are marginally lower than those for maize (FAO and ICRISAT, 1996).

Generally, the prices are usually the lowest immediately after good harvests and increase as the stocks get depleted (FAO, 2004). The average producer price of pearl millet in Namibia is around N$1.70 per kg to the grower, which is comparable to farm level prices of pearl millet in Sahelian West African Countries (Sattar *et al.*, 2003).

2.3 Pearl Millet Production Challenges

Producing a value-added produce as well as providing related services along a value chain follows a sequence of activities (Pauw and Thurrlow, 2011) such as production, processing, marketing, and distribution (Cowan, 2002). This creates a challenge in each step of the production network (Pauw and Thurrlow, 2011). The main challenges that limiting wide scale pearl millet production include, thin market, drought, inadequate agricultural inputs, unavailability of improved hybrid varieties, inadequate extension services, lack of capital, inadequate knowledge and skills in production, and pests and diseases. Each of these is explained in the sections that follow.

2.3.1 Thin market

The pearl millet marketing channels in the value chain are fragmented and poorly developed (Janick and Whipkey, 2007) such that the prices of pearl millet in the market chain decline as newly harvests start to supply the markets (FAO, 2011) this can be attributed by the fact that, producers of pearl millet in the chain are also the consumers

(Gill and Turton, 2001). Furthermore, stover of the crop sometimes does not have the market and farmers have to burn their stover in the field due to lack of marketing facilities (Kumar *et al.,* 2010). In addition, marketing uncertainty, especially faced by smallholders, dampens production motivation and contributes to the stagnation of the crop output in the chain (Coulter and Onumah, 2002). Therefore, thin market is the main disincentive, which compels farmers to produce at subsistence level without meaningful value addition downstream the value chain (Mwanga, 2002).

2.3.2 Drought

Climate change resulting mostly from global warming has been among the major causes of reduced agricultural production and productivity in many parts of Africa, including East Africa (Salami *et al.,* 2010). Pearl millet is mostly grown in drought region where rainfall is low and erratic (Murty *et al.,* 2007). The low and sporadic rains during the beginning of the season significantly interfere with the crop establishment while at the end of the season these phenomena adversely affect grain development all of which lead to low productivity (CAC, 2010). Moreover, drought lowers the production of grain yields of unimproved cultivars of pearl millet (Rai *et al.*, 1999).

2.3.3 Inadequate agricultural inputs

Pearl millet farming is mainly practiced by resource-poor smallholder farmers (FAO, 2008; Erbaugh *et al.,* 2010). In this respect, there are several cases of inefficiency in the production, supply, marketing, and utilization of machines and equipment.These inefficiencies constrain the production process and limit farmers' chances of maximizing value addition along the chain (Oni, 2011). The size of the area cultivated is limited to the type of equipment used in cultivation (Acquah, 1997; Kumar *et al.,* 2010). Pearl millet input demands by farmers in the value chain are very low. This is because farmers do not have the culture of buying inputs for these crops; most farmers cannot afford to buy inputs instead they rely on local technology and seed recycling (Mwanga, 2002). Therefore, the traditional implements and tools which are used in the production process add little output in the pearl millet farming (Kumar *et al.*, 2010).

2.3.4 Hybrid varieties availability

Most actors in the seed value chain play multiple roles including development of varieties, inspection and certification, seed production, processing, marketing, and the provision of extension services along the chain (Erbaugh, 2010). However, the quantities of new varieties which are released remain small relative to the requirements of farmers. Few farmers have access to these varieties and the distribution networks, which are required to get these improved seeds into the hands of most of the farmers, are extremely limited (Rohrbach and Kiriwaggulu, 2007; Kumar *et al.*, 2010). However, in most of Africa countries there are no commercial seed markets (Gill and Turton, 2001). Yet, there has been little agricultural research on products (Mwanga, 2002); as a result, the use of certified improved seeds for this crop appears to be low leading to low productivity of pearl millet (Muliokela, 2005 and Larson *et al.*, 2006 cited by Erbaugh *et al.*, 2010).

2.3.5 Inadequate extension services

A prosperous production system requires that the entire value chain functions well, a weak or missing link can reduce the intended benefits or undermine the viability of the whole crop value chain (Dararath, 2011). Accessibility of information and the sources of such information have been essential factors affecting the adoption of important innovations among farmers in the chain (IFOAM, 2003). The linkages between research, extension, and training within the value chain are weak and there is limited collaboration between public and private partners (Salami *et al.*, 2010). On the other hand, several studies such as

Ragasa *et al.*, 2010 have shown that in many developing countries, Sub-Saharan Africa in particular, there is persistent under investment in research and development and weak research capacity, both of which continue to undermine the crop marketing and value addition in the chain. Therefore, varied extension services are needed to help farmers remain competitive and profitable, diversify production, produce for niche markets, and move to higher-value products and more production (Oladele and Tekena, 2010).

2.3.6 Lack of capital

Most traditional farms have inadequate capital for the purchase of costly inputs such as farm machinery, fertilizer, herbicide and pesticide. Inadequacy of such inputs contributes to low production in the value chain (Ismaila *et al.,* 2010; Kumar *et al.,* 2010). Less than one per cent of commercial lending in Africa goes to agriculture; moreover, most of the loans to the sector go to large scale farmers, leaving smallholder farmers not adequately assisted in the value chain (Keeler, 2009). Commercial banks have little (if any) interest in lending money to the agricultural sector because of the risky nature of agriculture activities (Salami *et al.,* 2010). However, government inefficiencies in supporting the sector and the tendency of microfinance institutions to charge high interest rates of sometimes up to 100 % interest on trading activities lead to insignificant allocation of credit to smallholder farmers (Keeler, 2009).

2.3.7 Inadequate knowledge and skills in production

The small scale pearl millet producers lack appropriate production knowledge and skills which are required in adding value to the pearl millet value chain (Reddy *et al.,* 2008; Tijani, 2009). For example, pearl millet farmers do not follow optimum sowing time due to lack of knowledge and experience: this phenomenon has a negative effect in the pearl millet value addition and marketing (Kumar *et al.,* 2010). In addition, farmers select pearl millet panicles after harvest and use them as seeds in the following season, this practice results to low value addition in the chain (Roden *et al.,* 2007).

2.3.8 Pests and diseases

Pests and diseases can cause considerable yield losses of pearl millet along the production chain (Janick and Whipkey 2007). For example, rice moth, and rodents are the main pests that have been observed to negatively affect the quality of pearl millet grains (Thomas and Mpofu, 2013). In addition, biotic constraints, such as downy mildew are among the most destructive diseases causing severe economic losses. Other minor diseases affecting pearl millet include smut, ergot, and rust (ICRISAT, 2002a). Moreover at the household level, the pearl millet grains are commonly stored in traditional granaries, where pests' infestations normally occur (Thomas and Mpofu, 2013). This reduces the quality of yields of pearl millet in the chain (RSA, 2011) and hence fetching low price in the market (NAAS, 2012). On the other hand, crop risk management options such as pesticides and crop insurance in the value chain are limited (Janick and Whipkey, 2007).

