TECHNICAL EFFICIENCY IN MAIZE PRODUCTION AMONG SMALL-SCALE FARMERS IN BATTICALOA, SRI LANKA

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Abstract

Maize is largely a subsistence food under promotion as food security and it is also the source of income for small-scale farmers in rural areas. Considering food insecurity and poverty, the study of technical efficiency directs small-scale farmers to compare the expected potential yield and the actual yield sustainably using productive resources. Especially small-scale farmers in Koralaipattu North Division tend to underutilize or over utilize some of the factors of production. Therefore, 100 maize farmers were randomly selected as respondents among 150 farmers for the study to estimate the technical efficiency of maize and its determinants in Koralaipattu North, DS division from December to March 2022. Cobb Douglas, Stochastic frontier production function was applied to identify the impact of each input on maize production and the findings revealed that log forms of the inputs such as land size, labour hours and fertilizer significantly affected the maize production in this study area. Further, the findings indicated that the mean value of technical efficiency was 78 percent. An inefficiency effect model indicated that the coefficient for farmers' experience, education, and farm income and credit assistance were statistically significant and negative which reduced the technical inefficiency. The findings of the study suggest that the government should initiate programs to exchange farm experience among the community and promote farmers' education which encourages the adoption of new farming techniques and management. Further, providing additional income and credit facilities improves the efficiency of maize farming and their income in the future.

Keywords: Maize farmers, Stochastic frontier production, Technical efficiency, function, Technical inefficiency

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1. Introduction

Maize *(Zea mays L*) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It is one of the world's most important crops for food security, domesticated for human utilization as well as animal farming (Lana et al., 2017). Maize plays a key role in assuring food security as it provides about 3-5% percent and 5-10% percent of the world's protein and calories respectively FAO (2021). However, despite the increase in maize production, food insecurity is still a major problem worldwide. In 2020, almost 1,201,022 billion tons of maize were produced in more than 170 countries on about 208 million ha of land (Food and Agriculture Organization of the United Nations, 2022). Also due to higher demand from the livestock and poultry feed industries the Asia countries are currently increase its production largely. However, maize production decreased by 4 percent from 2021 to 2022 (44 million tons) due to a drop in production in several European countries due to widespread drought.

Agriculture is an important sector in the economy of Sri Lanka, which plays a significant role in the economy, and it contributes, about 8.3 percent of the GDP and creates employment for about 26.5 percent of Sri Lanka's population (Central Bank Report, 2023). Among the agricultural sector, cereals except rice recorded a sharp positive growth of 12.9 percent in the first quarter of 2020 compared to the first quarter of 2019 which reported a negative growth of 19.8 percent. The major proportion of this positive growth is shared by 'Maize production' which reported a production increase of 43.7 percent among other cereals and a price increase of 21 percent within the first quarter of 2020 when compared to the first quarter of 2019 (Sri Lanka Customs, 2022).

Therefore, domestic shortfalls of maize production are covered by imports due to the consumption of maize based food items like locally produced ready mix cereals, popcorn and boiled maize cobs have increased past few years. According to livestock CBSL (2022), imports have significantly dropped in 2023 only 1,181,420 8244 metric tons were imported as against 83195 metric tons imported in 2008.

However, FAO (2021) indicates that Maize production in Sri Lanka increased from 29,000 tons in the year 2000 to 351,000 tons in 2019, growing at an average annual rate of 16.73 percent. Yet the overall productivity of maize has not been adequate to meet the increasing local demand, and consequently maize imports have been taking place. Therefore, the production gap is clearly depicted that demand for maize is drastically increasing and the gap is being covered with the importation. According to the Sri Lanka Customs report 2018/ 2019, it is further observed that in Sri Lanka, 119,086 Tons of maize was imported in 2018 whereas 102,461 Tons were imported in 2019 and similarly, maize seeds for cultivation imported 1482 Tons in 2018 and 1076 Tons in 2019. Therefore, it is confirmed that local requirement has been met with importation.

