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IMPACT OF TECHNICAL PRODUCTION EFFICIENCY IN AGRICULTURE ON FOOD SECURITY IN RURAL TANZANIA

A thesis submitted in partial fulfillment of the requirement for the degree of M.Sc International Horticulture major Horticultural Economics

Submitted by

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DECLARATION

I Saeedullah Din Muhammad, hereby declare that this thesis which I submit for M.Sc International Horticulture, to the best of my knowledge is entirely my own work which has not been submitted to any other university for a degree. To the best of my knowledge the work of others which are used in this thesis are properly cited and acknowledged.

Signature: .... Date: 09 September, 2016

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ABSTRACT

This study focused to determine the level of technical production efficiency of maize farmers in two target region Dodoma and Morogoro in Tanzania. A sample size of 539 maize producers was collected randomly. The stochastic frontier model is used by applying Cobb-Douglas production function. The elasticity of inputs of production function, level of technical efficiency and the determinants of technical inefficiency were estimated. The mean technical efficiency found in the study area was 38%. The technical efficiency score was ranged between 0.002 and 0.889. The input variables land and seed showed higher positive elasticity in the production function. The result showed that family size, gender and region positively affected technical efficiency while age, off farm activities and migrant decreased technical efficiency. The finding shows that the increase of efficiency level in the study area positively affects the food consumption score and income while decrease the coping strategies index which enhances the food security condition in the area.

Keywords: Food security, Technical efficiency, Tanzania, Stochastic frontier analysis, Cobb-Douglas production function

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LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
SSA	Sub-Saharan Africa
T.E	Technical Efficiency
A.E	Allocative Efficiency
E.E	Economic Efficiency
DEA	Data Envelopment Analysis
SFA	Stochastic Frontier Analysis
FANTA	Food and Nutrition Technical Assistance
FCS	Food consumption score
HDDS	Household dietary diversity score
MAHP	Months of adequate household food provisioning
CSI	Coping strategies index
Trans-Sec	Innovating Strategies to safeguard Food Security using Technology and Knowledge Transfer

1. INTRODUCTION

Food insecurity recently becomes a serious issue in Sub-Saharan Africa (Otsuka, 2013). There is higher demand for food generally in the developing countries and particularly in Sub-Saharan Africa (SSA) where the use of modern technology is rare and the productivity is low (Kassie et al., 2007). Agriculture is the main source for the economic growth, reduction in poverty and improving the food security condition in SSA because mostly 50 million of small farms are dependent on the income generated from agriculture (Schaffnit-Chatterjee et al., 2014).

Food insecurity increased in SSA because of the marginal increase in the yield of cereals and the rapid growth of population which tends to put pressure on the limited land (Otsuka, 2013). Therefore to fulfill the demand of higher food for the growing population it is pivotal to increase agricultural productivity to maintain supply, availability and prices of food in the long run (Alston et al., 2009). There is a huge potential to increase agricultural productivity in SSA by the proper utilization of the inputs. The region is endowed with large amount of uncultivated land, untapped water resources and a large possibility to increase yields by bringing improvements in the use of inputs. The increase in global demand can be fulfilled by boosting the agriculture sector of Africa. In particular, increase in productivity of the small farms that mainly produce staple food tends to increase the food availability which improves the food security condition (Schaffnit-Chatterjee et al., 2014). In developing countries sustained agricultural production can be achieved by ensuring the efficient use of the scarce agricultural resources (Al-hassan, 2012).

Schultz (1964) hypothesis "poor but efficient" triggered most of the researchers to conduct studies to analyze the level of technical efficiency of farmers (Alemu et al., 2009). This hypothesis stated that the smallholder farmers efficiently allocate their resources. It got much attention generally and particularly in SSA because mostly the countries in SSA derive more than sixty percent of their livelihood from agriculture and other rural economic activities. Therefore the level of efficiency of smallholder farmers is crucial for the choice of development strategy. If farmers are fully efficient it means that they are lying on efficient frontier (Owuor and Shem, 2009). The higher technical efficiency of the farmers support the Schultz's hypothesis of "poor but efficient" which implies that the opportunities to increase the production through improving the efficiency are limited (Alene et al., 2005) therefore the productivity can be increased by introducing new inputs and technology which shifts the production possibility frontier upward. But on contrary if the farmers are not fully efficient it indicates that the productivity could be increased by efficiently using the resources that farmers have in their disposal with the available technology. Therefore the productivity could be increased by eliminating the factors that are causing inefficiency (Owuor and Shem, 2009).

In Sub-Saharan Africa (SSA) maize is considered as a main staple food in the daily diet (Hogh-Jensen et al., 2007). Tanzania is considered as a major maize producing country after Nigeria by area in Africa (DTMA, 2014). The economy of Tanzania is largely dependent on agriculture. The agriculture sector contributes 50 percent to the GDP and 51 percent to the foreign exchange of the country. It also employs 80 percent of the labor force in the country (Eskola, 2005). The value of maize in the production of crops in the country constitutes approximately 30 percent. It contributes 10 percent of value added in agriculture sector (Msuya et al., 2008).

Maize is considered as a primary food and cash crop in Tanzania (Kassie et al., 2007). The production of maize is an important activity in agriculture. It is a main driver of the economy of Tanzania (Thurlow and Wobst, 2003). It is the major producing cereal in Tanzania (Rowhani et al., 2011). Similarly maize is considered also as a main source of cereal consumption and a marketing commodity in the country (Shiferaw et al., 2008). It amounts for more than 75 percent cereal consumption in the country (Msuya et al., 2008) and about sixty percent of dietary calories come from the consumption of maize (Baha et al., 2013). Majority of maize producers (eighty percent) are small land holder who cultivates maize on less than ten hectares while ten percent of the production are from medium scale farming on (10-100 hectares) and the rest of five percent production occurs on large scale farms which have area more than 100 hectares (Kaliba et al., 1998). Maize is grown mostly in every part of Tanzania, but highly in two agro-ecological zones which consist of the semi-arid lands and southern and western highlands (Baha et al., 2013). Maize is not only a staple crop in surplus regions but a cash crop as well. For instance, in the Lake zone, maize competes aggressively with cotton for land, labor, and farmers' cash (Kaliba et al., 1998). The productivity of maize is decreasing despite the increase in the area of maize cultivation (Kassie et al., 2007) which will adversely affects the economic well-being of the farmers as well as become a hurdle to the efforts of government to ensure food security (Baha et al., 2013). Therefore to improve the livelihoods condition of smallholder farmers it is essential to increase the productivity of maize (Msuya et al., 2008). The productivity of agriculture can be increased either by introducing new technologies or by using the available resources efficiently with the existing technology (Bhasin, 2002). It has been widely recognized by researchers and policy makers that efficiency plays important role in increasing agricultural output (Omonona et al., 2010). The measurement of agricultural production efficiency makes it possible to estimate the efficiency level of small holder farmers. It also indicate that to which extent the small holder farmers use their available potential and inputs in agricultural activities (Ilembo and Kuzilwa, 2014). It will help to raise productivity by improving the efficiency with the available resources and technology particularly in the economies where resources are scarce and the modern technologies are difficult to implement (Tijani, 2006; Bifarin et al., 2008). Hence efforts to improve the efficiency are cost effective way to increase the agricultural production rather than introducing new technologies (Belbase and Grabowski, 1985). Moreover from applied perspective, efficiency measurement comes first in resource savings process which is essential for both policy formulation and management of firm (Bravo-Ureta and Reiger, 1991). However for increasing efficiency in agricultural sector particularly of small holder farmers, it is required to know the current level of inefficiency and factors that are responsible for it (Amos, 2007).

There are few studies which estimated the technical efficiency in the agriculture sector of Tanzania. But none of the study is noted so far that estimated the level of technical efficiency and the determinants of maize in Dodoma and Morogoro region of Tanzania. Further no study is noted so far that checked the impact of technical efficiency of maize on food security. Therefore this study will help to fill the gap by estimating technical efficiency which will help to answer the questions of current level of efficiency of farmers producing maize and the determinants that prevents the farmers to produce efficiently. Finally it will lead to find out the impact of technical efficiency on food security in Tanzania.

The remaining of the thesis is structured as follows. The second chapter reviews the literature related to previous studies of level of technical efficiency, determinants of efficiency, impact of technical efficiency on food security and the conceptual framework that illustrates the objectives of this study. The third chapter discuss about study area, data collection and methodology. In chapter four results and discussion are presented. Finally in chapter five the conclusion of main results, policy implication and suggestions for further research are discussed.

2. LITERATURE REVIEW

2.1 Efficiency

The history of measuring efficiency start from the work of Farrell (1957) who followed the work of Debreu (1951) and Koopmans (1951) to measure the efficiency of firm with multiple inputs (Coelli, 1995). Farrell (1957) defined that efficiency is the ability of a firm to produce maximum outputs from the given set of inputs. He proposed two components of efficiency i.e technical efficiency and price efficiency. Technical efficiency is the ability of a firm to produce maximum output from the given set of inputs while price efficiency is the ability of a firm to use the optimal level of inputs. Technical and price efficiency collectively called overall efficiency. The term price efficiency and overall efficiency used by Farrell is allocative efficiency and economic efficiency (Coelli et al., 2005).

Farrell (1957) simplified his idea by using a diagram showing that a firm can produce a single product (P) by using two different inputs X and Y while assuming constant return to scale.

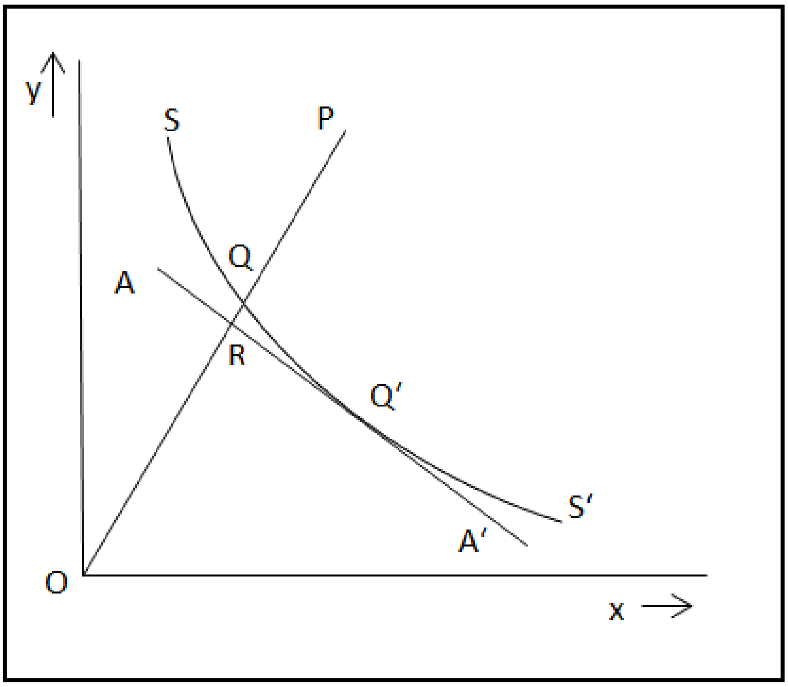

Figure 1: Illustration of technical and allocative efficiency (Farrell, 1957)

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 same as on Point P. SS' is the isoquant which shows the different combination of inputs that an efficient firm 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 also known as technical inefficiency. The ratio QP/OP shows the percentage reduction of inputs to achieve technical efficiency. The ratio OQ/OP is the Technical efficiency of a firm. The distance QP shows the technical inefficiency of the firm which shows 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 it shows that the firm is technically efficient. When the value is less than 1 it means that the firm is technically inefficient .AA' is the line on which the slope and the ratio of the prices of two inputs are same on 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). Mathematically

$$T.E * A.E = E.E$$

$$OQ/OP * OR/OQ = OR/OP$$

Kumbhakar et al. (2015) explained inefficiency by a diagram. In his diagram the production frontier is denoted by f (x). The inputs used in production frontier are denoted by (x) and the output by (y). All the points below the production frontier are considered inefficient. Point A lies here below the frontier hence it is inefficient. It indicates that with the available inputs the production unit can produce more output (y). Here line from A to point B on production frontier shows the technical inefficiency of production unit. Another way of explaining the inefficient point A is that the same level of output can be produced by reducing the inputs by AC.

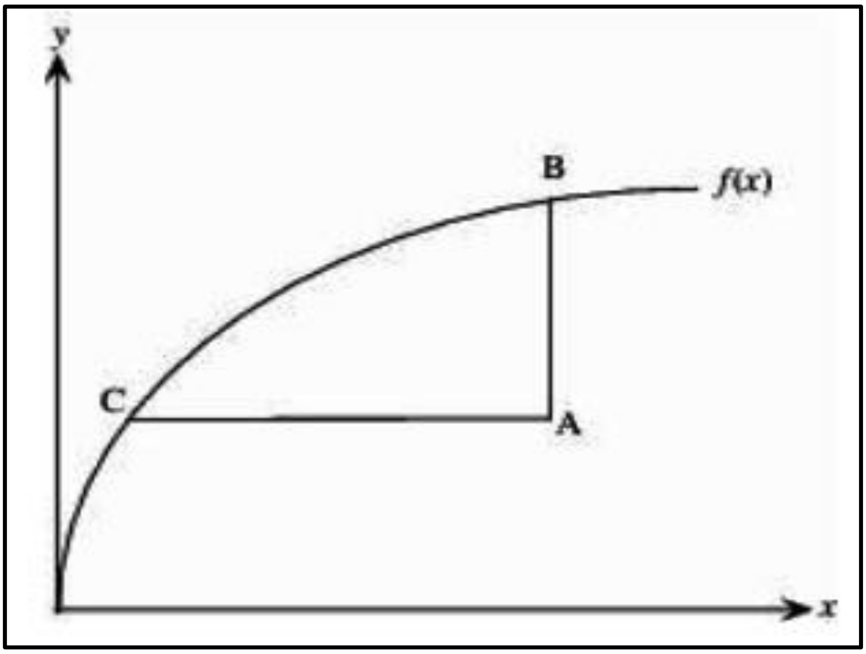

Figure 2: Technical inefficiency in one input and output case
(Kumbhakar et al., 2015)

2.2 Level of Technical Efficiency of Maize

Several studies has been done in many developing countries to study and estimate the level of efficiencies in food crops (Chirwa, 2007; Kibaara, 2005; Tchale and Sauer, 2007; Kitila and Alemu, 2014; Binam et al., 2005; Awunyo-Vitor et al., 2013).
But few studies focused on the efficiency of staple crops such as maize in Tanzania (Kidane et al., 2015; Baha et al., 2013; Msuya et al., 2008).