2.4 Theoretical Framework

Overview of efficiency

Farrell (1957) classified efficiency as technical (physical), allocative (price), and economic (overall) efficiency. Technical efficiency shows the ability of farmers to produce maximum amount of outputs using the existing level of inputs. On the other hand, allocative efficiency measures the ability of farmers to use inputs in an optimal proportion, given the price of inputs and outputs. A firm is economically (overall) efficient if it achieves both technical and allocative efficiencies.

For a given firm which uses two inputs (X_1 and X_2) to produce a single output (q) under a constant return to scale, Farrell (1957) illustrates the three types of efficiency using the graph shown in Figure 5. The isoquant SS' represents the different combinations of the two inputs that the firm uses to produce a given amount of output. The deviations from the isoquant imply technical inefficiency of the firm; thus, if the firm for example uses inputs at point P to produce a unique output on the isoquant; technical inefficiency of a firm is represented by the segment QP, which shows the amount by which all inputs could be proportionally reduced without the reduction in the level of output. (Coelli, *et al.,* 2005).

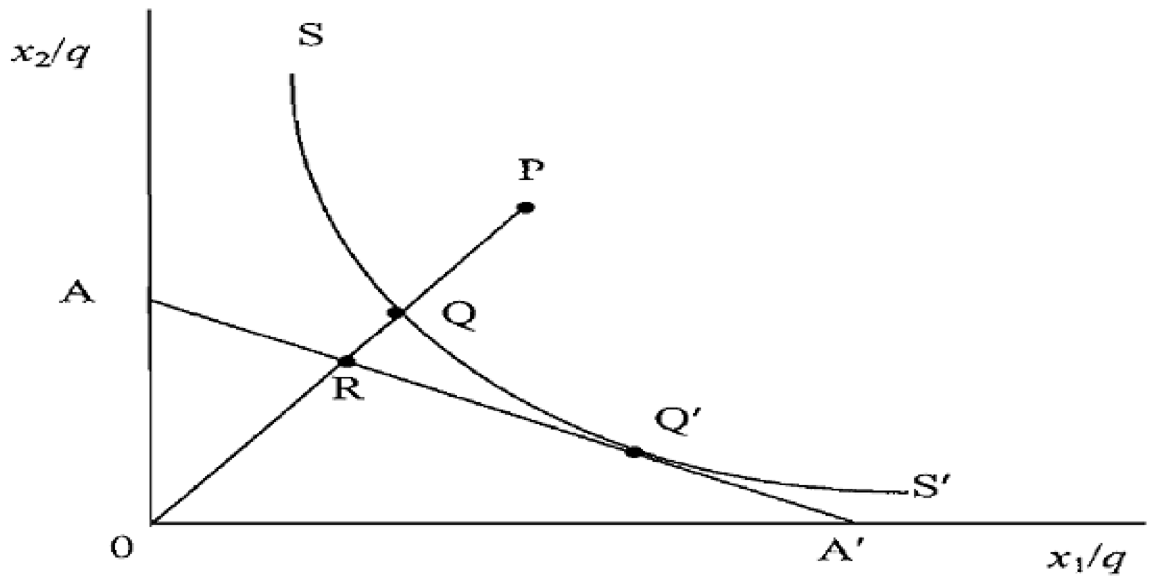

Figure 5: Graphical representation of Technical and allocative efficiencies (Coelli, *et al.*, 2005).

It is also assumed that the efficient production function which is the ability of an efficient firm to produce maximum output from the given set of inputs is known. X and Y are two factors of production. P shows the combination of two inputs to produce a single output. Q is the point on which the ratio of an efficient firm uses the two inputs is the same as in Point P. SS' is the isoquant which shows the different combination of inputs that an efficient firm should use to produce a single output. QP is the amount of inputs that can be given up to produce the same level of output and which is also known as technical inefficiency. The ratio QP/OP shows the percentage reduction of inputs of achieving technical efficiency. The ratio OQ/OP is the Technical efficiency of a firm. The distance QP shows the technical inefficiency of the firm which is the amount by which the inputs could be reduced while the output remains the same. The value of T.E lies between 0 and 1. When the value is 1 the firm is technically efficient. When the value is less than 1 the firm is technically inefficient .AA' is the line on which the slope and the ratio of the prices of two inputs are the same at point Q'. The ratio of OR/OQ shows the allocative efficiency of a firm. The ratio OR/OP shows the overall efficiency (Economic Efficiency) of a firm (Farrell, 1957). Thus, the technical efficiency of a firm is one minus the ratio of QP /OP as shown in the equation. On the other hand, allocative efficiency is measured by the ratio of input prices represented by the slope of isocost line AA', whereas economic (overall efficiency) is the product of technical and allocative efficiencies (Coelli *et al.*, 2005).

Technical efficiency TE = OQ /OP.

The technical efficiency is also defined as the ratio between the observed output and the corresponding frontier or maximum output.

TE=Yi/Y* Where by

Yi= f (Xi,β) exp(vi - ui), Y* = f (Xi,β) exp(vi) Therefore equation (2) can be written

$$T.E = \frac{f\ (Xi,\beta)\exp(vi - \mu i)}{f\ (Xi,\beta)\exp(vi)} = \exp\ (-u_i)$$

Allocative efficiency AE =OR/OQ

Economic efficiency EE = TE × AE = (OQ/OP) × (OR/OQ) = OR/OP

The range of technical efficiency is between 0 and 1. If $u_i = 0$ it means that farmers are fully efficient and lie on the frontier. In this case, the stochastic frontier production function is reduced back to simple production function which indicates that there is no inefficiency and the error term is only the factors that are outside from the farmer control. If $u_i > 0$ it means that farmers lie below the frontier which indicates that farmers are inefficient producers and make losses.

2.5 Review of Empirical studies

Sanusi *et al.* (2015) carried out a study to determine the resource use efficiency in pearl millet production in Niger State, Nigeria. The production function analyses which incorporate the conventional neoclassical test of economic and technical efficiencies were used as the analytical technique. The findings revealed that farmers were inefficient in the use of all the resources. Generally, inputs such as farm size, family labour, hired labour, seeds and fertilizers were under-utilized, while herbicides were over-utilized. The results indicate that there is a need to make inputs such as fertilizer, improved seeds, and herbicides affordable and accessible to farmers so as to improve efficiency.

Ajetomobi (2011) used stochastic production frontier analysis to assess productivity growth of millet in Economic Community of West African States (ECOWAS). The data were collected from Food and Agriculture Organization Statistical (FAOSTAT) database and covered a 45 year period (1961–2005) separated into pre-ECOWAS (1961–1978) and ECOWAS (1979–2005). The results show that: (1) there has been improvement in productivity in the sector of an interval of 0.7–15% in the periods studied and (2) technical change has had the greatest impact on productivity, indicating that producers have a tendency of catching-up with the front runners.