According to the resource profile (2020), six Divisional Secretariat Divisions in Koralai Pattu North are major contributors to the maize production and most of the farmers fully depend on rain fed irrigation. In this context, Vaharai has been selected for the research study where higher yield of maize is contributed to the Batticaloa District annually. Variations in productivity due to efficiency disparities among small-scale farmers may be influenced by a variety of regional and farm-specific socioeconomic factors. In order to discover these elements, a method of monitoring farmer performance must be developed. Therefore, improved efficiency of maize production contributes to overcoming the problems of lower yield. Further, it helps to find the possibility of increasing yield by improving efficiency without increasing the resource.

Maize production is a critical component of food security and rural livelihoods in many developing countries. However, small-scale maize farmers often face numerous challenges that hinder their productivity and efficiency. Agricultural production and productivity can be enhanced by increasing inputs or adopting improved technology, given a certain level of resources. Another effective approach to improving productivity is enhancing the efficiency of producers.

Studies highlight varying levels of technical efficiency among maize farmers across different regions. Osim and Oniah (2023) revealed that maize farmers in Nigeria were technically inefficient in their production processes. Similarly, Kongolo (2021) observed technical inefficiency in the use of productive resources among maize farmers in the Mwanza region of Tanzania. Abdi et al. (2024) reported that maize growers in the Sidama region of Ethiopia achieved an average technical efficiency of 72.7%, with efficiency levels ranging from 65% to 83%. This performance was 10.3% lower than that of top-performing farmers, suggesting that reallocating existing resources could improve efficiency. Belete (2020) noted a significant number of inefficient farmers in the Guji Zone and Oromia region districts of Ethiopia. Additionally, Ayodeji et al. (2024) confirmed that participation in social capital networks positively and significantly enhances the technical efficiency of maize farmers in Southwest Nigeria.

Although numerous empirical studies have examined the technical efficiency of maize production among smallholder farmers, there remains a lack of consistency in the selection of variables influencing inefficiency. Furthermore, studies specifically analyzing the technical efficiency of maize production in the study area are notably scarce. Also, small scale farmers have a tendency of underutilizing or over utilizing some of the factors of production. Therefore, there may be a knowledge gap in the technical efficiency of maize farmers in Sri Lanka.

Considering food insecurity and poverty, the study directs farmers to use the optimum combination of productive resources to achieve food sustainability. Koralaippattu North, Vaharai is one of the poorest DS Divisions in Batticaloa in terms of poverty with 28 percent living below the poverty line (Dung Doan, 2013). Small-scale farmers are in research area cultivating maize as their source of income. Approximately, farmers could be able to harvest 5000 Kg per acreage (Resource profile, KPN, 2020) which is less than average production of maize. To combat hunger, food insecurity, and poverty, agriculture must increase at a steady pace. Thus, this study intends to examine the technical efficiency of maize production in Koralaippattu North Division and factors affecting the technical efficiency of maize farmers in this research area to identify the reasons for the less production.

2. Literature Review

The measurement of efficiency (technical, allocative and economic) has carried out by various researchers for different crops all over the world. However, it is vital to developing countries, where resources are meager and opportunities for adopting better technologies are dwindling. Therefore, this section tries to analysis the previous studies to understand the determinants of the technical efficiency of a product and determine the extent to which it is possible to raise productivity by improving the efficiency, with the existing resource base and available technology.

Factors influencing the Technical Efficiency

Age

Higher age is, therefore, an indication of higher farm experience in rural area where agriculture is the main means of live lihood. A study by Belete (2024) tried to estimate the level of farmers' technical efficiency in maize production and identifying the factors which determine the variation in the level of technical efficiency among the farmers in Ethiopia and concluded that older farmers were less efficient than the younger ones. Bempomaa (2014) confirmed that farmers with more years of schooling to be more efficient in Ghana during the study period. But Battese et al (1996) used a single stage stochastic frontier model to estimate technical efficiencies in the production of wheat farmers in four districts of Pakistan and confirmed the older farmers had lesser technical inefficiencies.