Kidane et al. (2015) carried out a study to analyze the relative technical efficiency of maize and tobacco smallholder farmers in Tabora Tanzania. The objective of the study was to compare the efficiency level of tobacco and maize. The analysis was done by using the frontier production function. The results of the study showed that the variable labor, area, asset and fertilizer were used as inputs in the frontier production function. These input variables showed positive significant elasticities with the production of tobacco while for maize only the input variables area and cost of fertilizer were positive and significant. The variable land area had highest elasticity of 0.932 and 0.972 for both tobacco and maize farmers respectively. The mean technical efficiency of tobacco farmers found was 73.9% with the minimum level of zero and maximum level of 0.999. The mean level of technical efficiency for maize farmers was 76.8% with the minimum level of 0.003 and maximum level of 0.91. The mean level of technical efficiencies for both maize and tobacco farmers showed that the farmers who were associated with the cultivation of maize were more efficient than tobacco.

Kitila and Alemu (2014) conducted a study to find out the technical efficiency and its determinants of maize farmers Ethiopia. In this study the stochastic frontier approach was used by using the Cobb-Douglas production function. The mean technical efficiency found in the study area was 66 percent which indicates that the producers of maize in the study area are 34% inefficient. The range of technical efficiency scores were found 0.06 to 0.92. The maximum likelihood estimation of the Cobb-Douglas production function show that among the input variables of labor, oxen, land, seed, DAP and UREA only land, seed and DAP coefficients were significant and positively related to the production of maize. The result revealed that coefficient of seed has a higher magnitude of 0.45 which indicates that the maize production is highly responsive to the amount of seed used.

Mango et al. (2015) conducted a study to find out the technical efficiency of small holder maize producers in Zimbabwe. The analyses were done by using stochastic frontier approach by using the Cobb-Douglas production function. The result of the study revealed that the land, labor, quantity of seed and the use of inorganic fertilizers significantly increase the output of maize. The mean technical efficiency found in the study area was 65%.

Amaza et al. (2006) conducted a study to identify the factors of technical efficiency of food crop production in Nigeria. The maximum likelihood estimation technique by using stochastic frontier production function was used to determine the efficiency of farmers. The results revealed that variable fertilizer, land and hired labor were positively and significantly associated with the production. The study showed that the mean technical efficiency of the farmers was 68% which means that the farmers could increase their production by 32% by using the available resources and within the available technology.

Chiona et al. (2014) estimated the technical efficiency of maize in Zambia by using stochastic frontier analysis (SFA). The translog production function was preferred to use instead of Cobb-Douglas production function as the likelihood ratio test suggested that the translog function does not reduce to Cobb-Douglas function. The estimated elasticities of the output for the inputs fertilizer, seed, size of the farm and labor were positive and significant. The results showed that the mean level of technical efficiency associated with the maize farmers in the study area were 50% with a range of minimum 2% and maximum 84%.

Binam et al. (2005) conducted a study to find out the technical efficiency and their determinants of the farmers who were cultivating maize and peanut in Cameroon. The mean technical efficiency found for the maize monocrop, ground nut monocrop and maize and groundnut intercrop by stochastic frontier approach by using Cobb-Douglas production function were 80%, 78% and 77% respectively.

Baha et al. (2013) conducted a study to find out the level of technical efficiency of the small holder farmers who were cultivating maize in Babati district of Tanzania. The technical efficiency level of the farmers in the study area and their sources were determined by using the stochastic frontier model. The mean technical efficiency of the maize farmers was 62.3% which means that the farmers in the study area can increase their yield by using the available resources. The distribution of the efficiency scores range between 0.008 and 0.92.

Msuya et al. (2008) investigated the technical efficiency of maize producers in Tanzania. The data from the survey of maize value chain analysis were used. This data covered the regions of Mbeya and Manyara which were two major maize producing areas. The technical efficiency of the maize producers was estimated by using the stochastic production frontier by employing the Cobb-Douglas production function. The finding of the study showed that the mean level of technical efficiency in the study area was 60% with minimum level of 0.011 and maximum level of 0.910.

Abdulai et al. (2013) used the stochastic frontier methodology to find the technical efficiency of maize farmers in Ghana. He argued that efficient farm practices enable farmers to increase their yield. The minimum level of technical efficiency in the study area found was 12 Percent while maximum level of technical efficiency was 98 percent and 74% as a mean level of technical efficiency. The results showed that variables seed, farm size, fertilizer and weedicides were significant and positively associated with the output of maize.

Addai and Owusu (2014) conducted a study to find out the level of technical efficiency of maize farmers in various agro ecological zones of Ghana. A stochastic translog production frontier function was employed in the study to estimate the level of technical efficiency. The estimated mean technical efficiency score in three agro ecological regions were 64.1%. The mean technical efficiency for the region forest was 79.9% while for savannah and transitional region were 52.3% and 60.5% respectively. It was argued that policies regarding extension service, development of crop varieties and education are suitable for these zones.

Opaluwa et al. (2014) studied the technical efficiency of farmers associated with the cultivation of maize in Kogi State, Nigeria. The level of technical efficiency was estimated by using stochastic frontier approach by incorporating Cobb-Douglas production function. The mean technical efficiency level of maize farmers was 25 percent with minimum level of 2.41 percent and maximum of 87.40 percent. The results implied that the maize farmers in the study area were technically inefficient hence output could be maximized with available resources by improving the level of technical efficiency. The independent variables in the Cobb-Douglas production function were land area, quantity of seeds, fertilizer, chemical, capital and labor. Among these variables land area, quantity of seed, fertilizer and labor were positively and significantly related to output.

Chirwa (2007) conducted a study to estimate the level of technical efficiency of small holder maize producers in Malawi. He found that the farmers in the study area were inefficient. The mean level of technical efficiency was 53.11 percent with a range of minimum 3.26 and maximum 99.98 percent. The input variable land was negatively associated with the production of maize in the study area. He argued that the negative relationship between the output and land could be measurement errors of plot areas, transportation cost to the plot may be fixed or the quality of plot may have unobservable variation.

Sienso (2013) studied the level of technical efficiency of maize producers in Nkoranza area of Ghana. He used stochastic frontier approach to estimate the level of technical efficiency. The mean technical efficiency of maize farmers was 91 percent. He studied the difference in mean technical efficiencies between the farmers who used improved varieties and those who use cultivate local varieties by using t-test for equality of means. He found that those farmers who use improved varieties have higher mean technical efficiency than those who use local varieties. The input elasticities of production function showed positive association with output of maize. These inputs were area of maize cultivation, quantity of fertilizer and agrochemicals applied and rate of seed used. The highest elasticity of 16.2 estimated was for fertilizer followed by seeds, area, labor and agrochemicals having elasticity of 5.9, 5.3, 2.1 and 1.1 respectively.

2.3 Determinants of Technical Efficiency

In most of the studies age, extension, gender, credit, off farm employment, education, family size and farm size are used as determinants of technical inefficiency.

Kidane et al. (2015) used a multiple linear regression to find out the determinants of technical efficiency. He found that the variable age, gender, household size, education and the size of the farm were significant. Kitila and Alemu (2014) also used the variables age, education, size of the family, tenancy of land, contact with extension, gender, off farm activity, no of plots and credit, livestock, land holding, the square of age and the region variable for Guduru and Amuru. The results showed that the coefficient of the variable age was negative and significant which means that older farmers were more efficient than younger farmers. It was also found that the age square has positive sign and significant which indicates that the efficiency increases to a point with the increase of age but after that point the efficiency level decreases. The coefficient of the variable education was negative and significant which indicated that those farmers who were educated were found more efficient. The coefficient of extension contact was also negative and significant which indicated that the farmers who are in contact with extension were more efficient. It was found that the off farm activities had a negative sign and significant which revealed that those farmers who were engaged in off farm activities found to increase efficiency. Similarly the coefficient of fragmentation was negative and significant while the coefficient of land holding was positive and significant.

Mango et al. (2015) found that variables gender, size of the household, farm size, region and their frequency of visiting the extension were significant. The gender variable had negative sign with inefficiency variable which means that male farmers were found more efficient in production of maize. The size of household was found significant and had positive sign which indicated that larger family size were less efficient than the household whose size were smaller. The coefficient of farm size were found significant and had a negative sign indicating that the farmers with larger arable land were more efficient.

The study of Amaza et al. (2006) indicated that the variable age, education, credit, extension, crop diversification had negative significant sign while crop diversification had positive sign with the inefficiency. Based on these results the study concluded that the farmers in the study area can improve the efficiency by improved education of farmers and their access to extension services.

Chiona et al. (2014) investigated the determinants of technical inefficiency. His finding showed that the variables age, off farm income, hybrid seed and access to extension and loans had influence on technical efficiency. The variable access to credit, accesses to extension services, use of hybrid seed were found to positively influence the technical efficiency. The age of the farmers had positive coefficient which suggested that the older farmers were more efficient than the younger. The variable off farm income had negative sign with technical efficiency suggesting that the off farm income reduce the technical efficiency of the farmers in the study area.

Binam et al. (2005) studied the determinants of technical inefficiency. It was found that the young farmers whose age were below 25 years were more efficient than the above age farmers for maize mono crop and maize and peanut intercrop farmers. The result showed that the farmers associated with maize mono crop cultivation that had education level of four years or more were more efficient.

The study done by Baha et al. (2013) suggested that the number of contacts with extension officers, insecticides use, farm size and the number of owned plots have negative sign with inefficiency which means that these variables contribute to increase the efficiency of the maize producers in the study area. The variables household size, gender, use of traditional seeds varieties, credit and the use of fertilizer had positive sign with inefficiency which means that these variables decrease the efficiency level in the study area.

Msuya et al. (2008) studied the determinants of inefficiency. His findings revealed that the variables education, inorganic fertilizer use, size of the household, small business engagement and the use of hand hoe and gender were significant and had negative sign with the inefficiency variable. It was found that the use of insecticide had positive sign with the inefficiency.

Abdulai et al. (2013) used the determinants agricultural mechanization, experience, education, extension, gender and credit in his study. All of these variables had negative sign but only gender, experience and agricultural mechanization were found significant. The negative sign with the coefficient of agricultural mechanization indicated that those farmers who had access to agricultural mechanization were more efficient. The negative sign with the coefficient of experience indicated that those farmers who had more experience were more efficient. Because increasing experience helps the farmers to utilize their experience for better production decisions. Similarly gender variable also had negative sign with its coefficient indicating that male farmers were more efficient in the study area than the female farmers. It could be because of the association of females in non-economic activities and restrictions placed due to religious beliefs, traditions, customs and social norms.

Addai and Owusu (2014) used variables gender, experience, education, monocropping, hybrid seed, extension, access to credit and off farm work as determinants of technical inefficiency. He found that variables experience, education, monocropping, hybrid seed, extension access to credit had negative signs with technical inefficiency which means that they positively affect efficiency. While off farm work had positive coefficient which means that it reduces the technical efficiency.

Opaluwa et al (2014) used variables age, gender, marital status, schooling year, household size, farming experience, access to credit, cooperative membership and extension visit in estimating inefficiency model. He found that older farmers were more efficient in the study area. The result of schooling year showed negative sign with inefficiency which indicated that educated farmers are easy in adoption of new and improved innovation which reduce technical inefficiency. The farmers who had cooperative membership and access to credit were found more efficient.

Age is an important variable used as determinant of technical inefficiency. In many studies it is used as a proxy for farming experience. The literature showed mix result of age with inefficiency. The finding of Abdulai and Eberlin (2001), Owuor and Shem (2009), Bhasin, (2002), Amaza et al. (2006) and Amos et al. (2004) showed that younger farmers were more efficient than older farmers due to their physical strength while the findings of Mohammednur and Negash (2010), Kitila and Alemu (2014), Gebregziabher et al. (2012) and Kibara (2005) revealed that older farmers are more efficient than younger farmers due to their farming experience.

Abdulai and Eberlin (2001) argued that younger farmers are more efficient in the cultivation of maize until they reach to an age of 38 years. After reaching this age their efficiency in production of maize declines with further increase in farmers age. He argued that age also represent the experience of farmers in management practices related to production. Therefore with the increase of age the farmers on one hand become inefficient because of the decline of their physical strength but on other hand increase in the age of farmer represent their experience in farming activities. The older farmers have more skills and therefore more efficient. Owuor and Shem (2009) found younger farmers more efficient. He argued that older farmers use traditional methods of production and unwilling to adopt modern technology. They mostly grow those varieties which are less productive, thus reduces production and efficiency. Similarly Bhasin (2002) argued that younger farmers are more agile and therefore more efficient. He suggested that young farmers should be encouraged to engage in farming activities to increase efficiency. Amaza et al. (2006) argued that older farmers who are associated with the cultivation of food crops are less efficient. Because production of food crop is labor intensive in the activities of weeding and harvesting therefore the younger farmers could do that more efficiently. Further he argued that younger farmers are more agile and willing to adopt new method of production which makes them more efficient. Amos et al. (2004), Opaluwa et al. (2014), Kidane et al. (2015) and Amos (2007) found that age decreases technical efficiency of the farmers. He stated that older farmers cannot supervise farming activities more efficiently thus increasing inefficiency in production.