In another study, Kikuchi *et al.* (2017) focused on the production outcomes for five crops cultivated in Senegal: upland rice, lowland rice, groundnut, maize, and pearl millet. Technical efficiency (TE) of the production of each crop was estimated using data envelopment analysis, and the determinants of TEs were assessed using generalized linear regression analyses. The average TEs for upland rice, lowland rice, groundnut, maize, and pearl millet were estimated as 0.76, 0.88, 0.89, 0.94, and 0.90, respectively. The identified factors that had a positive impact on TE were years of cultivation experience, the amount of nitrogen fertilizer applied, and participation in a farmers' association. Weeding hours, seeding rate, the size of the cultivated area, and delays in sowing time were negatively associated with TE.

Mbai *et al.* (2016) used a stochastic Cobb-Douglas production frontier of the pearl millet smallholder farmers and examined their technical efficiency comparing Conservation and Traditional Agriculture practices in Northern Namibia. The estimated parameter of the model shows that land availability, the level of use of fertilizer and tractor power explains the variations in the production of pearl millet. The inefficiency model indicates that farm experience, farm size, and farm training have significant positive effect on efficiency.

Sibiya *et al.* (2016) carried a study in the eastern and northern regions of Uganda to characterize the pearl millet cropping system and to identify the most important production determinants. Using questionnaires, data were collected from 160 households through face-to-face interviews with the respondents. the results show that pearl millet is mainly grown for food and source of income. The area planted, spouse age and years of pearl millet cultivation are the important factors in enhancing production while the age of household head, the amount of seeds planted and distance to the market negatively affect grain yield.

In another study, Hessein *et al.*, (2015) focused on the economics of resource use in millet production under subsistence farming system in Nyala South Darfur State of the Sudan. The main objectives are: to test the situation of returns to scale for food grains production.

To evaluate the efficiency with which the farm households utilize their resources to maximize their farm output. Cobb – Douglas was specified as a suitable functional form for estimating the parameters. The main results include the output elasticity of millet showed decreasing returns to scale. And the efficiency index of operational area for millet production was statistically not different from unity.

Chepng'etich *et al.* (2014) analysed Technical Efficiency of Sorghum Production in Lower Eastern Kenya. Using data from a field survey of randomly selected sample of 143 smallholder farmers in Machakos and Makindu districts in Kenya, this paper used Data Envelopment Analysis (DEA) approach to estimate their technical efficiency scores. The results showed that the average technical efficiency was low (41%). Therefore, innovative arrangements should be enhanced to increase farmers' capacity to efficiently use the available resources in sorghum production.

Victor *et al.* (2015) investigated the level and determinants of small-scale cowpea production in Ejura Municipality in Ashanti Region using a stochastic frontier production function. The results indicate that small-scale cowpea farmers were not fully technically efficient as the mean efficiency was 66%. Farm size, seeds, pesticides and labour were the major input factors that influenced changes in cowpea output.

Jirgi *et al.* (2014) investigated the technical efficiency of cowpea farmers in Kebbi State Nigeria, with the aim of generating reliable information on the determinants of efficiency. Using Double Bootstrapping Approach technical efficiency scores of the millet and cowpea farmers ranged from 0.31 to 1.The average technical efficiency score is 0.86. On average, farmers can expand their output by 16% if they are to attain technical efficiency of one. This implies that the farmers can increase their output by 16% using the existing inputs. The study revealed further that personal characteristics of the respondents, age and experience have a statistical significant positive relationship with the technical efficiency of the millet and cowpea farmers.

Abdullahi *et al.* (2014) estimated the technical efficiency of maize producers in Zambia using Stochastic Frontier Analysis (SFA) and also determined the factors which influence technical efficiency in maize production. Empirical results showed that the average technical efficiency was 50%, with a minimum of 2% and a maximum of 84%. Also, the results showed that the age of the farmer, the use of certified hybrid seed, and access to loans, extension advice, and off-farm income influence technical efficiency.
Mussa *et al.* (2015) evaluated factor productivity of smallholder's pigeon pea production systems in northern Tanzania. Using a translog frontier production analysis, the results showed that the productivity of pigeon pea is positively and significantly associated with the size of cultivated land of pigeon pea, labour, interaction between plot size and seed quantity, and the interaction of seed-use with time.

Olufemi *et al.* (2015) investigated technical efficiency and drivers of efficiency among cocoa farmers, in southwest Nigeria. Data Envelopment Analysis (DEA), which is a non-parametric approach, was used to analyse technical efficiency and the OLS regression was used to profile socio-economic variables that affect technical efficiency. The result showed the mean technical efficiency of 81% .Also, education was positively and significantly associated with efficiency, while area of land and age of cocoa trees negatively affected technical efficiency.
Muhammad (2016) sought to determine the level of technical production efficiency of maize farmers in two target regions of Dodoma and Morogoro in Tanzania. A sample size of 539 maize producers was collected randomly. The stochastic frontier model was used by applying Cobb-Douglas production function. The elasticity of inputs of production

function, the level of technical efficiency, and the determinants of technical inefficiency were estimated. The mean technical efficiency which was found in the study area was 38%. The technical efficiency score ranged from 0.002 to 0.889. The input variables land and seeds showed higher positive elasticity in the production function. The results showed that family size, gender and region positively affect technical efficiency while age, off farm activities and migrant decrease technical efficiency. The finding showed that the increase of efficiency level in the study area positively affects the food consumption score and income but decreases the coping strategies index which enhances food security in the area.

Awudu and Richard (2001) used a translog stochastic frontier model to examine technical efficiency in maize and beans in Nicaragua. The average efficiency levels were 70% and 74% for maize and beans, respectively. In addition, the level of schooling represented human capital, access to formal credit and farming experience (represented by age) contribute positively to production efficiency, while farmers' participation in off-farm employment tends to reduce production efficiency. Large families appeared to be more efficient than small families. Although a larger family size puts extra pressure on farm income for food and clothing, it does ensure availability of enough family labour for timely farming operations. Positive correlation between inefficiency and participation in non-farm employment suggests that farmers reallocate time away from farm-related activities, such as the adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency. The result indicated that efficiency increases with age until a maximum efficiency is reached when the household head is 38 years old. The age variable probably picks up the effect of physical strength as well as farming experience for the household head.