In measuring technical efficiency of maize producers in Eastern Ethiopia, Abdi (2024) used a translog stochastic production frontier and a Cobb-Douglas production function. The key conclusion of the study was, younger farmers are more technically efficient than the older farmers. Further, older farmers are more experienced in farming activities and better able to assess the risks involved in farming than younger farmers also contribute to the improvement of technical efficiency. However, the opposite may be true that, older farmers who did not receive a better education may be more technically inefficient than the younger ones (Tchale, 2009).

Education and Efficiency

To evaluate the technical efficiency and determinant factors of maize production among smallholder farmers in Ethiopia Abdi (2024) applied the randomly selected sample from 353 farm households during the 2021/22 production season and confirmed that education level of the farmers had a significant impact on technical efficiency of production. Using Tamil Nadu maize farmers, Kalirajan (1985) conducted a quantitative analysis of various types of education in relation to productivity in order to determine whether schooling of farmers had a greater influence on yield than non- formal education. The findings revealed that schooling of farmers had an independent effect on yield, but it was not significant. On the other hand, a farmer's non-formal education was found to have a significant and greater influence on yield. Mukole (2021) concluded that farmers' schooling and productive capacity need not be significantly related under all circumstances.

In contrast, the findings of Daramola and Aturamu (2020), acquisition of formal education exposes the farmers to the availability and technical-know-how of innovations and increases their desirability for acquiring them because increased level of education of farmers leads to increased knowledge of input uses and their application. Further, similarly the study of Rudra Bahadur Shrestha et al. (2016) examined the determinants of inefficiency in vegetable farms for improving rural household income in Nepal and its results revealed that, vegetable farms can be improved the efficiency levels with higher levels of farmers' education, and increased number of trainings to the farmers in Nepal. Therefore, this study is tried to estimate the farmers' education and its effects on the maize yield in the study area.

Farm size and efficiency

The majority of maize farmers are small-scale, farming on less than 3acres. But many small-scale farmers along with subsistence producers follow low input cultivation practices. Gautam and Jeffrey (2003) used a stochastic cost function to measure efficiency among smallholder tobacco cultivators in Malawi. Their study revealed that larger tobacco farms are less cost inefficient. The paper uncovered evidence that access to credit retards the gain in cost efficiency from an increase in tobacco acreage. This suggested that the method of credit disbursement was faulty. However, farm size will be examined with yield level in this study.

According to Nieuwoudt (1990), small-scale farmers may use land much more intensively than large farmers and study revealed that farms with less than one hectare applied inputs much more intensively than farms with more than one hectare, thus, suggesting that smaller farms may maximize returns to land while larger farms maximize returns to labour and capital. In this line, Hasnain et al. (2015) analyzed the technical efficiency of rice farms in Bangladesh. He found that farm size significantly and positively affects the technical efficiency of rice production.

However, the effect of farm size on efficiency is a controversial issue, small-scale farms may be more efficient in terms of transaction costs than large ones on the other hand, and large farms have the advantage of attaining economies of scale by spreading fixed costs over more land and output, getting volume discount for purchased inputs (Ogolla and Mugabe, 1996). Other studies on productivity of crops in Sri Lanka such as rice (Shantha et al., 2012), tea (Basnayake and Gunaratne, 2002) and Potato (Amarasinghe and Weerahewa, 2001) has revealed that land is a significant factor of production. Therefore, farm size is also a crucial factor to be analyzed the productivity of the study area.

Gender issues and efficiency

Informal sector activities have become increasingly important in rural areas. For some women, formal employment outside the home is not a feasible income generating strategy for reasons which include lack of access to transport, domestic responsibilities, inadequate job training or previously work experience, and other barriers to entering the workforce (Orberhauser, 1993).

Further, a study by Yiadom et al. (2013), on rice farmers in the Ashanti Region, Ghana and found that female headed farms recorded a mean technical efficiency of 16.5% with a range of between 2 and 66 percent. The male headed farms, on the other hand, showed a mean technical efficiency of 30.8 percent, and a range between 2 and 85 percent. The results imply that on the average, female rice farmers are relatively technically inefficient than their male counterparts. Hence, this study will examine productivity with regard to gender.