But on contrary Mohammednur and Negash (2010) found in his study that older farmers are more efficient than younger farmers. He argued that age can be used as a proxy variable for farming experience. Thus farmers become more experienced as they grow old. He justified his findings by the argument that older farmers manage their farming activities efficiently with the experience he gets over time. Old farmers can easily accumulate resources such as labor, farm tools and oxen. The availability and use of these resources on time enhance increase efficiency of farmers. Kitila and Alemu (2014) and Gebregziabher et al. (2012) studied that the efficiency of farmers increases as they become older but after reaching to a point their efficiency declines. The decline of efficiency is due to loss of their physical strength after they reach to middle age. As age is used as a proxy of experience therefore older farmers becomes more experienced thus increasing efficiency. Similarly Kibarra (2005) also argued that the farmers who are above 50 years were less efficient than those who are below it as age represents both the physical strength as well as experience of the farmers. Alemdar and Ören (2006), Tshilambilu (2011), Bifarin et al. (2008) found that older farmers are more efficient than younger farmers.

Sienso (2013) found male farmers more efficient than female farmers. He argued that women face restrictions to have access to new information and technologies due to customs and traditions, social norms and religious beliefs. Therefore male farmers are more efficient and hence closer to the frontier. Further females have lower access to credit facilities than men which make difficult for them to buy inputs such as fertilizer, seeds and the use of other farming techniques in production. Oladeebo and Fajuyibgve (2007) also argued that land rights, less access and difficulty to adopt new technologies in farming activities are the reasons of lower efficiency of women. Koirala et al. (2015) stated that women could be more efficient if they have same access to factors of production as men. Because the availability of inputs and land area to male farmers are more compared to female farmers which make them more efficient. Mango et al. (2015) found male farmers more efficient in maize production than female farmers. He argued that male farmers are efficient because farm management activities such as planting, weeding and harvesting are labor intensive. Female household also have less access to productive resources than their counterparts which make them more inefficient in production. Dossah and Mohammed (2016) argued that women faces insecurity in land tenure. They have less access to land and the use of inputs, technology, information and extension services are limited compared to men. If women have access to land but still the quality of land differs. Addai and Owusu (2014) argued that the household who are headed by women despite involved only in farming activities also perform other important domestic and economic roles which make them inefficient than their counterparts. Some of their activities done by females households are non-economic and cannot be measured such as taking care of children, cleaning and cooking. Kidane et al. (2015) and Kibara (2005) also found male farmers more efficient in though not significant.

Abdulai and Eberlin (2001) found that a household who has more members are more efficient. He argued that though larger family size put pressure on income generated from farming but despite that larger family tends to provide more family labor for farming activities which make them more efficient. Tshilambilu (2011) argued that family labor replaces capital in farming activities involved in maize cultivation. Therefore larger families provide family labor to farmers which act as catalyst for increasing the yield. Due to the availability of more family labor farmers do not face shortage of labor during peak season. Similarly Al-hassan (2012) also argued that family labor in form of larger families increases efficiency in labor intensive method of production. Amos (2007), Baha (2013), Kidane et al. (2015) also found larger family size more efficient. They argued that household with more members provides more labor during peak production season.

But Mango et al. (2015) found contrary results. His finding showed that smaller household involved in farming tends to be more efficient. He argued that despite that larger family provides more labor to the farming activities it also increases the dependency ratio which contribute to poverty. Those larger households which have more members tend to put pressure on the available resources of the farmers. This pressure leads to poverty. Those farmers who are poor tend to be more inefficient because they cannot buy and afford inputs used in production.

Education is an important determinant of technical efficiency which represents the human capital of household head (Abdulai and Eberlin, 2001). Formal and informal education in agricultural sector is important for reducing poverty and improving food security condition (Sienso, 2013).

Abduali and Eberlin (2001) found that increase in farmer's education tends to decrease inefficiency. Similarly Addai and Owusu (2014) argued that education increases the technical and managerial skills of the farmers which lead to manage resources efficiently and thus farmers produces optimally. Kitila and Alemu (2014) also found that educated farmers who were involved in production of maize were more efficient than illiterate farmers. He argued that educated farmers have the ability to acquire technical knowledge which makes them more efficient and close to frontier. Al-hassan (2012) argued that education enable the farmers to acquire the ability of collecting, retrieving, analyzing and disseminating the information. The farmer with more education tends to be the part of farmer organizations which help them to get easy access to credit and extension services. Similarly Taru et al. (2011), Bhasin (2002), Amaza et al. (2006), Kidane et al. (2015), Amos et al. (2004) and Awunyo-Vitor et al. (2013) found that increase in education makes farmers more efficient than illiterate farmers.

Ahmed et al. (2002) argued that those farmers who has no formal education but are able to read and write are more efficient than those who have formal education. Also Owuor and Shem (2009) found contrary result. He found that education decreases efficiency of farmers. He argued that in developing countries farming activities are mostly influenced by agricultural training rather than formal education. Due to exposure to these trainings farmers can accumulate technical knowledge and information related to agricultural activities. Similarly Alemdar and Ören (2006) argued that with increase in formal education the farmers do not involve only in farming but they shift their activities from farming to off farm activities. Bifarin et al. (2008) also found that educated farmers are less efficient due to their engagement in off farm activities. They mainly utilize hired labor which cannot be supervised effectively due to the time spent on off farm activities.

But Baha (2013) and Kibaara (2005) argued that education is less important factor that enhances productivity because the farmers who are producing for subsistence purpose use mainly traditional methods of cultivation and hence education is not required for the efficient use of inputs.

Abdulai and Eberlin (2001) found that engagement of farmers in non-farm activities tends to reduce efficiency. He argued that engagement in these activities makes the farmers to spend more time away from farming activities. Similarly Chiona et al. (2014) argued that involvement in off farm activities reduces efficiency of farmers because of the withdrawal of managerial inputs from farming activities to non-farming activities. But Kitila and Alemu (2014) found that involvement in off farm activities provides them more income which could be used to buy inputs thus increasing efficiency of farmers.

2.4 Impact of Technical Efficiency on Food Security

Food security is a multidimensional concept (Napoli et al., 2011; Jones et al., 2013). The concept of food security was defined first in the Hot Spring Conference of Food and Agriculture in 1943 as "secure, adequate and suitable supply of food for everyone". After this conference initiatives were directed towards bringing the surplus in agricultural production to those countries that were in need. But this effort was affected during 1972-1974 food crisis time when there were unstable supplies and prices. Until 1970 the issue of food security was considered mainly from the lower supply of food which arose from various crises. But after the green revolution of 1980's the production of food was increased but still there were the problem of famine. Hence it was realized that only the food supply was not the only reason behind the food security (Napoli et al., 2011; Weingärtner, 2005). It was realized that food availability is a necessary but not a sufficient condition for food security because despite the availability of food the people who are in need would not be able to have access to it (Gross et al., 2000). Therefore the concept of food security were modified and developed over time after the World Food Conference of 1974 (Maxwell, 1996). Smith et al. (1993) counted almost two hundred various definitions of food security. Food security was defined in 1996 World Food Summit as "Food security, exist when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

There are four dimensions of food security based on the definition developed in the World Food Summit in 1996. These dimensions include availability, access, utilization and stability factor.

The availability pillar is related to the supply side or physical quantity of food which means that this pillar accounts the amount of food that are available in the country through the domestic production, stock of food, import and food aid .

The access of food is related to the ability of individual to get an adequate amount of food through the sources of purchasing from market, gifts, barter, food assistance and borrowings. There are three elements of food access. The physical access for food is related to the infrastructure and the means that are used for the transportation. Even if there is sufficient quantity of food available in one part of the country but because of the lack of physical sources it will not reach to the area which is in need. Food access can also be attributed to the purchasing power of the individuals which illustrates that even though if food is accessible in the region but the people will not have ability to buy it. The third element of access is the socio-cultural aspect which means that even though if food is available and the people can afford it but they cannot attain it because of the social issues related to the civil and social conflict.

The utilization pillar is the third dimension of food security which is the ability of individual to consume safe and nutritious food which give them sufficient energy that are required for the daily physical activities. Utilization covers the hygiene aspect of safe drinking water, the facilities of sanitary and the dietary habits of individuals. It includes the methods of storing, preparing and processing of food. It also includes how the food is shared within the household and the health status.

The fourth dimension of food security is concerned about the stability of the remaining three pillars of availability, access and utilization over time (Napoli et al., 2011; Weingärtner, 2005; WFP, 2009).

The framework of food security consists of two factors which are physical factor and temporal factor. The physical factor includes the three pillars which are availability, access and utilization while the temporal factor includes the stability pillar of food security. Each individual pillar of food security is necessary but not sufficient condition to ensure food security. For instance the physical factors such as availability of food do not guarantee access to food. If there is access to food it does not ensure the proper utilization of food. Further the temporal factor stability can affect the components availability, access and utilization of physical factor (Napoli et al., 2011; Weingärtner, 2005).

Increase in agricultural production tends to overcome the problem of food insecurity. When the production increases it decreases the prices of food for consumers. It also increases rural incomes which contribute to economic development. But higher agricultural production is necessary but not sufficient condition for economic development and reducing poverty. Although in developing countries poverty reduction requires institutional and industrial development but it can only be achieved when first agricultural productivity is increased. The food consumption of people is also affected by low level of income, lack of infrastructures and roads and education. It indicates that even though if sufficient food is available in the country it does not indicates that all people are food secure. Therefore to achieve food security it is also important to increase access to food and agricultural production (Post note, 2006).

To the best of my knowledge there are few studies that checked the effect of efficiency on food security. For instance Karki et al. (2015) studied impact of technical efficiency of African indigenous vegetables on income and food security. Oyakhilomen et al. (2015) studied the effect of technical efficiency of poultry eggs on food security in Nigeria. Oyakhilomen et al. (2015) examined the correlation between technical efficiency and poverty gap.

Karki et al. (2015) studied the impact of technical efficiency of farmers producing indigenous vegetables on income and food security in Kenya. She used food consumption score as an indicator for household food access. It was found that an increase in technical efficiency tends to increase household income and food consumption score.

Oyakhilomen et al. (2015) also found positive direct relation between technical efficiency of poultry egg and food security. He argued that increase in technical efficiency improves accessibility of households to nutritious food which lead to increase in food security. Moreover Asogwa et al. (2012) found that technical efficiency is inversely related to poverty gap. He argued that an increase in productivity tends to decrease poverty. Cordeiro et al. (2012) argued that when the quantity and quality of food declines it makes the household to employ more coping strategies with more frequency.

Koirala et al. (2015) argued that staple crop such as maize in Malawi plays an important role in overcoming problem of food insecurity. The food security in the country is mainly defined by access to maize which could be increased by high productivity and efficiency in maize production.

Adewumi and Animashaun (2013) conducted a study to find out correlation between technical efficiency, households dietary diversity and farm income focusing on small scale farmers in Nigeria. He argued that improving technical efficiency leads to increase the output but it may not necessary to raise farm income and improve household dietary diversity. The reason is that the farmers may not spend the additional income on staple food but rather spend it on other consumer goods. He found that technical efficiency has negative linear relationship with farm income and household dietary diversity. The negative relationship between income and technical efficiency is due to lack of facilities related to marketing, processing and storing the output. He argued that excess supply may result in reduction of prices due to the inelastic nature of supply. However it was found that farm income and household dietary diversity has positive relationship it implies that with the increase of income household dietary diversity increases.

In literature few studies examined the impact of technical efficiency on food security. But to the best of my knowledge no study has been noted that checked the impact of technical efficiency of maize on food security in Tanzania. Therefore this study will help to fill this gap by examining the impact of technical efficiency of maize on different dimensions of food security.

2.5 Conceptual Framework

In a competitive market those producers who use inputs efficiently remains in the market while driving out inefficient users of inputs from the market, assuming that all producers are commercial producers and market oriented. In this case even if farmers are producing for subsistence purposes it is assumed that they will involve in market for inputs. In this premise the subsistence producers will use the inputs more efficiently. In other words efficiency of farmers in production is needed to improve the living condition of the farmers and overcome the problem of food insecurity (Owuor and Shem, 2009). Agricultural productivity is limited by production inefficiencies therefore increasing production efficiency of small holder farmers' increases output of smallholder which improves household food security by raising income of small holder farmers (Mango et al., 2015). Because those farms that are efficient tend to have higher incomes which provide better opportunity for the survival and prosperity (Bravo-Ureta and Reiger, 1991).

The performance of agriculture is mostly depending on the productivity of factor of production such as land, labor and capital and the technical efficiency of the owner of farm in management practices. It indicates that improving the efficiency of farmers in their management practices increases agricultural production. The factors that explain inefficiency could be grouped into human capital and institutional and socio economic variables. Human capital variables include those variables which dominates the decision making process of farmers such as age, experience and education of farmers. Institutional factors include extension services while socio economic variables include distance to input and output market, distance to farm from home and practices aimed to improve soil fertility. It is important for policy purposes to know the factors that influence agricultural production among farmers. Agricultural production could be increased by identifying and improving factors on which agriculture production and technical efficiency depends. It will help the policy makers to make appropriate policies for increasing agricultural productivity by improving efficiency of farmers. Thus increasing agricultural production solves the problem of food insecurity because increased production leads to increase in incomes of the farmers (Bhasin, 2002).

The conceptual frame work for this study is shown in figure 3. In the first step conventional inputs will be used to estimate the production function. This will help to find answer for the first research question of estimating the level of technical efficiency. If they are not fully efficient and lying below the efficient frontier then in the next step household and farm characteristics is used as determinants of technical efficiency. This will answer the second research question of finding the determinants of technical efficiency. Further the impact of technical efficiency on different pillars of food security will be analyzed.