Etwile *et al.* (2015) evaluated the impact of credit on smallholders' technical efficiency using cross-sectional data from 233 maize-producing households in northern Ghana. Due to the exogenous assignment of credit and assumption of homogeneity in farm technologies, the propensity score matching analysis was used to compare the average difference in technical efficiency between farmers with credit and those without credit. The results show that credit impact positively on farmers' technical efficiency. The provision of credit enhances timely purchase and efficient allocation of factor inputs to produce the maximum output. Income and age also plays an important role in reducing smallholders' technical inefficiency. The major recommendation of this study is that, the credit programme of agricultural interventions should target several resource poor farmers in order to enhance efficiency gains. Financial institutions must collaborate with agricultural and farmer development projects to facilitate credit delivery to smallholder farmers.

Kizito *et al.* (2015) measured Farm-level Technical Efficiency of Urban Agriculture in Tanzanian Towns: The policy implications technical efficiency indices of Urban Agriculture (UA) were determined using the stochastic frontier production function which incorporates a model of technical inefficiency effects. In 2010, farm-level data of 270 urban agriculture farmers in the urban wards of Tanzanian towns of Arusha, Dar es Salaam and Dodoma were obtained using semi-structured questionnaires. The parameters were estimated simultaneously with those of the model of inefficiency effects. Using the maximum likelihood estimation technique, asymptotic parameter estimates were evaluated to describe efficiency determinants. The study results revealed that the mean technical efficiency index (TEI) of 0.72 was achieved implying that output from urban agriculture production could be increased by 28% using the available technologies. Despite the fact that urban farmers have entrepreneurial acumen, they faced several challenges in resource allocation. Land size, total variable costs, and extension service charges had negative impact on TEI. The study recommends that the government using urban agriculture and livestock extension agents should explore profitable levels for promoting UA enterprises to ascertain profitable TEI levels and UA units

2.6 Conceptual Framework

Conceptual framework is defined as a network of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena of a study (Jabareen, 2009). According to Scarborough and Kydd (1992), a framework has to show the most important areas to focus the limited resources and to ensure that the data collected are relevant to the objective of the research. In the current study, the conceptual frame work development process was guided by the objectives of the study.

The general objective of the study was to analyse the factors influencing technical efficiency of smallholder's pearl millet production in the semi-arid farming system of Dodoma, Tanzania. The specific objectives of this study were to analyse the level of technical efficiency of smallholder pearl millet farmers in Chamwino, Tanzania and also to analyse social-economic factors affecting the technical efficiency of smallholder pearl millet farmers in Chamwino, Tanzania.

A production process involves the transformation of inputs into outputs. In crop production, technical inputs such as seeds land, labour, and fertilizer are combined to produce the crop. The transformation process depends not only on the levels of inputs used but also on the management practices that the farmers use to combine these inputs. The management practices which are used in production represent an amalgamation of knowledge and skills that the farmer has or acquires overtime and the characteristics of the farm.

The technical inputs and management practices jointly determine the quantity and quality of pearl millet output produced. The pearl millet production process is summarized in Figure 6.

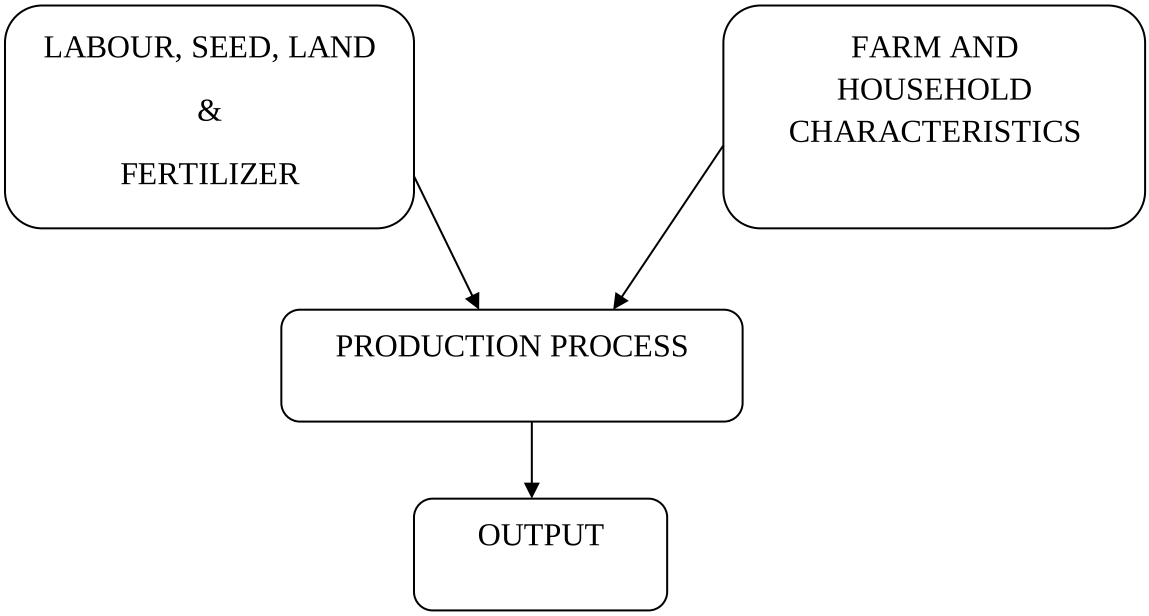

Figure 6: Conceptual framework

The performance of agriculture is mostly dependent on the productivity of factors of production such as land, labour, and capital and the technical efficiency of the owner of the farm in the management practices. This implies that improvement of farmers' efficiency in their management practices lead to an increase in agricultural production. The factors which cause inefficiency can be grouped into human capital, institutional variables, and socio economic variables. Agricultural production can be increased by identifying and improving the factors on which agriculture production and technical efficiency depend. Thus, increasing agricultural production solves the problem of food insecurity because the former leads to an increase of farmers' incomes (Bhasin, 2002).

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Description of study area

This study was conducted in two villages of Chamwino District in semi-arid Dodoma region in 2016. Two villages Ilolo and Ndebwe in Chamwino District were selected to represent the semi-arid climate. Food production in Chamwino is predominantly rain fed. Dodoma region receives one rainfall season with an average of 350–500 mm per annum and many areas are characterized with high food insecurity.

3.2 Source of data

This study used household data which were collected under the Trans-Sec research project based at Sokoine University of Agriculture. The trans-Sec project was implemented through consortium of Tanzania Germany researchers in selected villages in the semi-arid Dodoma and in Sub-humid Morogoro. A sample size of 300 farmers was deemed to be representative of small holder of pearl millet farmers in the two villages of the Chamwino District, namely Ilolo and Ndebwe.

3.3 Sampling procedure

A total of 300 respondents were chosen randomly from a list of households practicing pearl millet production from both villages. The following formula was used to determine sample size; $n = z^2pq/e^2$ Where n = required sample size, t = confidence level at 95% (standard value of 1.96) p = proportion of number of household cultivating pearl millet in the project area (65% estimated) e = margin of error at 5% (standard value of 0.05). Using the above equation a sample of 350 pearl millet farmers was obtained. From the calculated sample size, 50 respondents were dropped due to problems of missing data on millet production, and this reduced the sample size to 300 respondents for the meaningful analysis.