Labour source and efficiency

The greater efficiency of family labour on small-scale farms may be due to two factors; first, as the ratio of hired labour to family labour rises, supervision becomes more time-consuming and less effective. Second, as the social distance between the supervisors and the hired labour increases, the effectiveness of supervision will decrease (Boyce, 1987).

Carter and Wiebe (1990), argue that small-scale hyper productivity is eventually overwhelmed by capital constraints-as farm size increases; it becomes less easy to substitute family labour for hired labour and other purchased inputs. Since credit markets in many less-developed countries are characterized by undeveloped financial institutions the cost of and access to credit are inversely related to farm size (Cornia, 1985).

However, another study done by Michael (2011) in Nigeria among yam farmers and resulted that labour from family sources was mostly used in yam production and Labour for land preparation and maintenance with farm distance showed a negative decreasing function to the factors and reduced yam output. Labour resource is a crucial factor to be analyzed the productivity in the study area.

Hybrid Seed and efficiency

Considering the level of technology generally used by smallholder farmers in producing maize, the farmers tend to depend on family and communal, cooperation labour (Kimenyi, 2002). Using improved seeds in crop production is one way of increasing productivity in terms of quantity and quality (Kiplangat, 2003).

Despite the low level of production technology used by smallholder farmers in developing countries, the use of improved seeds is said to be on the increase (Kiplangat, 2003). The availability of these seeds is usually in the markets. Thus, farmers with more access to the market may have increased potential of using them appropriately, and subsequently improve crop productivity.

Chemical Fertilizer and efficiency

The use of chemical fertilizer is known to be a commonly used method in improving
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productivity and in the intensification of agricultural production as a whole chemical fertilizer plays a big role in regions where the scarcity of farm land is a big problem and traditional fallow periods are either very short or no longer in existence. However, the appropriate use of these fertilizers is very important in achieving the desired results disproportionate use of fertilizers is usually common among farmers with little knowledge about them, or with little access to extension agents. In such a case, productivity may be affected negatively (Hopper, 1965).

Further, Dominic Tasila Konjal et al. (2019) studied the technical and resource use efficiency among smallholder rice farmers in Northern Ghana. The Translog production frontier was analyzed to estimate the efficiency scores and the results show that quantity of weedicide used has positive effects on output of rice.

Therefore, fertilizer is also to be analyzed for the technical efficiency of maize production in the study area. Also, Mardiyah et al. (2024) revealed that organic fertilizer has no significant effect on corn production at East Java since farmers were not interested to use their corn production. However, NPK fertilizer input in corn farming is the most important part of producing quality corn production and farmers in this study area applied and get benefit from them.

Access to extension service and efficiency

By contrast, Awoniyi and Bolarin (2007), and Kibirige (2013) expressed in their study that increase in farmers' access to extension services would increase their efficiency in maize production, but rather results in the model indicate that increase in farmers' access to input use training leads to a decrease in the technical efficiency. The negative relationship between access to extension services and technical efficiency may be a result of poor-quality extension services rendered to farmers due to technically unqualified extension staff or farmers do not put into practice what is being taught by extension officers.

Further, a study by Getachew Wollie (2018) was to estimate technical efficiency of barley production in the case of smallholder farmers in market district in Ethiopia. He indicated that extension contact significantly and negatively affected technical inefficiency score in the study.

However, a study mentioned that promotion of technical change through the generation of agricultural technologies by research and their dissemination to end users play a critical role in boosting agricultural productivity in developing countries (Mapila, 2011). Hence, extension service also, is an important factor in productivity.

Uses of tractor and efficiency

Farmers currently use some form of mechanization in cultivation. Abramov and Malek (2012) found in their study that the use of tractors in land preparation reduces the technical efficiency through timely land preparation and planting. By contrast, Ali and Khan (2014) mentioned in their study that tractor plow significantly increases wheat productivity. Hence, uses of tractor as an input to analyze technical efficiency.