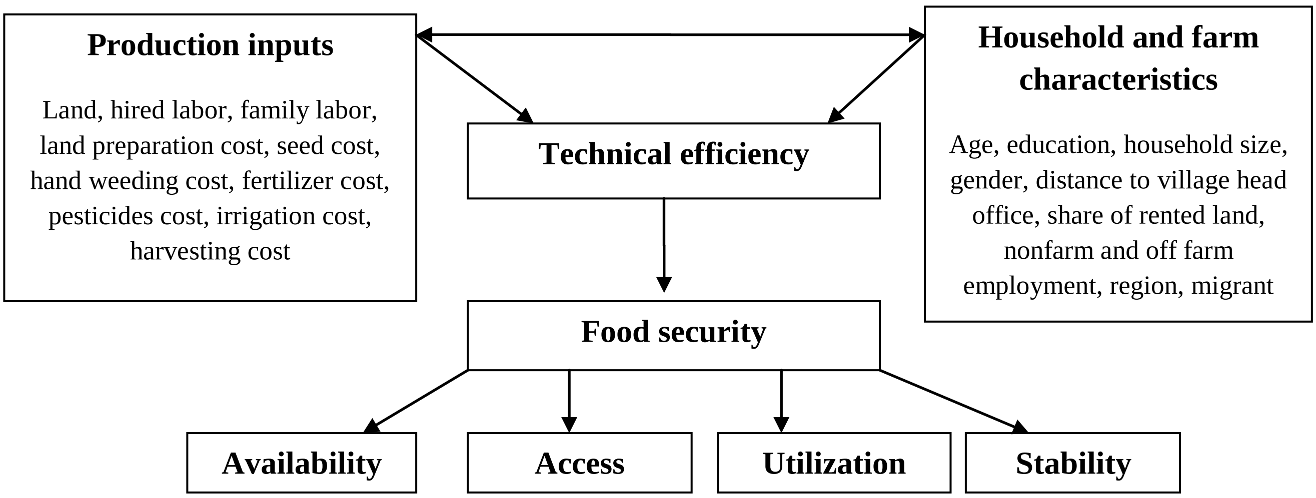

Figure 3: Conceptual framework

3. DATA AND METHODOLGOY

The data from the project "Innovating strategies to safeguard food security using technology and knowledge transfer" Trans-Sec was used in this study.

3.1 Study Area

Two target regions Dodoma and Morogoro were selected in Tanzania for this study as shown in figure 4. Each region has different food systems. Morogoro is semi humid area having highlands. The food system is based on maize, sorghum, legumes, rice and horticulture and partly with livestock.

Dodoma lies in the central zone of Tanzania which is the part of semi-arid zone. In this region the rainfall has erratic pattern. The economy of this region is depending on crop production and livestock. The productivity of agriculture in this region is low. The major crops in this region are sorghum, millet and maize while some other crops like sweet potatoes, cassava, millet and horticultural crops (Kaliba et al., 1998).

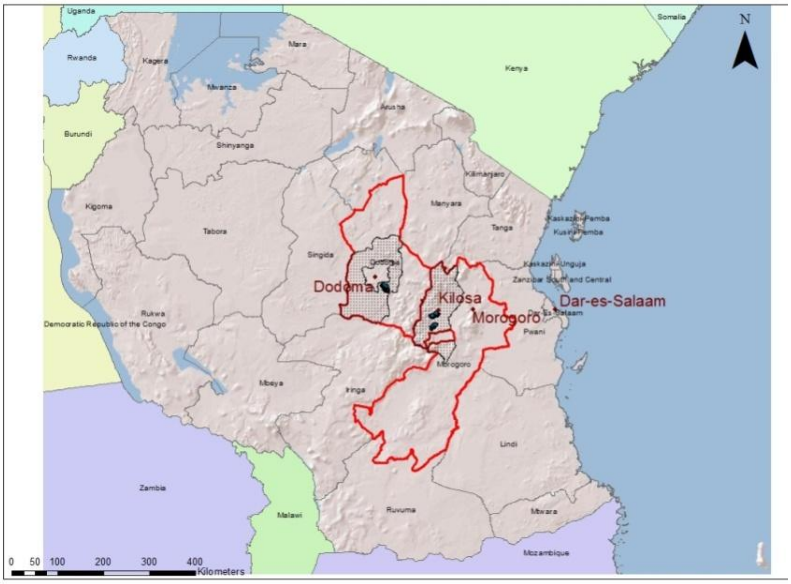

Figure 4: Case study regions in Tanzania, Dodoma and Morogoro

(Source: IUW, 2014)

3.2 Data Collection

The data was collected by a baseline survey (wave 1) in January to February 2014 for the reference year 2013. The survey regions were Morogoro and Dodoma. Three case study villages were selected from each target region.

The total sample size of maize producers in both target regions Dodoma and Morogoro are 539 households. These households were selected randomly based on the list that was provided by the village head. The questionnaire consisted questions regarding agriculture production, off-farm and self-employment activities, expenditures for food and non-food items and food security on household level. The data collected for input variables used in the production of maize includes land, family and hired labor and expenditure of household on preparation of land, seeds, weeding, fertilizer, pesticides, irrigation and harvesting. The data collected includes variables related to market, household and demographic characteristics. The income of the household includes the variables number of nonfarm and off farm employment and income from crop. The data regarding household consumption of different group was collected for different indicators of food security.

3.3 Measurement of Efficiency

A production function is the transformation process which converts inputs into outputs (Kumbhakar et al., 2015). In other words a function which gives maximum attainable quantity of output from the given level of inputs with a given technology is called production function (Kumbhakar et al., 2015; Schmidt, 1985; Coelli, 1995).

Mathematically a production function is represented as

$$y = f\ (x_1,x_2,x_3,........x_n)$$

When we perform a regression by considering output on inputs, the results gives us positive as well as negative residuals. It is because the mean output is obtained by the regression but to answer some economic questions it is important to obtain the maximum output as a function of inputs which is known as frontier production function (Schmidt, 1985).

The ordinary least square regression estimates the average function which illustrates the technology used by an average firm while the estimation of the frontier function represents the best performing firms and the technology they use. The idea of efficiency could be explained by considering a production function which represents the current technology of a firm in the industry. There are two possibilities for the firm; either to be operating on the frontier which indicates that the firm is fully efficient or below the frontier if the firm is not completely efficient. In this case the productivity could be improved by two ways. One way is to bring technological change which will result an upward shift in the production frontier while the alternative way is the improvement in efficiency by implementation of some procedures like improving farmer education to make able the farmers to use efficiently the current technology (Coelli, 1995).

The measurement of technical efficiency is essential to predict and address the causes associated with inefficiency which are important for the policy makers in developing private and public policies to enhance the performance (Ajibefun, 2008). Economic efficiency can be measured by using different frontier models based on Farrell's work, which can be divided into parametric and non-parametric frontier models (Murillo-Zamorano, 2004). The frontier analysis makes it possible to estimate the allocative, technical and economic efficiency of production (Ajibefun, 2008). The development of parametric and non-parametric methods to estimate the efficiency is based on Farrell's (1957) work. The two widely used approaches to measure the technical efficiency is the Stochastic Frontier Analysis (SFA) and the Data envelopment Analysis (de-Graft Acquah, 2014; Alemdar and Ören, 2006).

There are some similarities and differences associated with these methods which give preference of one method on other to be used. The common theme in both these methods is a frontier (Ajibefun, 2008). In these methods a production frontier is constructed and the comparison of efficiency of production unit with this frontier is carried out. The frontier constructed is the maximum output from the given inputs with the available technology (Alemdar and Ören, 2006). The units that lies on the production frontier is efficient units and those lie below the production frontier are inefficient units while the deviation from the frontier denotes the inefficiency level (Ajibefun, 2008).

3.3.1 Non-parametric approach

Data envelopment analysis (DEA) is non-parametric method mainly based on linear mathematical programming technique estimate the envelopment surface called efficiency frontier(Ajibefun, 2008; Coelli, 1995). Data envelopment analysis was firstly used by Charnes, Cooper and Rhodes (1978). In DEA there is no need to develop a production function (de-Graft Acquah, 2014; Alemdar and Ören, 2006) and hence the possibility of invalid functional form is avoided (Read, 1998). but a piecewise linear function is made from the observed data (Alemdar and Ören, 2006). It can be used to many outputs and many inputs having differed units. DEA shows the deterministic trend assuming that deviation from the frontier is due to inefficiencies only and there is no noise. DEA fails to estimate the parameters for the model which leads to the failure of testing the hypothesis related to the performance of the model (de-Graft Acquah, 2014).This method is not used mostly in agriculture frontier estimation because of the criticism for not taking into account the possibility of the influence of error term or noise associated with the data. The advantage of this method is the avoidance of the assumption of functional form of the frontier and the distribution of the inefficiency component (Coelli, 1995).

3.3.2 Parametric approach

The stochastic frontier approach was developed after several improvements and modification based on the pioneer work of Farrell (1957). The frontier suggested by Farrell was transformed into production function by Aigner and Chu (1968).

The stochastic frontier approach was first used by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) and Battese and Corra (1977). Stochastic frontier model has a functional form. (de-Graft Acquah, 2014) and the parameters of the production function can be measured statistically (Alemdar and Ören, 2006). Stochastic frontier function is estimated by using econometric techniques which helps to determine the inefficiency component of the error term (Ahmed et al., 2002).

Stochastic frontier production model divide error term into two sided symmetric component and one sided component. The two sided symmetric component denotes the factors that are outside the control of the production unit while one sided components denotes the inefficiency (Thiam et al., 2001).

It suggests that the deviation from the frontier is due to inefficiency and noise. SFA has the ability to test the hypothesis of the performance of the model. The drawback of SFA is to pre-determine a functional form and assume the distribution for technical inefficiency (de-Graft Acquah, 2014). Stochastic frontier function can be estimated by maximum likelihood method. In the estimation of stochastic frontier the Cobb-Douglas and translog functions are commonly used. One feature of the Cobb-Douglas functional form is that it can be easily computed by using econometric techniques because the inputs are transformed into logs. But instead of this simplicity it imposes some restriction such as constant return to scale (Coelli, 1995).

The stochastic frontier method to determine the production efficiency or inefficiency in agricultural production is widely used in the last two decades (Agbonlahor et al., 2007). It is recommended to use in agricultural economics because the agriculture production is associated with several uncertainties (Coelli et al., 1998). This method is useful in agricultural production because the agriculture production is mostly affected by exogenous shocks (Msuya et al., 2008). Therefore the use of stochastic frontier method could be encouraged due to its easy modeling ability of production variables (Agbonlahor et al., 2007). It is difficult to give preference of one approach on the other. The performances of these methods are mostly dependent on the data set that will be analyzed. In order to validate the results, the application of both methods to the same data set, will explain the similarities and differences in the estimates (Read, 1998). But Amaza et al. (2006) argued that based on literature the econometric approach of stochastic frontier production model is preferred in agriculture. One reason for the choice of stochastic frontier model is that in data envelopment analysis (DEA) it is assumed that all the deviation from the frontier is due to inefficiency which is not acceptable because variation in agricultural production can also be attributed to other factors that are outside of the control of farmers such as weather and diseases. Secondly most of the farmers are small holders that do not keep always the record of data associated with production, hence exposed to measurement errors.

3.4 Stochastic Frontier Model

The stochastic frontier approach which were proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) are used in this study.

The stochastic frontier model can be expressed as:

$$Yi = f(X_i, \beta) + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where

Y_i denotes the output level of i^{th} farmer

X_i represents the input used

β shows the coefficient of the unknown parameters

The error term εi in equation (1) is composed of two components $\varepsilon i = (vi-ui)$.

Where v_i accounts for random variations in output due to the factors that are outside the control of farmers which is the effect of statistical noise. These factors are weather, diseases, measurements errors and fluctuation in prices of inputs.

u_i is non-negative random variable which shows the technical inefficiency in production relative to stochastic frontier. It is assumed that the symmetric error term v_i is identically and independently distributed as N $(0, \sigma v^2)$. However one sided error term or inefficiency component ui are assumed to have half normal distribution as $N(0,\sigma u^2)$. Both v_i and u_i are assumed to be independently distributed.

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

$$TE = \frac{Yi}{Y*} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where

$Y_i = f(X_i,\beta) \exp(v_i - u_i)$

$Y^* = f(X_i,\beta) \exp(v_i)$

Therefore equation (2) can be written as

$$T.E = \frac{f\ (Xi,\beta)\exp(vi-\mu i)}{f(Xi,\beta)\exp(vi)} = \exp(-u_i)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The range of the technical efficiency is between 0 and 1. If $u_i = 0$ it means that the farmers are fully efficient and lie on the frontier. In this case the stochastic frontier production function reduces 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 the farmers lie below the frontier which indicates that the farmers is inefficient producer and make losses.

There are several functions that measure the relation between inputs and outputs. The most common production functions are Cobb-Douglas and transcendental logarithmic (translog) functions.

Kibaara (2005) estimated Cobb-Douglas and translog function and found similar level of technical efficiencies. But on his contrary Thiam et al., (2001) argued in his Meta-analysis of technical efficiencies in developing countries that the restricted functional form such as Cobb-Douglas production function generates lower technical efficiencies.

To check the choice of production function a likelihood ratio test is conducted for the selection of appropriate functional form. The likelihood ratio test is defined as

$$\lambda = -2[\ln\{L(H_0) - \ln\{L(H_1)\}]\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where the value of the likelihood function of null hypothesis (H_0) is denoted by L (H_0) and for the alternative hypothesis (H_1) is denoted by L (H_1).

If the null hypothesis is true, the likelihood ratio test statistic has an approximately a mixed chi-square or chi-square distribution and the degree of freedom equal to the difference between the number of parameters in the restricted and unrestricted model.

The hypothesis to check whether the Cobb-Douglas production function is nested within the translog production function is checked. If the null hypothesis is failed to reject indicates that Cobb-Douglas production function is an appropriate production function (Sesabo and Tol, 2007). The result of the likelihood ratio test showed that we fail to reject the null hypothesis hence Cobb-Douglas production function best fit the data.

The Cobb-Douglas production function can be written as:

$$\ln y_i = \beta_0 + \sum_{k=1}^{10} \beta ik \;\; lnXik + vi - ui\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The variables used in production function are land in hectares, hired and family labours in person days, expenditure on land preparation, seeds, hand weeding, mineral fertilizer, pesticides, irrigation and harvesting.