3.4 Data Analysis

3.4.1 Assessing the level of technical efficiency of smallholder peal millet farmers in Chamwino district, Tanzania.

The empirical stochastic production frontier model was used for the analysis of technical efficiency of small holder pearl millet farmers. The model is characterized by error term comprising two components, the stochastic component (Vi) and the inefficiency of the producer (Ui). While the stochastic error term represents random shocks such as adverse weather and other factors beyond the control of a producer, the inefficiency component constitutes a deviation from the production frontier as a result of the producer's inefficiency. Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of the explanatory variables, reflecting the producer's characteristics.

The advantage of this model is that it allows the estimation of the farm-specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure.

Assuming that the production function of the sorghum producers in the study area is given by the stochastic frontier, the production function is specified as:

$Yi= (xi.\beta)+ei$……………………………………….....………………………………1

$ei=vi -ui$………………………………..………………….…………………………2

Where:

Yi = quantity of output of the ith farm

xi= vector of the inputs used by the ith farm

β = a vector of the parameters to be estimated

ei = composed error term

vi= random error outside farmer‘s control

ui = technical inefficiency effects

In the specification of the stochastic frontier production function, the model allows for specification of two equations on the right hand side. One equation specifies the main factors of production such as seeds, fertilizers and labour and the other equation specifies the variables that are assumed to cause inefficiency such as access to credit and the gender of the household head. This is done in a one-stage process.

According to Ogundari (2006), this has been used by many empirical studies particularly those relating to agriculture in developing countries. Also, the functional form meets the requirement of being self-dual (allowing an examination of economic efficiency):

The Cobb-Douglas functional form is specified as follows:

$$\ln Y = \beta o + \beta 1 \ln X1i + \beta 2 \ln X2i + \beta 3 \ln X3i + \beta 4 \ln X4i + (Vi-Ui) \ldots\ldots 3$$

And the Translog production functional form is given as:

$$\ln Y= \beta o+ \beta 1 \ln X1i + \beta 2 \ln X2i + \beta 3 \ln X3i + \beta 4 \ln X4i+ \beta 5 \ln X1 \ln X2+ \beta 6 \ln X1 \ln X3+ \beta 7 \ln X1 \ln X4+ \beta 8 \ln X2 \ln X3+ \beta 9 \ln X2 \ln X4+ \beta 10 \ln X3 \ln X4+ \tfrac{1}{2}\{\beta 11 \ln X1^2+ \beta 12 \ln X2^2+ \beta 13 \ln X3^2+ \beta 14 \ln X4^2\}+ (Vi-Ui) \ldots\ldots 4$$

Two functional forms of a production function, which is mostly estimated in stochastic frontier analysis, are the Cobb Douglas and the Translog Production functions. The former is simple but is restrictive; the latter is flexible, which implies that it does not impose assumptions about constant elasticity of production neither does it impose assumptions about elasticities of substitutions between inputs.

Where by,

ln = the natural logarithm

Y = output of pearl millet (Kg)

βo = constant term

β_1- β_4 = regression coefficients

X_1= land size (ha)

X_2 = quantity of seed (kg)

X_3 = total labour used (man days)

X_4 =quantity of fertilizer (kg)

Vi = random variability in the production that cannot be influenced by the farmer.

Ui = deviation from maximum potential output attributable to technically inefficiency.

Where Yi represents the output level of the ith sample farm; f (xi;ß) is a suitable function such as Cobb-Douglas or translog production functions of vector, xi, of inputs for the ith farm and a vector, ß, of unknown parameters. The ei is an error term made up of two components: vi is a random error having zero mean, N(0; σ^2v,), which is associated with random factors such as measurement errors in production and weather which the farmer does not have control over; and this is assumed to be symmetric independently distributed as N (0, σ ^{2}V) random variables and independent of ui. On the other hand, ui is a non-negative truncated half normal, N (0, σ u^2) a random variable which is associated with farm-specific factors, leading to the ith firm not attaining maximum efficiency of production; ui is associated with technical inefficiency of the farm and ranges from zero to one. However, ui can also have other distributions such as gamma and exponential. N represents the number of firms involved in the cross sectional survey of the farms. Technical efficiency of an individual firm is defined in terms of the ratio of the observed output to the corresponding frontier output, which is conditioned on the level of inputs used by the firm. Technical inefficiency is therefore defined as the amount by which the level of production for the firm is less than the frontier output.

Table 1: The expected signs from stochastic frontier production function for main factors of production (seed, fertilizer, land and labour)

Variables	Expected Sign
Seed	+
Labour	+
Fertilizer	+
Land	+

3.4.2 Identifying social-economic factors affecting technical efficiency of small holder pearl millet farmers in Chamwino District, Tanzania

The determinants of technical inefficiency were estimated by regressing the predicted technical inefficiency on characteristics of farmers using the model shown below. The inefficiency of production, Ui was modelled in terms of the factors that are assumed to affect efficiency of production of farmers. Such factors are related to the socio-economic and management variables of the farmers. The determinant of technical inefficiency is defined by:

$$Ui=\delta0+\delta11nZ1+\delta2lnZ2+\delta3lnZ3+\delta4lnZ4+\delta5lnZ5+ \delta6lnZ6+ \delta7lnZ7 \ldots\ldots 5$$

Whereby;

U_i = inefficiency effects

Z_1 = Gender of Household head (Dummy)

Z_2 = Extension Access (Dummy)

Z_3= Farmers experience (Number of years in farming)

Z_4 = Education (years of schooling)

Z_5 = Household size (number of family members)

Z_6 = Household size Square (number of family members)

Z_7 = Total income

δ_0 = constant

δ_1-δ_7 = Parameters to be estimated.

These variables are assumed to influence technical efficiency of the pearl millet farmers.

$\varepsilon = V_i - U_i$ and Y^* is the observed output adjusted for statistical noise

The term V is a symmetric error, which accounts for random variations in the output due to factors beyond the control of the farmer such as weather, disease outbreaks, measurements errors, and the like. The term U is non-negative random variable representing inefficiency in production relative to the stochastic frontier. The random error V_i is assumed to be independently and identically distributed as $N(o, \delta v2)$ random variables independent of the U_i which are assumed to be non-negative truncation of the $N(o, \delta u2)$ distribution (Half-normal distribution) or have exponential distribution.