Farm income and efficiency

The study by Goyal et al. (2006) on paddy farming is significant at 1% level revealed that, as the farm income increases, it is possible to reduce the technical inefficiency by spending more expenditure on paddy to buy necessary inputs and improving the production in the next season.

Similarly, Obwona (2006) estimated a Trans-log production function to determine technical efficiency of tobacco farmers in Uganda using a stochastic frontier approach. The estimated efficiencies were explained by socioeconomic and demographic factors. The results showed that farm assets contribute positively towards the improvement of efficiency. Another study mentioned that, farm income influences the technical efficiency of farm household agricultural production in Pakistan (Mehmood, 2017). Hence, farm income or asset is an important factor to be analyzed efficiency of the production in the study area.

Credit Assistance and efficiency

Binam et al. (2004) examined factors influencing technical efficiency of groundnut and maize farmers in Cameroon and the study concluded that access to credit, social capital, and distance from the road were important factors explaining the variations in technical efficiencies. Similarly, another study was done by Addai and Owusu (2014) on technical efficiency of maize farmers across various Agro Ecological Zones of Ghana. The results showed that credit assistance positively influenced the productivity of maize.

Further, evidence from Sri Lanka show that smallholder farmers can benefit from contract farming arrangements with private sector companies (Esham et al., 2005). Further, they mentioned in their study that government should provide incentives to the private sector to enhance their role as partners in contract farming schemes involving smallholder farmers. Hence, credit assistance must be examined in order to analyze the efficiency of maize production.

Theoretical Framework

Technical efficiency (TE) relates to rate of the maximum output from a given of inputs or uses the minimum amount of inputs to produce a given output. This technical efficiency led to output-oriented and input-oriented efficiency measures. These two measures of technical efficiency will coincide when the technology displays constant returns to scale (Coelli et al., 2005). Therefore, technical efficiency is an important to be analyzed the factors affecting any production. Different methods for measuring TE have been developed and currently, two approaches namely the Stochastic Frontier Analysis (SFA) and the Data Envelopment Analysis (DEA) are mostly used in measuring TE. These approaches are qualified as a primary model in the analysis of technical efficiency (Coelli, 1996; Thiam et al., 2001).

Cobb Douglas Production Function

The Cobb–Douglas production function is widely used to represent the technological relationship between two or more inputs and the output that can be produced by those inputs. Also, this form of stochastic frontier model was used in this study.

A linear relationship Cobb-Douglas production was established for the study as follows.

$$\ln(Y) = a_0 + \sum_i a_i \ln(I_i)$$

where;