The empirical model can be written as:

ln (output) = β0 + $\beta_1$ln(land) + β2ln(hired labor) + β3 ln(family labor) + β4 ln (land preparation cost) + β5 ln(seed cost) + β6 (hand weeding cost) + β7 ln(mineral fertilizer cost) + β8ln(pesticides cost) + β9ln(irrigation cost) + β10 (harvesting cost) + v_i - u_i

v_i = the identically and independently distributed random error N $(0,\sigma v^2)$ which accounts for all the factors that are outside the farmer control

u_i = the non-negative error term shows the technical inefficiency and distributed as N $(0,\sigma u^2)$

Table 1: Description of variables and expected signs of frontier production function

Variable	Description	Expected sign	References
Land	area of maize producers in hectares	+	(Kitila & Alemu, 2014; Mango et al., 2015)
Hired labor	Hired labor expressed in person days	+	(Amaza et al., 2006; Msuya et al., 2008)
Family labor	Family labor expressed in person days	+/-	(Basnayake and Gunaratne ,2011)/ (Msuya et al, 2008)
Land preparation cost	Expenditure on land preparation in PPP$	+	(Boundeth et al., 2012)
Seed cost	Expenditure on seed in PPP$	+	(Kitila & Alemu, 2014; Mango et al., 2015)
Hand weeding cost	Expenditure on weeding in PPP$	+	(Abdulai et al., 2013)
Mineral fertlizer cost	Expenditure on mineral fertlizer in PPP$	+/-	(Amaza et al., 2006; Chionaet al., 2014)/ (Kitila and Alemu, 2014)
Pesticides cost	Expenditure on Pesticides in PPP$	+	(Awunyo-Vitor et al., 2013)
Irrigation cost	Expenditure on irrigation in PPP$	+	(Koirala et al., 2016)
Harvesting cost	Expenditure on harvesting in PPP$	+	Own consideration

3.5 Determinants of Inefficiency

It is useful to estimate the sources of inefficiency after estimating the technical inefficiency. The variables used as determinants of technical inefficiency include both continuous and dummy variables. Dummy variables include gender of the household, region of the household and migrant from a household. Continuous variables are age of the household head, education in years, family size, distance to village head office and number of off-farm and nonfarm activities.

In the second stage determinants of technical inefficiency are estimated by regressing the predicted technical inefficiency on variables of characteristics of farmers using the following model.

$$\mu_i = \delta_0 + \delta_i + w_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where

u_i = Technical inefficiency

δ_i = parameters to be estimated

w_i = error term

$$\mu_i = \delta_0 + \delta_1 Age + \delta_2 Education + \delta_3 Family\ size + \delta_4\ Gender + \delta_5\ Distance\ to\ vho + \delta_6\ Share\ of\ rented\ land + \delta_7\ Nonfarm\ employment + \delta_8\ Off\text{-}farm\ employment + \delta_9\ Region + \delta_1 0\ Migrant + w_i$$

Based on the literature review the following signs are expected for the inefficiency variables.

Table 2: Description of inefficiency variables and expected signs

Variables	**Description**	**Expected signs**	**References**
Age	Age of the household in years	+/-	(Bozoglu and Ceyhan, 2007;Kidane et al., 2015)/(Kitila & Alemu,2014;Amaza et al., 2006)
Education	Education of the household in years	-	(Boundethet al., 2012; Kidane et al., 2015)
Family size	Family size in number	+/-	(Boundeth et al., 2012; Msuya et al., 2008 /Mango et al., 2015)
Gender	Gender of the household 1= male	-	(Mango et al., 2015; Abdulai et al., 2013)
Distance to village head office	Km	-	(Tiruneh and Geta 2015; Alemu et al., 2009)
Share of rented land	Share of land rented in percentage	+	(Koirala et al.,2016;Tiruneh & Geta., 2015)
Off farm activities	Off farm activities of the household in numbers	+/-	(Chiona et al., 2014)/(Kitila & Alemu, 2014)
Region	Region of the household	+	Own consideration
Migrant	1 if there is migrant	+	Own consideration

3.6 Impact of Technical Efficiency on Food Security

3.6.1 Econometric model (ordinary least square regression)

An ordinary least square regression is used to check the impact of technical efficiency on the indicators food consumption score (FCS), household dietary diversity score (HDDS), caloric and protein intake, months of adequate household food provisioning (MAHFP), coping strategy index (CSI) and income from maize crops.

$$Yi = \beta_i x_i + e_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

3.6.2 Measurement of food security

There is no single tool to measure the food security because of the multidimensional nature of food security (WFP, 2008). The measurement of food insecurity is on one hand costly and on the other hand complicated to measure (Maxwell & Caldwell, 2008).

Therefore there is need of suitable indicators that cover the multiple dimensions of food security. These dimensions are availability, access, utilization and stability (Napoli et al., 2011). Since last decade progress has been done to develop indicators for household food access (Coates, 2013).

Many indicators focus on the national level of food security rather than focusing on the household level. The measurement of household level food security mainly focuses on the dynamics between and within the household. The household level measurements capture the access pillar of food security (Jones et al., 2013; Kennedy et al., 2010). The consumption of the food measured in kilo calories provides a standard for measuring food security. The food consumption score is used as a proxy for household food access (Jones et al., 2013). It also captures the quality aspect of diet (Wiesmann et al., 2009).

The food consumption score (FCS) developed by World Food Program (WFP) is defined as "*a composite score based on dietary diversity, food frequency and relative nutritional importance of different food groups*". The FCS is calculated by asking the household about the consumption frequency related to specific food groups in 7 days recall period. After that the consumption frequencies of each group is summed up while considering the value more than seven as seven. The score obtained from each group is multiplied by the assigned weights based on their nutrients density to each group. The weights given for main staples is

2, pulses 3, vegetables 1, fruit 1, meat and fish 4, milk 4, sugar 0.5, oil 0.5 and condiments 0. The scores are summed up and represent food consumption score. The threshold for the FCS considers the scores which ranges 0-21 as poor, 21.5 to 35 as borderline and above 35 acceptable (WFP 2008; Jones et al., 2013).

Household dietary diversity (HDDS) is another proxy indicator for household food access developed by Food and Nutrition Technical Assistance (FANTA). The HDDS is calculated by dividing food items into 12 groups. Then the households are asked about these 12 groups if they consumed in 24 hours recall period. The food groups that are consumed will take the value of one other wise zeros. Then these number of food groups consumed by household summed up will calculate HDDS. Thus HDDS will take the value 0-12 where 0 is none from the food group consumed by the household while 12 represents that the household consumed all the food groups in 24 hours recall period. The difference between FCS and HDDS is due to the recall period. In FCS the recall period is 7 days while in HDDS the recall period is 24 hours. In FCS the frequency of food group and their weighting is taking into consideration while HDDS does not count the frequency and weights but only take a value of 1 if a group of food is consumed in a day (Wiesmann et al., 2009; Swindale and Bilinsky, 2006).

Maxwell et al., (2013) argued that caloric intake per capita indicates the quantity and current consumption. The utilization dimension is measured by anthropometric indicators. It is the ability of individuals to take sufficient nutrients. If a diet is lacking the amount of micronutrients, it will cause the problems like stunting (Pangaribowo et al., 2013). The value of food production is used as an indicator for the availability dimension of food security (FAO, 2013).

The months of adequate household food provisioning (MAHFP) is another indicator developed by FANTA that captures the changes in the ability of household while addressing the vulnerable situation. The MAHP is calculated by subtracting the number of months when the households do not have sufficient food from the 12 months. When a household does not have food in a month, it will take value of 0 and if they have food in a month that meet their food needs will take a value of 1. Thus the range of MAHP is between 0 and 12. If MAHP is zero it means that the household does not have enough food through the year and more food insecure while if MAHP is 12 it indicates that the household have sufficient food that is required for their needs in all the year around (Bilinsky and Swindale, 2010). Coates (2013) showed that MAHP is used as a proxy indicator for certainty and stability.

The coping strategies index (CSI) developed by the WFP is one of the participatory approach that are used for the assessment of food security (Jones et al., 2013). This approach is characterized by its simplicity and easy to measure. It is used to assess the food security condition in Africa Asia and Middle East (Maxwell and Caldwell, 2008).

The CSI is made from a series of questions which are given numerical score and focusing on the coping strategies of the households when there is food shortage. The CSI score have a meaning when it is used for comparison purposes to check whether the food security situation of the household are improving or declining (Jones et al., 2013, Maxwell & Caldwell, 2008). The CSI measures the behavior of household when deals with uncertainty and vulnerability (Coates, 2013; Maxwell and Caldwell, 2008).

In order to give the numerical values to the coping strategies four categories were constructed. The categories range as most severe to least severe. The most severe category is weighted of value 4, next is valued as 3, next as a 2 and less severe as 1.

When people face a situation where they do not have enough food for eating they mostly cope with this situation by employing four types of coping strategies related to consumption. The first strategy is that households bring change in their diet. They change their consumption from food they like to the food which is cheaper. In other words from preferred food to less preferred which are substitute for preferred food. Secondly the household deals with this situation by employing short term strategies like borrowing money, begging and consuming of the seed stocks and wild foods. The third strategy the household employs when they face shortage of food is to send some household members to eat somewhere else for example kids are sent to eat with neighbors when they are eating which will reduce the number of feeding people in the household. The fourth strategy to deal with this situation is to ration the food by reducing the number of meals, spending whole day without eating or giving preference to some members in household on others for eating. When people cope more it means that they are food insecure. In other words with the given weight of severity values the higher CSI shows the greater food insecurity (Maxwell and Caldwell, 2008).

Table 3: Description of food security indicators

Variable	Description	References
Food consumption score (FCS)	A proxy variable for household food access/Quality	(Jones et al., 2013; Wiesmann et al., 2009; WFP, 2008)
Household dietary diversity score (HDDS)	A proxy variable for household food access/ Quality	(Swindale and Bilinsky, 2006; Wiesmann et al., 2009; Jones et al., 2013)
Caloric Intake	Consumption of total kcal by adult equivalent per week (Availability/Utilization)	Maxwell et al., (2013); Wiesmann et al., 2009; Jones et al., 2013)
Protien intake	Consumption of total protein by adult equivalent in gram (Availability/ Utilization)	(Wiesmann et al., 2009)
Income from crops	Income from crops (Availability)	(FAO, 2013)
Months of adequate household food provisioning (MAHP)	A proxy variable for stability	(Coates, 2013)
Coping strategy index (CSI)	A proxy variable for stability	(Coates, 2013)

4. RESULTS AND DISCUSSION

4.1 Descriptive Analysis

The descriptive analysis such as mean and standard deviation of the variables that are used in the estimation of technical efficiency are presented in table 4.

Table 4: Descriptive statistic of production function variables (n =539)

Production function (Variables)	**Mean**	**Std. Dev.**	**Min**	**Max**
Output (kg)	734.516	996.697	1	10300
Land (ha)	0.867	0.839	0.04	10.117
Hired labor (person days)	64.319	210.912	0	2880
Family labor (person days)	457.686	2710.952	0	61416
Land preparation cost (PPP$)	29.690	74.924	0	661.791
Seeds cost (PPP$)	22.836	34.075	0	311.805
Hand weed cost (PPP$)	17.570	51.802	0	509.070
Mineral fertilizer cost (PPP$)	0.230	3.319	0	64.634
Pesticides cost (PPP$)	0.535	5.474	0	114.541
Irrigation cost (PPP$)	0.283	6.578	0	152.721
Harvesting cost (PPP$)	17.594	54.105	0	585.431

Person days = number of people worked per day * number of days worked

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

The dependent variable used in the production function is the output of maize in kilograms (kg). The independent variables or the factors of production include land, hired and family labor and the cost of land preparation, seeds, hand weeding, mineral fertilizer, pesticide irrigation and harvesting.

The table 4 shows that on average the farmers in the study area produced 734 kg of maize with 10,300 kg of output were recorded for the largest producer of maize. The standard deviation of maize output was 997 kg. Land is the total cultivated area represented in hectares. The farmers associated with maize cultivation in the study area had minimum land of 0.04 hectares and maximum of 10.117 hectares with a mean of 0.86 hectares. The standard deviation of land was 0.839 hectares. The hired labor and family labor included the labor utilized in the production of maize from preparation of land, seed, and seedlings and planting, hand weeding, fertilizer and pesticides application, irrigation to harvesting and threshing. The hired and family labor was converted into person day's equivalent by multiplying person days into average hours worked per person per day. The mean hired labor in person days used were 64.319 with a standard deviation of 210.912 person days. The maximum number of hired labor used in the study area in person days is 2880 person days. The mean family labor utilized is 457.6859 person days with a standard deviation of 2710.952 person days. The maximum family labor utilized is 61416 person days. The results shows that the family labor is mostly utilized in the study area as compared to hired labor. The expenditure on intermediate inputs converted into PPP$ includes the expenditure for land preparation, seed, seedlings and planting, hand weeding, fertilizer and pesticides application and harvesting and threshing. The descriptive results shows higher mean expenditure of 29.68, 22.83 and 17.59 for land preparation, hand weeding and harvesting respectively compared to other inputs expenditures.

The descriptive results of the variables used in the inefficiency model are given in table 5.

Table 5: Descriptive statistic of inefficiency variables (n = 539)

Inefficiency variables	**Mean**	**Std. Dev.**	**Min**	**Max**
Age (years)	48.256	16.882	19	116
Education (years)	4.779	3.359	0	16
Family size (persons)	4.469	2.285	1	13
Gender (1 = male)	0.814	0.389	0	1
Distance to village head office (km)	2.101	1.900	0.003	9
Share of rented land (%)	0.204	0.388	0	1
Non-farm employment (numbers)	0.226	0.489	0	3
Off farm employment (numbers)	0.365	0.720	0	4
Region (1= Morogoro)	0.774	0.419	0	1
Migrant(1= yes)	0.098	0.298	0	1

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

The variables included in the inefficiency model are age in years, education represented in years of schooling, household size as number of persons living in household, gender as a dummy variable taking value of 1 if the household is headed by male otherwise zero, distance to village head office in kilometers which is used as a proxy variable for market, share of rented land in percentage, non-farm and off-farm employment in numbers, region is used as a dummy variable taking value of 1 if the household belongs to Morogoro region and zero if household belongs to Dodoma and migrant is used as dummy variable taking value of 1 if the household has migrants otherwise zero.