Table 2: The expected signs from stochastic frontier production function for factors that are assumed to cause inefficiency

Variable name	Expected sign
Gender	**-/+**
Extension Access	**-**
Experience	**-**
Education	**-**
Household Size	**-**
Household Size Square	**-**
Total Income	**+/-**

The Translog production frontier function which is defined by equation (4) and the inefficiency model which is defined by equation (5) are jointly estimated by the maximum-likelihood (ML) method using FRONTIER 4.1 (Coelli 1996). The FRONTIER software uses a three-step estimation method to obtain the final maximum-likelihood estimates. First, estimates of the α -parameters are obtained by OLS. A two-phase grid search for γ is conducted in the Second step with α -estimates set to the OLS values and other parameters set to zero. The Third step involves an iterative procedure, using the Davidon-Fletcher-Powell Quasi Newton method to obtain the final maximum-likelihood estimates with the values selected in a grid search as starting values.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-Economic Characteristics of Pearl millet Farmers

In this section, the general socio-economic characteristics of smallholder pearl millet farmers in two villages Ilolo and Ndebwe in Chamwino District are provided. These include educational level, household size, farming experience, output quantity, off-farm income and farm income. Socio-economic characteristics are essential elements in understanding the general behaviour and attitude in decision making and the probable expected responses to many stimuli exposed to it (Akyoo, 2004) .

Experience influences individuals perception and understanding of the management requirements and consequently improve farm produce. Farming experience is another important socio-economic factor that can cause an increase in productivity. From the results in Table 3, the mean farming experience is 15.45 years with a minimum 5 years and a maximum of 86 years of farming experience. Farming experience is used as a measure of management ability, the more experienced the farmer is, the higher the ability of making farm decision. This result showed that most of the respondents had long years of farming experience, implying that such farmers are likely to make decisions that would increase their output and income.

The result of the study in Table 3 revealed that the mean household size was 8 with the minimum of 2 and a maximum of 19 family members. This implies that relatively large household sizes are likely to increase the supply of family labour for farming operations, hence supporting favourably, productive capacities of the farmers, and which are already enhanced by their age.

Also, the findings from Table 3 indicate that farm income generated by pearl millet farmers in Chamwino District is the maximum of 2472120 Tshs and the minimum of 6431 Tshs with the mean farm income of 390220 Tshs. Farm income is very useful as it is used by pearl millet farmers for purchasing inputs and for meeting other household needs.

The results of this study from Table 3 revealed that the mean level of small holder pearl millet farmers' off-farm income is 381500 Tshs with the minimum of 6544 Tshs income and the maximum of 625660 Tshs. This implies that majority of the farmers depend on farming for income generation. Access to off-farm income is likely to affect the production process since farmers without off-farm income are likely to have difficulties in purchasing some of the important inputs such as fertilizers and hybrid seeds, which are necessary in the production of pearl millet.

The findings of this study revealed that the mean of education level is 6 years of schooling with the maximum of 11 years and the minimum of 2 years of studying. These findings show that majority of small scale pearl millet farmers in the study area have formal education despite their differences in the number of years of schooling. Education plays a very crucial role in agriculture since it can potentially help small scale pearl millet farmers undertake smart decisions in making agricultural improvements.

Table 3: Small holder pearl millet Farmers' household characteristics in the study area

Variable	Units	Minimum	Maximum	Mean	Std. Deviation
Output	Kilograms	45.00	3000.00	189.0067	262.57393
Area	Hectares	0.10	2.90	0.6280	0.48951
Seed	Kilograms	1.00	120.00	21.1700	18.01322
Labour	Man days	1.00	12.00	8.8400	8.91774
Farm income	Tshs	6431	2469940	390220	466520
Fertilizer	Kilograms	0.00	6000.00	620.0700	4926.04944
Experience	Years	5.00	86.00	15.4533	12.52427
Education	Years	2.00	11.00	6.2300	3.10309
Household size	Number of people	2.00	19.00	7.5300	2.65567
Off-farm income	Tshs	6544	4632500	381500	555900

4.2 Hypothesis Testing and Model Robustness

Before examining the parameter estimates of the production frontier and the factors that affect efficiency of the smallholder pearl millet farmers, we investigate the validity of the model used for the analysis. The Maximum Likelihood estimates and inefficiency determinants of the specified frontier are presented in Table 4. The study revealed that the generalized log likelihood function which is used to assess whether or not the function form is appropriate was -346.56. The log likelihood ratio value represents the value that maximizes the joint densities in the estimated model. Thus, the functional form that is translog, which is used in this estimation, is an adequate representation of the data.

Though the log likelihood function for C-D stochastic production function is larger than the log likelihood function of translog stochastic production function, the translog function was chosen because of its flexibility as it does not impose assumptions about constant elasticity of production neither does it impose assumptions about elasticities of substitutions between inputs; it is also more informative because it incorporates interaction and squared terms.

The value of gamma (γ) is estimated to be 0.67 and is significant at 1%. This indicates that a significant portion of the variation in the output for the sample farmers in pearl millet production from the total variation was due to technical inefficiency, in other words, about 67% of the variation in output was due to inefficiency in their respective sites and not as a result of random variability. Since these factors are under the control of the farmer, reducing the influence of the effect of γ will greatly enhance the technical efficiency of the farmers and improve their yields. However, 33% of the variation in the output was due to random noise beyond the control of farmers. Examples of such random shocks include weather (poor rainfall), crop and pests diseases.

The value of sigma squared ($\sigma 2$) was 1.59 and was significant at 1%. This indicates a good fit and correctness of the specified distributional assumptions of the composite error terms while the gamma γ indicates the systematic influences that are unexplained by the production function and the dominant sources of random error. This means that the inefficiency effects make significant contribution to the technical inefficiencies of pearl millet farmers.

Thus, the first null hypothesis, which stated that the level of technical efficiency of small holder pearl millet farmers in Chamwino District is low, was rejected. This hypothesis was rejected based on the results from Table 5, which revealed that the high mean level technical efficiency of pearl millet farmers in Chamwino District Tanzania is 0.78. Therefore, these results were enough for the rejection of the null hypothesis cited here. The second null hypothesis, which is tested in H_0: $\delta_0 = \delta_1 = \ldots = \delta_7 = 0$ implying that the farm level technical inefficiencies are not affected by the farm farmer-oriented variables, policy variables and socio-economic variables included in the inefficiency model, is also rejected. This implies that the variables present in the inefficiency model have a collective significant contribution in explaining technical inefficiency effects for the pearl millet farmers. The results of the likelihood ratio test (LR = 17.69) confirms that farmers' low production efficiency mainly relates to the variance in farming management.

4.3 Efficiency of Pearl millet Production

Table 4 shows the results of both the OLS and MLE estimates. In total, 21 parameters were estimated in the stochastic production frontier model including 14 in the Translog production frontier model and 7 parameters in the inefficiency model. Out of the 21 parameters estimated, 11 are statistically significant. Three are significant at one percent level; two are significant at five percent while the remaining seven are significant at ten percent level.