Y = Output

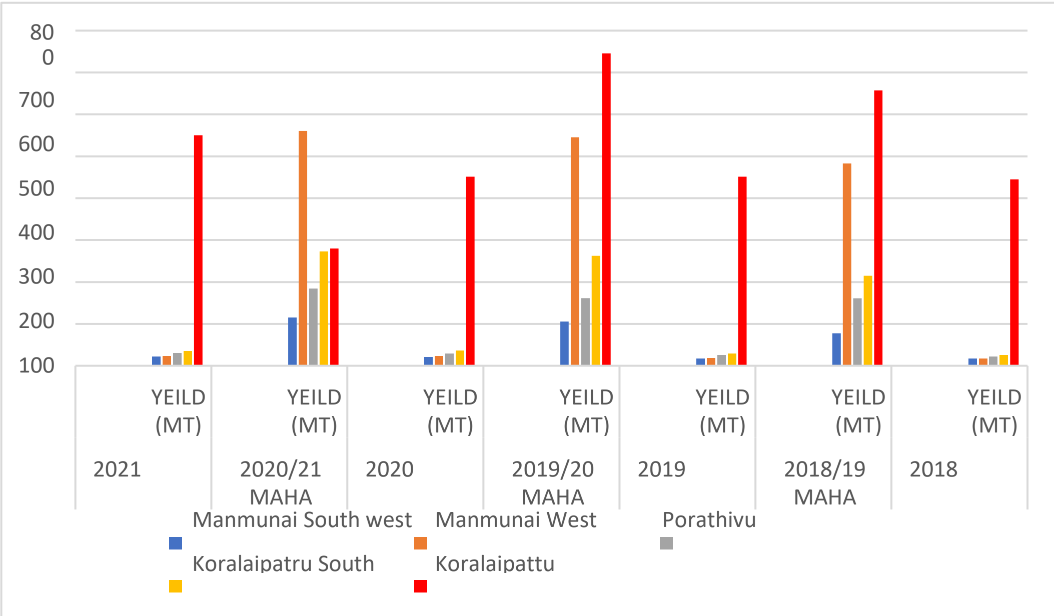
I_i = Inputs

a_i = Model coefficients

3. Research Methodology

The present study was conducted in Kallarippu village, Koralaippattu North Divisional Secretariat, Vaharai. Farmers are engaging in Maize cultivation during the rainy seasons only and around 150 farmers are residing in this village. They involved in persistent maize cultivation for their source of livelihood and they have been cultivated once in every three months annually by pumping water from Verugal river basin and consequently they could be contributed to the Batticaloa District as a leading and main contributor in the line of maize production (Resource Profile, KPN, 2020). Primary data was collected using structured questionnaires with randomly selected 100 farmers among 150 maize farmers in this study area.

Figure 1: Trend in maize cultivated season and the yield in Batticaloa District



Source: Resource Profile, District Secretariat, Batticaloa, 2023

As shown in the Figure 1, KPN Division has recorded the highest yield compared to the other DS Divisions in Batticaloa District except for the Maha season in 2020/21.

4. Analytical Tools and Techniques

As the Cobb-Douglas (C-D) production function is commonly used in Stochastic Frontier Analysis (SFA), the following methods of techniques were applied to analyze the data in the study. Further, the variables of this study were shown in Table 1.

Table 1: Variables Description of the model

Variable		Definition
Yield		Yield of maize in kilogram per acre
Land		Area under maize cultivation in acres
Labour		Labour used per hectare (number)
Tractor		Duration of tractor use per acre (hours)
Seed		Seed used per acre (kg)
Fertilizer		Chemical / Organic fertilizers used per acre (kg)
Farming Experience		How many years of experience do respondent have
Resource	Age	Age of farmer in years

accessibility		
	Education	Household heads' education in number of years of schooling
	Farm Income	How much earn from the farm per cultivation
	Family Size	How many members in the family
	Credit Assistance	How much credit assistance receive per cultivation
	Extension service	How many times an extension agent visit
Number of observations		n = 100

Source: Modified from Esham (2009), Sibiko (2012), Sapkota and Joshi (2021)

Stochastic frontier production function

This measure of the efficiency scores of individual famers, Cobb - Douglas production function of the stochastic frontier production function was used in the study where the maize production was taken as output and five inputs such as land size, labour hours, quantity of seed, and quantity of fertilizer and duration of tractor defined as production inputs. The empirical model of the Cobb - Douglas production function is taken the maize production as dependent variable and its major inputs taken are as independent variables in the model as below:

$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \varepsilon_i$ …………………(1)

Where,

$\ln Yi$ = Yield of maize production (kg)

$\ln X_1$ = Size of cultivated land (Acres)

$\ln X_2$ = Labour (Hours)

$\ln X_3$ = Quantity of seed (kg)

$\ln X4$ = Quantity of fertilizer (kg)

$\ln X5$ = Duration of tractor (Hours)

$\beta 0$ = Constant term

$\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, and $\beta 5$ are the coefficients of each independent variable respectively.

εi = Error term

Inefficiency effect model

After estimating the technical scores using production, the inefficiency effect model is also employed to identify the impact of farmers' demographic and farming characters on technical inefficiency. For this purpose, variables related to demographic characteristics and farming characteristics among the stakeholder agricultural farmers were collected from the respondents in the study area. Thus, the determinants of technical efficiency were modeled in terms of those characters which are specified by the following efficiency model.