Majority 77% percent of farmers are within the active working age (21-60) years while 26 percent of the farmers are above 60 years of age. The descriptive results showed that the farmers in the study area are of minimum age of 19 years and maximum age of 116 years with mean age of 48.25 years. The standard deviation of the age is 16.882. The mean age indicated thaton average the farmers in the study area are old which will make rational decisions about farm operations in the study area.

The mean education level in the study area was 4.77 years with maximum level of 16 years. It indicated that on average the farmers in the study area had low level of education. The size of the family showed that there are maximum 13 persons in the household with an average of 4.46 persons. Large family size implies for more family labor in farming activities which reduces the cost of production of maize cultivation. The frequency distribution according to the gender in the study area implied that mostly 81 percent of farmers associated with production of maize were male while the remaining 19 percent of the respondent were females. This reveals that maize production was dominated by male in the study area.

The village head office has a mean distance of 2 km with a maximum of 9.06 km. The share of rented land has the value of 20% in the study area. The maximum number of non-farm and off farm employment is 3 and 4 respectively. The descriptive for the region variable shows the mean value of 0.77 which means that 77% of farmers producing maize in the study area belongs to Morogoro while the rest 28% belongs to Dodoma. The results of migrant indicated that there were 9% of migrants from the study area.

The descriptive results of the indicators of food security are given in table 6.

Table 6: Descriptive statistic of food security indicators

Indicators	Mean	Std. Dev.	Min	Max
Food consumption core (FCS)	45.556	16.812	8.6	112
Household dietary diversity score (HDDS)	7.074	1.886	2	11
Caloric intake (kcal adult equivalent per week)	17939.85	6792.744	3595.71	34815.87
Protein intake(adult equivalent per week in gram)	552.019	379.780	43.749	3998.151
Months of adequate household food provisioning (MAHP)	6.985	4.550	0	12
Coping strategies index (average 2013)	18.255	23.829	0	208
Net income from crop in PPP$	303.935	434.709	-531.207	3423.496

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

The food consumption score in the study area has a mean value of 45.556 with a standard deviation of 16.812. The minimum food consumption score is 8.6 while the maximum is 112. The descriptive indicates that there are households in the study area whose food consumption scores are below 21 threshold level (poor) and above 35 (acceptable). The household dietary score indicates that household at minimum consume 2 food groups and maximum 11 food groups with a mean value of 7 in 24 hours recall period. Similarly the mean caloric intake by adult equivalent per week is 17939 and average protein intake is 552 grams. The result of months of adequate household food provisioning shows that household in the study area has on average 7 months of food throughout the year. The coping strategies index also shows minimum value of 0 and maximum of 208. It implies that there are farmers whose implies coping strategies while facing vulnerable situation and also farmers who are not using coping strategies. The mean net income from maize crop is 304 PPP $ with maximum income of 3423.496 PPP $.

4.2 Production Frontier Analysis

4.2.1 Stochastic frontier analysis

A stochastic frontier analysis is carried out to find out the level of technical efficiency of maize in the study area. In order to proceed to the other steps of finding the technical efficiency and the determinants it is important to check presence of the inefficiency in the production of maize. The likelihood-ratio test checked the presence of inefficiency by assuming the null hypothesis that there is no technical inefficiency (H_0: Sigma u=0). The analysis of the Cobb-Douglas stochastic frontier production function was done by using the STATA software.

Table 7: Results of Frontier production function

Lnouput	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Ln land	0.643	0.049	13.110	0.000***	0.547	0.739
Ln hired labor	0.019	0.028	0.700	0.486	-0.035	0.074
Ln family labor	0.091	0.028	3.250	0.001***	0.036	0.146
Ln land prepartion cost	0.096	0.024	4.000	0.000***	0.049	0.143
Ln seed cost	0.129	0.031	4.210	0.000***	0.069	0.189
Ln hand weeding cost	0.081	0.035	2.330	0.020**	0.013	0.149
Ln mineral fertlizer cost	-0.101	0.123	-0.820	0.412	-0.341	0.140
Ln pesticides cost	0.064	0.094	0.680	0.496	-0.120	0.248
Ln irrigation cost	-0.053	0.159	-0.330	0.738	-0.366	0.259
Ln harvesting cost	0.003	0.027	0.120	0.903	-0.049	0.056
_cons	6.471	0.187	34.620	0.000***	6.104	6.837
/lnsig2v	-2.456	0.315	-7.800	0.000***	-3.074	-1.839
/lnsig2u	1.138	0.083	13.780	0.000***	0.976	1.300
sigma_v	0.293	0.046			0.215	0.399
sigma_u	1.767	0.073			1.629	1.916
sigma2	3.207	0.246			2.726	3.689
lambda	6.034	0.104			5.830	6.237
Prob > chi2				0.000***		
Wald chi2(10)	424.65					
Log-likelihood	-767.43					
No. of observations	539					

Likelihood-ratio test of sigma_u=0: chibar2(01) = 1.1e+02Prob>=chibar2 = 0.000

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

Note: * shows significance at p < 0.1, ** shows significance at p < 0.05, *** shows significance at p < 0.01

The likelihood ratio test of the null hypothesis that there is no technical inefficiency is computed automatically from estimating the frontier model.

The result of likelihood-ratio test showed significant result which means that we fail to accept the null hypothesis of no technical inefficiency. Therefore the null hypothesis (H0: Sigma u=0) is rejected and hence there is technical inefficiency in the model.

The significance of inefficiency can also be shown by the value of lambda (λ). Lambda (λ) is an indicator for efficiency which is derived from $\lambda = \sigma_u / \sigma_v$. If the variance of the symmetric error termσ_v is higher it indicates that the value of λ is closer to zero which means that the variation between the observed and frontier output is dominated by all those random factors which are outside of the control of farmers. If λ is greater than one it indicated that the variability is due to technical inefficiency (Owuor and Shem, 2009). The value of λ is higher than one which indicates the inefficiency. Moreover $\ln\sigma^2 u$ is highly significant which means that there is significant level of inefficiency in maize production. Thus it justifies the specification of stochastic frontier approach.

The Cobb-Douglas production function estimates the coefficient of the production function which could be explained as elasticity of the independent variables. The results in table 7 shows that the input variables land, family labor, expenditure on land preparation, expenditure on seed and weeding showed significant positive result. The size of land showed positive elasticity of 0.64 with output and significant at 1 percent. The higher elasticity of land indicated that land influence the production of maize significantly. For instance if there is 1% increase in the land the output of maize increase up to 64 percent.

Similarly the result showed positive association of family labor with the output of maize and significant at 1 percent. It indicated that an increase of 1 percent use of family labor in farming activities will increase the output by 9 percent. The preparation of land for the cultivation of maize also showed positive elasticity with output which is significant at 1 percent. This implies that if there is 1 percent increase in the expenditure on preparing the land it will tends to increase the output of maize by 9 percent. The coefficient of the variable expenditure on seeds is significant at 1 percent and also showed positive association with output of maize. It indicated that if there is 1 percent more expenditure on buying seeds of maize, it will increase the output by 12 percent. The hand weeding also influences the output of maize with an elasticity of 0.08. It indicates that an increase of 1 percent expenditure on hand weeding increases the output by 8 percent.

4.2.2 The distribution of efficiency scores

Technical efficiency scores were obtained for maize producers in two study regions Dodoma and Morogoro and also for each region separately. The frequency distribution of efficiency is shown in table 8.

Table 8: Frequency distribution of efficiency scores

Distribution of technical efficacy scores	**All**		**Morogoro**		**Dodoma**	
Efficiency (%)	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
0-20	151	28	60	14	91	75
21-40	153	28	138	33	15	12
41-60	112	21	102	25	10	8
61-80	93	17	90	22	3	3
81-100	30	6	27	6	3	2
Total	539	100	417	100	122	100
Mean	**.377**	**38**	**.440**	**44**	**.165**	**16.5**
Min	.002		.012		.001	
Max	.888		.884		.888	

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

The estimated results of overall technical efficiency show that the minimum level of technical efficiency of maize farmers in the study area is 0.002 while the maximum technical efficiency is 0.889. This suggests that none of the farmers in the study area are fully efficient and there is a room for inefficiency in the area. The mean technical efficiency found in the study area is 0.37 which indicated that the farmers in the study area were 37.7 percent efficient. The frequency distribution shows that 77 percent of the farmers produce below 60 percent of efficiency level while 23 percent of the farmers have efficiency above 60 percent. It indicates that mostly the farmers are not producing efficiently. The result indicates that the farmers are not efficiently using their available resources and hence none of the farmer achieved full efficiency therefore the farmers lie below the frontier. It implies that farmers in the study area could increase their production by 62.3 percent by using the available resources and technology.

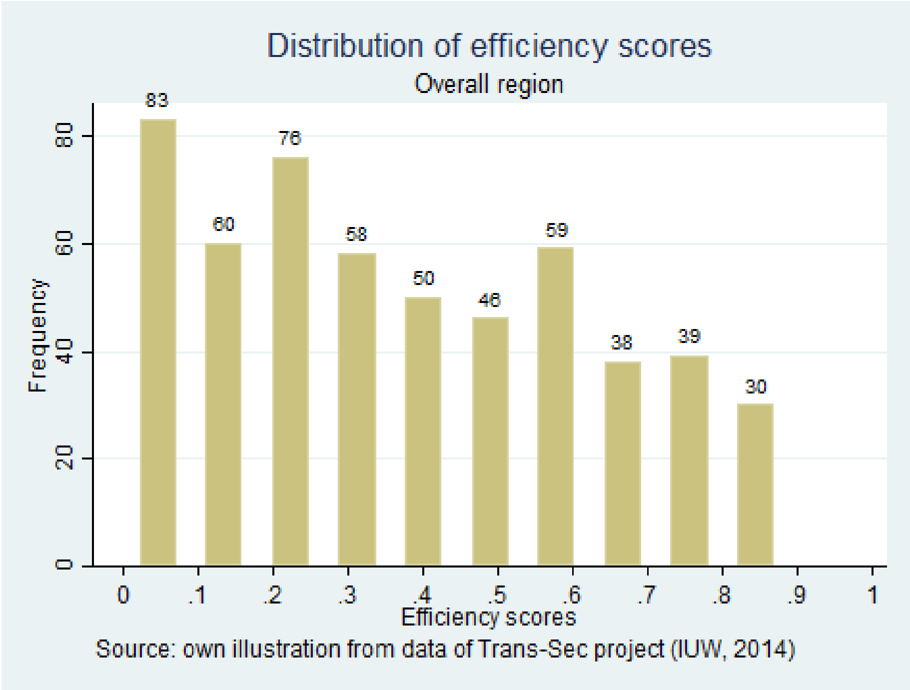

Figure 5: Distribution of efficiency scores for overall region

The mean efficiency level of farmers who were cultivating maize in Morogoro is 44 percent which have technical efficiency range of minimum 0.01 and maximum 0.88. The frequency distribution of efficiency scores shows that only 6 percent of the farmers are producing above 60 percent efficiency level while the rest are producing below 60 percent. However estimation shows that in Dodoma region the mean level of technical efficiency is 16 percent. The minimum level of efficiency in Dodoma is 0.001 and maximum level of efficiency is 0.88. The distribution of efficiency scores for Dodoma only 5 percent of farmers have more than 60 percent efficiency.