Table 4: Results of OLS and MLE of Stochastic Frontier Production Function of Pearl millet production

Variables	Parameters	OLS		MLE	
		Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Constant	β_0	5.3742***	5.3773	6.2434***	7.1701
Ln(Land)	β_1	1.2171**	2.3561	1.2623***	2.6985
Ln(Seed)	β_2	0.0842	0.2012	0.1313	0.3516
Ln(Labour)	β_3	-0.7844*	-1.818	-1.0231*	-1.7218
Ln(Fertilizer)	β_4	0.0186	0.1366	0.1679	0.1266
LnLandSquare	β_5	0.1531*	1.6852	0.1504*	1.7507
LnSeedSquare	β_6	0.0392	0.7427	0.071	1.415
LnLabourSquare	β_7	0.2261***	3.8721	0.2476***	4.383
LnFertlizerSquare	β_8	0.0077	0.8067	0.0093	1.0037
LnLand*LnSeed	β_9	-0.1048	-0.876	-1.7729	-0.6964
LnLand*LnLabour	β_{10}	-0.1572	-0.0133	-0.2001	-1.1804
LnLand*LnFertilizer	β_{11}	-0.022	-0.7256	0.0355	-1.2169
LnSeed*LnFertilizer	β_{12}	-0.03716	-1.361	-0.0275	-1.4023
LnSeed*LnLabour	β_{13}	-0.0533	-0.5358	-0.0222	-0.2443
LnLabour*LnFertilizer	β_{14}	0.0243	0.9545	0.0165	0.6608
Diagnostic statistics					
Sigma-square(u)	σ^2			1.59***	5.4686
Gamma	γ			0.67***	8.6834
Ln (likelihood)			-355.41	-346.56	
LR - Test (1)				17.69	
Mean Technical Efficiency				0.78	

***, **, ***Significant at 10%, 5%, and 1% probability respectively**

The results show that Pearl millet output in Chamwino District is determined by factors such as land, land square and seed square. Land, labour square, and land square coefficients, which were positive and significant at 1%, 10% and 1% level of probability respectively, except labour and the interaction between seeds and fertilizers which had negative signs and significant at 5% and 10% level of probability respectively and hence play a major role in pearl millet production in the study area.

The average technical efficiency for the farmers was 0.78 implying that, on average, small holder pearl millet farmers are able to obtain 78% of the potential output from a given mixture of production inputs. Thus, in a short run, there is a minimal scope (22%) of increasing the efficiency by adopting the technology and techniques used by the best pearl millet farmer.

The estimated coefficient for land was positive, which conforms to the priori expectation, and was significant at 1% level. The magnitude of the coefficient of land which is 1.2623 indicates that the Pearl millet production is relatively more responsive to the level of cultivated land more than any input. The 1.22 elasticity of land implies that under ceteris paribus, an increase in the extent of land under pearl millet production would significantly lead to an increase in pearl millet output, and vice versa. This suggests that the more farm land a farmer allocates to the pearl millet farming, the higher the yields obtained. Similar findings are reported by Goni *et al.* (2007) who reveal that most smallholder farmers usually fail to maximize pearl millet yields due to underutilization of farm land.

The estimated coefficient of labour was negative, which did not conform to the priori expectation and was statistically significant at 10% level of probability. The 1.0231 elasticity of labour implies that under ceteris paribus, an increase in the extent of labour under pearl millet production would significantly lead to a decrease in pearl millet output, and vice versa . This is in line with a study done by Avea *et al.,* (2016) which reveal a negative relationship between labour in terms of the number man days and output. the findings are also in the line with the findings in a study by Msuya *et al.*(2008), which after decomposing labour into family labour and hired labour, the study revealed a negative relationship between family labour and maize output. The authors suggest that the negative sign might be influenced by having too many family members and too much time spent in the production process. This might be due to limited opportunities for income generating activities outside agriculture especially in the rural areas

The estimated coefficient of land square was 0.15, which is positive and statistically significant at 1% level of probability. The 0.15 parameter estimate of land implies that the higher the increase of hectares of land the pearl millet output, and vice versa .This shows that land is an important variable in pearl millet farming in the study area. The significance of labour quantity is however due to the fact that labour to a large extent determines the pearl millet output obtained after land. This suggests that the more farm land a farmer allocates to pearl millet farming, the higher the yields obtained, which echoes similar findings as those reported by Osuni *et al.* (2014)

The estimated coefficient of labour square was 0.25, which is positive and statistically significant at 1% level of probability. The 0.25 coefficient estimate of labour square implies that an increase of the number of labour man days leads to an increase of the pearl millet output. This shows that labour is an important variable in the pearl millet farming in the study area. This is in line with studies by Boundeth *et al.* (2012), which show the importance of labour in farming, particularly in developing countries where mechanization is rare on small scale farms. In the study area, human power plays a crucial role in virtually all farming activities.

The estimated coefficient for seed is 0.08 which is positive but not statistically significant. The estimated 0.08 elasticity of seed implies that an increase in seed quantity will increase pearl millet output. If correct seed rates and quality seeds are not used the output would be low even if other inputs are in abundance. The production elasticity of output with respect to the quantity of fertilizer is 0.17, which is positive but not statistically significant. This implies that an increase in fertilizer would increase pearl millet output. Fertilizer is a major land augmenting input because it improves the quality of land by raising yields per hectare. This finding is consistent with the findings of Sanusi *et al*. (2015) and Oladiebo and Fajuyigbe (2007) which revealed a positive relationship between the quantity of fertilizer used and pearl millet output.

The estimated coefficients with negative signs in the inefficiency model indicate that they (the negative signs) reduce technical inefficiency among the pearl millet farmers, while the positive signs indicate that the coefficients increase technical inefficiency or reduce technical efficiency. Thus, a negative coefficient means an increase in efficiency and a positive effect on productivity. The results show that education level, household size, farming experience and household size square were the determinants of technical inefficiency among the pearl millet farmers in Chamwino District. Education, household size and farming experience were negatively related with technical inefficiency, while household size square was positively related with technical inefficiency.

The coefficient of Household size was -0.9758 and was significant at 5% probability level. This implies that as the household size increases, the technical efficiency increases thereby reducing technical inefficiency of pearl millet farmers. It also implies that technical efficiency of pearl millet farmers can be improved taking into consideration the household size of the pearl millet farmers. This is consistent with the findings of Adewale *et al.* (2005), which indicate that the larger the household size, the higher the likelihood of sustainable labour efficiency on the farmers’ farm given the constant labour supply.

According to Oluwatayo *et al.* (2008), there is a positive and significant relationship between household size and farmers' efficiency in production. However, the absolute number of people in a certain family cannot be used to justify the potential of a productive farm work. This is because the productive farm work can be affected by some other important factors such as age, sex, and health status.