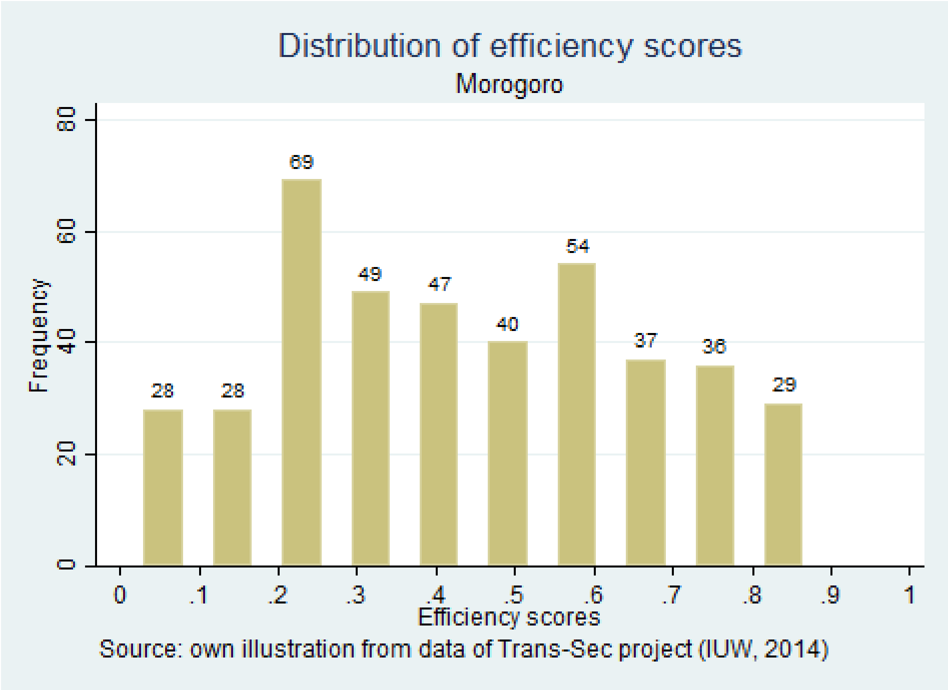

Figure 6: Distribution of efficiency scores for Morogoro region

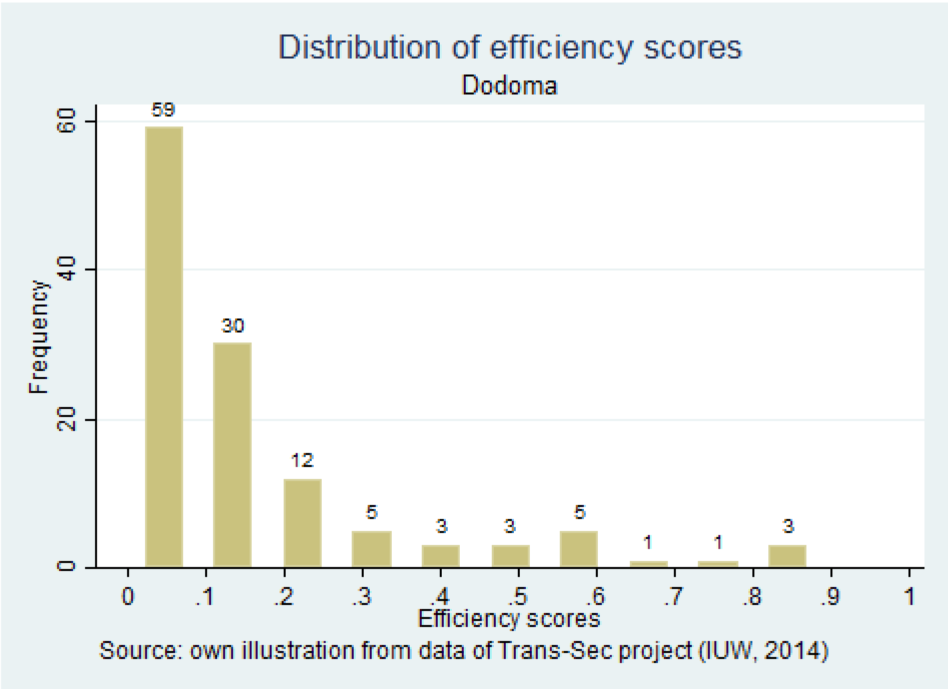

Figure 7: Distribution of efficiency scores for Dodoma region

4.3 Determinants of Technical Inefficiency of Maize

The coefficients of the variables of inefficiency model estimated are given in table 9. The dependent variable inefficiency is regressed on the determinants. It should be noted that the interpretation of the variables is done by the signs associated with each coefficient. The negative sign indicates positive effect on efficiency while positive sign indicates negative effect on efficiency.

Table 9: Determinants of technical inefficiency

Inefficiency	Coef.	Std. Err.	t	P>t	[95%Conf.	Interval]
Age (years)	0.002	0.001	2.540	0.011**	0.000	0.003
Education (years)	0.001	0.003	0.240	0.813	-0.006	0.007
Family size (persons)	-0.010	0.004	-2.290	0.022**	-0.019	-0.001
Gender (1= male)	-0.047	0.026	-1.820	0.069*	-0.099	0.004
Distance to village head office (km)	-0.009	0.005	-1.640	0.102	-0.019	0.002
Share of rented land (%)	-0.016	0.026	-0.620	0.538	-0.067	0.035
Nonfarm employment (numbers)	0.004	0.020	0.180	0.857	-0.036	0.043
Off farm employment (numbers)	0.039	0.014	2.840	0.005***	0.012	0.066
Region (1= Morogoro)	-0.244	0.025	-9.720	0.000***	-0.293	-0.194
Migrant (absent since last 3 months)	0.056	0.033	1.720	0.086*	-0.008	0.120
_cons	0.816	0.054	15.190	0.000***	0.710	0.921

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

Note: * shows significance at $p < 0.1$, ** shows significance at $p < 0.05$, *** shows significance at $p < 0.01$

The results show that the coefficients of age, family size, gender, off farm employment, region and migrant showed significant association with technical efficiency.

The coefficient of age has a positive sign and statistically significant at 1 percent. It indicates that older farmers in the study area are more inefficient. In other words younger farmers tend to decrease inefficiency of maize.

The household size has a negative significant coefficient which indicates that those household whose have more family labors in the study area are tend to be more efficient than less family members.

The gender variable has a negative significant sign with inefficiency. It means that the male farmers were found more efficient in the production of maize than their counterparts.

The variable off farm employment has a significantly positive coefficient. It indicated that the farmers who were engaged with off farm employments were inefficient

The regional dummy variable used in the study indicated a positive significant sign. It implies that he farmers who were associated with maize production in the region of Morogoro were more efficient compared to the Dodoma region.

The variable migrant showed positive sign with inefficiency. It implies that those household who do not have more migrated members are more efficient in producing maize.

4.4 Impact of Technical Efficiency on Food Security

The impact of technical efficiency on different indicators of food security is checked by using ordinary least square regression. The indicators FCS, HDDS, caloric intake, protein intake, MAHP, CSI and income from crops in PPP$ are used as dependent variables while technical efficiency score obtained by stochastic frontier analysis and the determinants of technical efficiency as independent variables. The result of ordinary least square regression is given in table 10. The results indicate that efficiency is positively related to the food consumption score and statistically significant at 1 percent. It implies that increase in the efficiency level of maize producers lead to increase food consumption scores. The result also showed that the coping strategy index decreases with the increase of efficiency and statistically significant at 5 percent. The income from maize crop also increases significantly with the increase of efficiency. However HDDS, caloric and protein intake and MAHP also increases with increase of efficiency but not significantly.

Table 10: Impact of technical efficiency on food security

	FCS	HDDS	Caloric intake	Protien intake	MAHP	CSI	Income from crop
Efficiency	9.245***	0.235	105.409	60.279	1.212	-12.797**	886.119***
Age (years)	-0.063	-0.012**	-27.122	2.088**	-0.008	0.008	1.460
Education (years)	0.071	0.029	140.426	2.172	0.017	0.356	6.069
Family size (persons)	0.189	-0.042	-1188.896***	-67.461***	-0.027	0.753	27.958***
Gender (1= male)	0.593	0.063	412.077	-6.184	0.384	-6.912**	49.437
Distance to village head office (km)	-1.014**	-0.173***	353.376**	13.659*	0.087	0.107	3.597
Share of rented land (%)	2.661	0.143	251.505	39.478	-0.497	-2.264	-36.045
Nonfarm employment (numbers)	4.370**	0.701***	927.004	30.281	0.775*	-3.170	22.480
Off farm employment (numbers)	-0.716	-0.125	-90.757	-3.686	-0.239	-0.122	-34.320
Region (1= Morogoro)	8.831***	1.272***	491.818	23.794	-0.330	-9.823**	97.350**
Migrant (absent since last 3 months)	-1.518	0.001	-1554.715	-92.204*	-0.236	4.271	-1.865
_cons	37.366***	6.832***	22416.630***	670.356***	6.790***	31.763***	-360.316
Prob>F	0.000***	0.000***	0.000***	0.000***	0.493	0.000***	0.000***
R-squared	0.134	0.186	0.179	0.092	0.020	0.092	0.362
No. of observations	499	510	510	497	510	497	510

Source: Own estimation from data of Trans-Sec project (IUW, 2014)

Note: * shows significance at $p < 0.1$, ** shows significance at $p < 0.05$, *** shows significance at $p < 0.01$

4.5 Discussion

A stochastic frontier approach is used to find out the level of technical efficiency in the study area. A Cobb-Douglas production function is used to estimate the parameters of the variables used in the production of maize. The results of table 7 revealed that land, family labor, cost on land preparation, seeds and hand weeding are increasing the output of maize significantly.

Land is a significant factor in production of maize. The result for land is as expected. Mostly farmers in the study area are small land holders therefore an increase in land will contribute significantly to the output of maize. This finding are consistent with the finding of Kitila and Alemu (2014), Mango et al. (2015) , Amaza et al. (2006), Chiona et al. (2014), Msuya et al. (2008), Basnayake and Gunaratne, (2002) and Awunyo-Vitor et al. (2013).

Another finding is that the use of family labor significantly increases the output of maize. This might be plausible because during the peak period farmer can easily utilize family labor in production activities. The availability of labor in farming operations is critical for increasing the output of maize. Due to the labor intensive nature of maize production, farmers may use more labor for planting, weeding and harvesting purposes. Similar finding were found by Basnayake and gunaratne (2002) but Msuya et al. (2008) found contrary results in his study of technical efficiency of maize in Tanzania. He argued that it could be because most of the studies reviewed did not use labor as a hired and family labor separately in their studies but rather they used it as a single variable with both hired and family labor.

The expenditure on land preparation increases the production of maize significantly. It could be due to the reason that the use of machinery or conventional methods of land preparation ensures that land is ready for sowing and better management of weeding. Similar result was found by Boundeth et al. (2012).The expenditure of seeds also increases the output of maize significantly. This result is also according to priori expectation. This result is in line with the finding of Kitila and Alemu (2014), Mango et al. (2015), Chiona et al. (2014) and Awunyo-Vitor et al. (2013). It could be because of buying and spending money on good quality of seeds tends to increase output of maize.

Expenditure on weeding also increases the output of maize significantly. This result is also as expected. This finding is consistent with the finding of Abdulai et al. (2013) and Tschale and Sauer (2007). It could be due to the reason that the output of maize could be affected by weeds. It might because weeds compete with the crop for water and nutrients which becomes a challenge in increasing output of maize.

Another surprising result is the expenditure of mineral fertilizer which is contrary to priori expectation. The expenditure on mineral fertilizer found to decrease the output of maize though not significant. It could be because appropriate use of fertilizer is important. Farmers may have inadequate knowledge of using the fertilizer which leads to the reduction of the effectiveness of fertilizer application. This finding is also similar to the finding of Kitila and Alemu (2014) who found that urea application reduces output of maize in Ethiopia but not significant.

The results of stochastic frontier approach showed that the farmers in the study area are not fully efficient. The mean level of technical efficiency found was 38 percent which implies that the farmers in the study area are producing below the frontier. Hence their production can be increased by 62 percent within the available resource base. The efficiency level of Dodoma region is lower compared to Morogoro region. The mean efficiency level of Morogoro region is 44 percent. While mean efficiency level of Dodoma region is 16.5 percent. In Morogoro region the maize producers are more efficient compared to Dodoma region. Hence the overall mean efficiency level of 38 percent is due to higher inefficiency of farmers in Dodoma region. The mean technical efficiency level of 38 percent is low compared to the technical efficiency score of Baha et al., (2013) which found the mean technical efficiency of 62.3 percent of maize farmers in Bhabati district and Msuya et al. (2008) who found the average score of technical efficiency of 60.2% with a range of in the region of Mbeya and Manyara in Tanzania.. But the range of the inefficiency is comparable to the study of Baha et al. (2013) who found the range of 0.008 as a minimum efficiency level to 0.92 as a maximum efficiency level. The study of Msuya et al. (2008) also found the minimum efficiency level of 0.011 and maximum efficiency level of 0.910.

The determinants of technical inefficiency are estimated. The results shown in table 9 shows that age, household size, gender, off farm activities, region and migrants significantly influence technical efficiency.

Age is an important variable used as determinant of technical inefficiency. In many studies it is used as a proxy for farming experience. The finding of the determinant of age shows that younger farmers are more efficient in production of maize in the study area. It could be because with the increase in age the physical strength of farmers declines which lead to increase in inefficiency. Older farmers use traditional methods of production and unwilling to adopt modern technology. They mostly grow those varieties which are less productive, thus reduces production and efficiency. But younger farmers are more agile and willing to adopt new method of production which makes them more efficient. Another reason could be because production of food crop is labor intensive in the activities of weeding and harvesting therefore the younger farmers could do that more efficiently. Older farmers also might not be able to supervise farming activities more efficiently thus increasing inefficiency in production. This finding is consistent with the finding ofKidane et al. (2015), Ilembu and Kuzilwa (2014), Bozoglu and Ceyhan (2007), Abdulai and Eberlin (2001), Owuor and Shem (2009), Bhasin, (2002), Amaza et al. (2006) and Amos et al. (2004) whose showed that younger farmers were more efficient than older farmers due to their physical strength. While the findings of Mohammednur and Negash (2010), Kitila and Alemu (2014), Gebregziabher et al. (2012) and Kibara (2005) revealed that older farmers are more efficient than younger farmers due to their farming experience.

The variable household size indicates that those household whose have more family labors in the study area are tend to be more efficient. It could be because larger family tends to provide more family labor for farming activities and replaces capital which makes them more efficient. Another reason could be that the availability of more family labor farmers does not face shortage of labor during peak season in labor intensive activities. This finding is in line with the finding of Abdulai and Eberlin(2001), Tshilambilu (2011), Al-hassan (2012), Amos (2007), Baha et al. (2013) and Kidane et al. (2015). But Mango et al. (2015) found contrary result. His finding showed that smaller household involved in farming tends to be more efficient. He argued that despite that larger family provides more labor to the farming activities it also increases the dependency ratio which contribute to poverty. Those larger households which have more members tend to put pressure on the available resources of the farmers. This pressure leads to poverty. Those farmers who are poor tend to be more inefficient because they cannot buy and afford inputs used in production.

The variable gender shows that male farmers are more efficient in the study area than their counterpart. This finding is in line with Sienso (2013), Oladeebo and Fajuyibgye (2007), Msuya et al. (2008), Koirala et al. (2015) and Mango et al. (2015). It could be because of women face restrictions to have access to new information and technologies due to customs and traditions, social norms and religious beliefs. Therefore male farmers are more efficient and hence closer to the frontier. Moreover females have lower access to credit facilities than men which make difficult for them to buy inputs such as fertilizer, seeds and the use of other farming techniques in production. Another reason of lower efficiency of women could be land rights, less access and difficulty to adopt new technologies in farming activities. The household who are headed by women despite involved only in farming activities also perform other important domestic and economic roles which make them inefficient than their counterparts. Some of the activities done by females households are non-economic and cannot be measured such as taking care of children, cleaning and cooking.

Those farmers who are involved in off farm activities are more inefficient. It might be because engagement of farmers in off farm activities makes the farmers to spend more time away from farming activities. Hence they will not be able to supervise their farms efficiently. This finding is similar with the finding of Chiona et al. (2014) but Kitila and Alemu (2014) found that involvement in off farm activities provides the farmers more income which could be used to buy inputs thus increasing efficiency of farmers.

The results also show that those farmers who produce maize in Morogoro region are more efficient than those who are producing in Dodoma region. It might be due to the reason that mostly farmers produce maize in Morogoro while in Dodoma they are involved with producing other crops and the regional characteristics may differ. The result shows that migration out from area tends to decrease efficiency. It could be argued that mostly family labor is utilized in the production of maize in the study area. Therefore migration of family members out from the area tends to decrease labor availability to manage farming activities. Because mostly the farmers in the study rely on family labor due to migration they will not have many members to carry out their farming activities as family labor. Another reason might be if young farmers migrate to other places in search of wages, the old farmers might not be able to better manage their farming activities.

The impact of technical efficiency of maize on different pillars of food security is examined in this study. The results revealed that food consumption score and technical efficiency are positively related. It implies that food consumption score increases with the increase of technical efficiency. Food consumption score is an indicator for the access dimension of food security. Hence the increase in efficiency level of farmers improves the access dimension of food security. It implies that household would have better access to sufficient food which leads to increase their consumption score from poor and borderline to acceptable level. This finding is in line with the finding of Karki et al. (2015) who found positive impact of technical efficiency of food consumption score and Oyakhilomen et al. (2015) who found that technical efficiency increases accessibility to nutritious food.

Income from maize crop is used as a proxy indicator for availability dimension of food security. Therefore, increase in income of farmers indicates the improvement in the availability dimension. The result shows that income from crops increases significantly with the increase of technical efficiency. This could be because increase in technical efficiency tends to increase the output of maize. As in the study area farmers mostly produce for subsistence purposes. But when production increases farmers could have a chance of surplus production which could be sold and hence will increase income of the farmers. The surplus production can be sold in the market which increases income of farmers. It implies that farmers could have economic access to food. This finding is in line with the finding of Karki et al. (2015) who found that improving technical efficiency increases income of farmers. Asogwa et al. (2012) also argued that technical efficiency tends to decrease the poverty gap. But Adewumi and Animashaun (2013) argued that due to increase of farm income, household dietary diversity increases but technical efficiency does not increase income of farmers due to the lack of marketing, processing and storing facilities. He argued that excess supply may result in reduction of prices due to the inelastic nature of supply.

The caloric and protein intake used as indicators for utilization dimension of food security though not significant but positively related to efficiency. Klennert (2009) argued that food fortification can be used to improve the micro nutrients deficiencies. In fortification nutrients are added to food to maintain the quality of diet. The fortification of maize flour is cost effective during milling (Chitpan et al., 2005) therefore in Tanzania the fortification of maize should be prioritized as it is a main diet of the population (Mazengo et al., 1997).

Coping strategy index is used as an indicator for the stability dimension of food security. The finding shows that when farmers are producing efficiently their coping strategy index decreases. It implies that efficient production ensures that the farmers have sufficient food over time therefore, their respond to vulnerable situations decreases.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The first objective of this study is to estimate the level of technical efficiency of maize farmers in two target regions Dodoma and Morogoro in Tanzania. The level of technical efficiency is estimated by stochastic frontier approach using Cobb-Douglas production function. The technical efficiency score was ranged between 0.002 and 0.889 indicating that none of the farmers achieved full efficiency. The mean level of technical efficiency in the study area is 38 percent which indicates that farmers can increase their output by 62 percent within the available resource base.

The second objective of the study is to find the determinants of technical efficiency. The finding shows that younger farmers are more efficient in the study area. The farmers with larger family size are also found efficient. The result of gender shows that male farmers producing more efficiently than female farmers. Those farmers who are involved in off farm activities are less efficient. The finding indicates that farmers in Morogoro region are more efficient compared to Dodoma region. Furthermore migration tends to reduce the efficiency of farmers.

The third objective is to study the impact of technical efficiency on food security. The finding shows that with the increase of efficiency level, food consumption score and income increases while coping strategies index decreases. The food consumption score, income from maize crop and coping strategies index are proxy indicators for the access, availability and stability dimension of food security. Hence with the increase of efficiency the access, availability and stability dimension can be improved. The caloric and protein intakes used as indicator for utilization pillar can be improved by fortifying maize flour as it is cost effective way of maintaining diet quality.

Based on the results it is recommended for government and policy makers to develop policies to encourage the young farmers to participate in the farming activities. The government should use appropriate policies to ensure that women have equal access to conventional inputs, information and other resources needed for production of maize as their counterparts. Moreover the government should focus on wages to reduce the migration of young farmers in search of higher wages into other areas.

This study suggests further research to harmonize and validate the different indicators used for the four pillars of food security. As in this study a simple linear regression is used to check the impact of technical efficiency on different pillars of food security therefore further research can be done to check for the robustness and endogeneity in the model. It will be interesting to analyze the impact of technical efficiency on food security after fortification of maize to check whether fortification enhance food security condition.

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7. APPENDIX

Breusch-Pagan Godfrey Test

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Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: Age Education Familysize Headofthehousehold distancetoVHO
                    shareoflandsizerented nonfarmselfemployment offfarmemployment Region Migrant

         chi2(10)     =    14.36
         Prob > chi2  =   0.1571
```

Multicollinearity test

Variable	VIF	1/VIF
Education	1.31	0.762999
Age	1.25	0.799440
Region	1.24	0.808097
Headoftheh~d	1.13	0.888140
Familysize	1.12	0.891925
distanceto~O	1.12	0.896556
offfarmemp~t	1.11	0.899604
shareoflan~d	1.10	0.907058
nonfarmsel~t	1.10	0.908810
Migrant	1.06	0.942309
Mean VIF	1.15	

Model specification test (Ramsey's RESET test)

```
Ramsey RESET test using powers of the fitted values of inefficiency
       Ho:  model has no omitted variables
                 F(3, 496) =      1.36
                  Prob > F =      0.2531
```

Likelihood ratio test

Likelihood-ratio test LR chi2(23) = 8.25
(Assumption: CD nested in Tran) Prob> chi2 = 0.9979

Table 1: Impact of technical efficiency on food consumption score

FCS_year	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	9.245397	3.400399	2.72	0.007	2.564132	15.92666
Age	-.0629742	.0477804	-1.32	0.188	-.1568553	.0309069
Education	.0714633	.2443453	0.29	0.770	-.4086378	.5515644
Familysize	.1888284	.336718	0.56	0.575	-.4727711	.8504279
Headofthehousehold	.5927123	1.977976	0.30	0.765	-3.293708	4.479132
distancetoVHO	-1.013754	.3951404	-2.57	0.011	-1.790144	-.2373632
shareoflandsizerented	2.660881	1.922498	1.38	0.167	-1.116533	6.438296
nonfarmselfemployment	4.370477	1.508059	2.90	0.004	1.407371	7.333583
offfarmemployment	-.7164154	1.038652	-0.69	0.491	-2.757208	1.324377
Region	8.831135	2.101972	4.20	0.000	4.701082	12.96119
Migrant	-1.517534	2.457165	-0.62	0.537	-6.345488	3.31042
_cons	37.36621	4.147457	9.01	0.000	29.21709	45.51533

Table 2: Impact of technical efficiency on household dietary diversity score

HDDS	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	.2348311	.3559319	0.66	0.510	-.4644823	.9341444
Age	-.0123646	.005006	-2.47	0.014	-.0222	-.0025291
Education	.0291091	.0257332	1.13	0.259	-.0214499	.0796681
Familysize	-.041765	.0356514	-1.17	0.242	-.1118106	.0282807
Headofthehousehold	.0628602	.2073886	0.30	0.762	-.3446044	.4703247
distancetoVHO	-.1728102	.0421395	-4.10	0.000	-.2556034	-.0900171
shareoflandsizerented	.1426584	.2053372	0.69	0.488	-.2607755	.5460924
nonfarmselfemployment	.7011761	.1602343	4.38	0.000	.3863574	1.015995
offfarmemployment	-.1254359	.1100301	-1.14	0.255	-.3416164	.0907445
Region	1.272353	.2172796	5.86	0.000	.8454555	1.699251
Migrant	.0007769	.2601281	0.00	0.998	-.5103069	.5118608
_cons	6.831921	.4318993	15.82	0.000	5.983351	7.68049

Table 3: Impact of technical efficiency on caloric intake

kcaladult_e	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	105.4089	1301.348	0.08	0.935	-2451.401	2662.219
Age	-27.12184	18.30275	-1.48	0.139	-63.08196	8.838274
Education	140.4255	94.08499	1.49	0.136	-44.42692	325.278
Familysize	-1188.896	130.3475	-9.12	0.000	-1444.995	-932.7975
Headofthehousehold	412.0773	758.2485	0.54	0.587	-1077.683	1901.838
distancetoVHO	353.3758	154.0693	2.29	0.022	50.66976	656.0818
shareoflandsizerented	251.5046	750.748	0.34	0.738	-1223.519	1726.528
nonfarmselfemployment	927.0039	585.8442	1.58	0.114	-224.0271	2078.035
offfarmemployment	-90.75669	402.2889	-0.23	0.822	-881.1495	699.6361
Region	491.8184	794.4117	0.62	0.536	-1068.993	2052.63
Migrant	-1554.715	951.0731	-1.63	0.103	-3423.325	313.8958
_cons	22416.63	1579.098	14.20	0.000	19314.12	25519.15

Table 4: Impact of technical efficiency on protien intake

proadult_e	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	60.27857	66.05484	0.91	0.362	-69.50194	190.0591
Age	2.087532	.9290248	2.25	0.025	.2622406	3.912823
Education	2.17208	4.775638	0.45	0.649	-7.210802	11.55496
Familysize	-67.46082	6.616278	-10.20	0.000	-80.46008	-54.46157
Headofthehousehold	-6.184197	38.48776	-0.16	0.872	-81.8026	69.4342
distancetoVHO	13.65933	7.820369	1.75	0.081	-1.705656	29.02431
shareoflandsizerented	39.47777	38.10704	1.04	0.301	-35.39262	114.3482
nonfarmselfemployment	30.28137	29.73673	1.02	0.309	-28.14354	88.70629
offfarmemployment	-3.686401	20.41969	-0.18	0.857	-43.80576	36.43296
Region	23.79435	40.32336	0.59	0.555	-55.43052	103.0192
Migrant	-92.20432	48.2753	-1.91	0.057	-187.0527	2.644036
_cons	670.3557	80.15307	8.36	0.000	512.8758	827.8355

Table 5: Impact of technical efficiency on coping strategies index

CSI_per_year	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	-12.79685	4.972031	-2.57	0.010	-22.56623	-3.027468
Age	.007958	.0698622	0.11	0.909	-.1293119	.145228
Education	.3561586	.3572486	1.00	0.319	-.3457874	1.058105
Familysize	.7534188	.4922949	1.53	0.127	-.2138754	1.720713
Headofthehousehold	-6.912074	2.88896	-2.39	0.017	-12.5885	-1.23565
distancetoVHO	.1065677	.5772187	0.18	0.854	-1.02759	1.240726
shareoflandsizerented	-2.263898	2.83691	-0.80	0.425	-7.83805	3.310254
nonfarmselfemployment	-3.170497	2.210714	-1.43	0.152	-7.514256	1.173263
offfarmemployment	-.1219007	1.540704	-0.08	0.937	-3.14918	2.905378
Region	-9.823258	3.092946	-3.18	0.002	-15.90049	-3.746029
Migrant	4.270564	3.591038	1.19	0.235	-2.785349	11.32648
_cons	31.76294	6.064334	5.24	0.000	19.84733	43.67855

Table 6: Impact of technical efficiency on months of adequate household food provisioning

MAHFP	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	1.212424	.9494567	1.28	0.202	-.6530108	3.077858
Age	-.0083373	.0133536	-0.62	0.533	-.0345736	.017899
Education	.0172427	.0686439	0.25	0.802	-.1176247	.15211
Familysize	-.027204	.0951008	-0.29	0.775	-.2140522	.1596443
Headofthehousehold	.384177	.553214	0.69	0.488	-.7027441	1.471098
distancetoVHO	.0874581	.1124082	0.78	0.437	-.1333946	.3083108
shareoflandsizerented	-.4973827	.5477417	-0.91	0.364	-1.573552	.5787867
nonfarmselfemployment	.7749742	.4274288	1.81	0.070	-.0648117	1.61476
offfarmemployment	-.2386806	.2935078	-0.81	0.416	-.8153469	.3379856
Region	-.329976	.5795985	-0.57	0.569	-1.468736	.8087837
Migrant	-.2363655	.6938978	-0.34	0.734	-1.599693	1.126963
_cons	6.790056	1.152101	5.89	0.000	4.526478	9.053634

Table 7: Impact of technical efficiency on income from crop

Net income from crop	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
efficiency	886.1186	73.30919	12.09	0.000	742.0851	1030.152
Age	1.460117	1.031053	1.42	0.157	-.5656337	3.485867
Education	6.068755	5.300114	1.15	0.253	-4.344585	16.4821
Familysize	27.95761	7.342899	3.81	0.000	13.53073	42.38449
Headofthehousehold	49.43717	42.71461	1.16	0.248	-34.48589	133.3602
distancetoVHO	3.596518	8.679228	0.41	0.679	-13.4559	20.64893
shareoflandsizerented	-36.04548	42.29208	-0.85	0.394	-119.1384	47.04742
nonfarmselfemployment	22.47993	33.00251	0.68	0.496	-42.3614	87.32125
offfarmemployment	-34.3199	22.66225	-1.51	0.131	-78.8453	10.20549
Region	97.35016	44.7518	2.18	0.030	9.424561	185.2758
Migrant	-1.864612	53.57705	-0.03	0.972	-107.1295	103.4003
_cons	-360.316	88.95574	-4.05	0.000	-535.0908	-185.5412