On the other hand, we have included the variable household size square to see the influence of exponential increase of household size on technical efficiency. The result of our analysis indicates that the coefficient of household size square on inefficiency was positive 0.0464 and statistically significant at 10%, which suggests that small holder peal millet farmers efficiency decreases with excessive increase in the household size. This finding agrees with the finding by Ajetomobi (2011) who reported that as the household size increases, the technical efficiency decreases. They observed that this may be as a result of the fact that most of the household members who are still at a very young age may not be able to contribute to the labour supply since they are likely to be in school during the period of agricultural production activities. Essentially, it is the composition of the household that determine labour supply for the accomplishment of farm operations.

The coefficient of Education level was -0.2945 and significant at 10% probability level. Education level of farmers is a factor that the literature frequently relates to as technical efficiency. Education variable is used in this study to reflect educational level in terms of years of schooling of the sample farmers. The estimated coefficient of education variable was estimated to be negative as expected and statistically significant at 10% level for pearl millet farmers, which indicates that farmers with more years of formal education tend to be more efficient technically in pearl millet production probably due to their enhanced ability to acquire technical knowledge, which makes them produce closer to the frontier output. This finding is in line with the finding by Mbai *et al.* (2016), who pointed out that education has a positive and significant impact on farmers' efficiency in production. Thus, literacy level would greatly influence the decision making on the adoption of innovation by farmers, which may lead to an increase in productivity.

The coefficient of experience was -0.4498 and significant at 1% probability level. This indicates that a small holder pearl millet farmer with more years in pearl millet farming is expected to have more output. The coefficients of experience in this study was estimated to be negative as expected and statistically significant at 1% level for pearl millet farmers, which indicates that older farmers are more technically efficient in pearl millet production than younger ones. This may be due to better farm management practices developed over the years of farming experience, ability to acquire technical knowledge, which makes them produce closer to the frontier output. This finding is in line with the finding by Mbai *et al.* (2016) and Sibiya *et al.* (2016), who pointed out that experience has a positive and significant impact on farmer's efficiency in production. Moreover, farmers at older age may accumulate good command of resources such as labour, oxen, and farm tools that could enhance their efficiency, since better availability of farm resources enhances timely application of inputs in crop production that enhance efficiency of the farm (Mohammednur and Negash, 2010).

Table 5: Maximum-likelihood estimate for parameters of the inefficiency model

Variables	Parameters	Coefficients	Standard error	t-ratio
Stochastic frontier				
Constant	δ_0	5.3742***	3.7136	7.1101
Sex	δ_1	0.4472	-0.0084	0.0845
Extension	δ_2	-0.4911	0.0674	-0.0711
Experience	δ_3	-0.4498***	0.1699	-2.648
Education Level	δ_4	-0.2945*	0.1511	-1.9491
Household size	δ_5	-0.9758**	0.0014	-2.8745
Household size Square	δ_6	0.0464*	0.0414	1.7025
Total Income	δ_7	0.0017	0.1743	0.0584

***, **, ***Significant at 10, 5, and 1 percent probability respectively**

4.5 Distribution of respondents according to technical efficiency of pearl millet farmers in the study area

The frequency distribution of the technical efficiency estimates for small holder pearl millet farmers in Chamwino District as obtained from the stochastic frontier model is presented in Table 5. The study revealed that none of the pearl millet farmers operate at less than 10% technical efficiency; about 45% had technical efficiency of between 0.40-0.80; and 55% of the pearl millet farmers had technical efficiency (TE) of greater than 0.80 and above. The pearl millet farmers with the best and least practices had technical efficiencies of 0.91 and 0.18 respectively. This implies that on average, pearl millet output falls by 9% from the maximum possible level of 1.00 due to technical inefficiencies.

The results also show a mean technical efficiency of 0.78. This means that majority of the pearl millet farmers operated closer to their production frontier. Also, this implies that on average, pearl millet farmers are able to obtain 78% of the potential output from a given mix of productive resources. In a short-run, there is a scope for increasing pearl millet output by 22% by adopting techniques and technologies, which are employed by the best pearl millet farmers.

Table 6: Distribution of technical efficiency scores of pearl millet farmers in the study area

Efficiency Levels	Frequency	Percentage
< 0.50	11	4
0.50-0.60	12	4
0.60-0.70	28	9
0.70-0.80	84	28
0.80-0.90	160	53
> 0.90	5	2
Mean TE	**0.78**	
Minimum TE	**0.18**	
Maximum TE	**0.91**	
< 0.78	**135**	**45**

However, it should be noticed that when we say pearl millet for smallholder farmer's production can be increased without additional investment on new technology, we are not suggesting that new technologies are not required. Rather we mean that as long as the existing technology is not fully utilized, it is more cost effective to improve pearl millet production through improving technical efficiency of farmers than through investing in new technologies.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The primary objective of this study was to analyse technical efficiency of smallholder pearl millet farmers in the semi-arid farming system of Dodoma, Tanzania. This was achieved by determining the production efficiency of smallholder pearl millet farmers and identifying the determinants of inefficiency. The study used a stochastic frontier model, employing cross sectional data covering randomly sample of 300 smallholder pearl millet farmers in two selected villages in Chamwino District in Dodoma region. The results obtained from the stochastic frontier estimation show that inefficiency exist among smallholder pearl millet farmers in the study area.

This study revealed that the coefficient estimate of land was found to be positive and significant on pearl millet production, which implies that there is the potential for increasing pearl millet output by increasing the size of farm under pearl millet production. The mean technical efficiency of sample farmers was 78% of the maximum attainable output for a given a set of input levels and technology. This implies that the output per farm can be increased towards a frontier output the average by 78% under prevailing technology, without increasing any additional inputs. There were only 55% of the total sample farmers who obtained more than 80% of technical efficiency score.

However, no farmer was found to be fully efficient as for the socio-economic household factors that affect pearl millet technical efficiency, the results have shown that farmers with higher level of education, more farming experience and large household size can increase their efficiency by reducing inefficiency.

5.2 Recommendations

The study confirmed that technical efficiency of smallholder pearl millet famers can be increased by increasing farm size with the current level of inputs used. Thus, it is recommended that emphasis should be in creating favourable environment for increasing farm sizes among smallholder farmers to economies of scale.

It is also recommended that farmers' education level is a key factor of increasing technical efficiency of small holder pearl millet farmers in the study area. Thus, the provision of literacy campaigns, training and field demonstrations on best farming practices as well as encouraging farmers to engage in adult continuing education programs or exposure to simple knowledge dissemination outlets such as brochure, study tour or establishment of demonstration centres in the area may help inefficient farmers to improve their efficiency. Moreover, continuing emphasis on human capital development among farmers through extension and training and technological improvements in pearl millet production would be crucial.

It is also recommended that strategies and mechanisms should be devised to promote and encourage farmers to farmer skills transfer so that inefficient farmers can learn from efficient farmers. There is a need of reviewing the quality and timeliness of the extension services provided to farmers and of making the necessary improvements that would assist farmers to increase their production efficiency. Also, the government of the major producers of millet should invest more in functional agricultural extension services to enhance efficient use of available productivity in increasing inputs.

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