$| \mu_i | = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 +$ …………………(2)

Where

μ_i: Inefficiency

α_0: Intercept term

Z_1: Education level of farmer (Years)

Z_2: Experience of farmer (Years)

Z_3: Credit Assistance (Amount)
Z_4: Age of farmer (Years)
Z_5: Family size (Number)
Z_6: Family income (Amount)
Z_7: Extension Service (Number)
Є: Random error

5. Data analysis

The collected data was first entered into Microsoft Excel. For the Maximum Likelihood Estimation (MLE), data were imported and analyzed using STATA. The unknown parameters of the stochastic frontier production and the inefficiency effects were estimated simultaneously.

From the estimation of the stochastic frontier production function, the effects of the production inputs on maize output were obtained and statistical tests at this level revealed the significant determinants. The stochastic frontier production function and the inefficiency model defined by equations (1) and (2) are simultaneously estimated by using STATA. The variance parameters are expressed in terms of $\gamma= (\sigma^2_u / \sigma^2_u + \sigma^2_v)$ and the γ parameter lies between zero and one.

Hypotheses test of the study

The hypotheses to be tested were:

1. There are no inefficiency effects in the specified stochastic production function and the value of gamma [$\gamma= (\sigma^2_u / \sigma^2_v + \sigma^2_u)$] equals zero: $H_o: \gamma = 0$.
2. There are no inefficiency joint effects of the considered socio-demographic and institutional factors on technical efficiency in the study area. This null hypothesis is then written as $H_0: \sigma_1=\sigma_2=...=\sigma_7=0$, where σ represents the parameters of the considered factors.

6. Results and Discussion

Democratic Information of Respondents

Small-scale farmers distinguished based on the physical parameters of farms (utilized agricultural area, inputs used e.g. labour, fertilizer, seed), the economic size of farms in terms of standard output, and the ratio of market participation (Davidova et al., 2010). In this study concerned farmers' socio-economic parameters related to production in order to identify the technical efficiency which directly interconnected to the farm productivity.

Table 2 depicts the number of sampled farmers by gender and marital status from the study area. Among the sample, 86 percent were male while only 14 percent were female and 87 percent of respondents were married while only 13 percent of them were single. Generally, in Vaharai Division, men are more engaged in agricultural activities especially in maize cultivation for their livelihood.

Table 2: Democratic information of respondents

Variables	Percent (%)
Gender	
Male	86
Female	14
Civil Status	
Married	87
Single	13
Education level	
Grade 1-5	56
Grade 6-10	34
O/L	5
A/L	4
Degree	1
Extension service	
One time	25
Two times	11
Three times	20
Four times	38
Five times	6
Experience (years)	
less than 5	9
6 to 10	24
11 to 15	30
16 to 20	12
21 to 25	9
25 to 30	4
Total Sample 100	

Source: Researcher's calculation

As the results presented in Table 2 the majority of the maize farmers did not complete the compulsory education as mentioned by the Ministry of Education of GOSL. Among the respondents, the majority of 56 percent of respondents completed grade 1 to grade 5 and 34 percent of respondents completed grade 6 to grade 10 while a few of them completed O/L, A/L and degree. This is indicated that many unskilled householders engaging maize farming and majority of the respondents depend on maize farming as their livelihood.

Further, majority 38 percent of the respondents received four times of the extension services from the Ministry of Agriculture of GOSL during maize farming period and only 25 percent and 11 percent of the respondents received one time and two times of extension agent's visits respectively it may be due to the difficult access from the town to the farm and thereby, extension officer might not be able to reach the farmer very often.

The majority of the respondents have been involved in maize farming for more than ten years and however, only 9 percent of respondents had less than five years of experience while only 4 percent of respondents had more than 25 years of experience. All the maize farmers have had some knowledge of prior experience regarding maize farming management and practices.

The mean age in the study sample was found to be 47.2 and the mean number of persons per household was 3.93 as given in Table 2. The majority of the respondents were young and they are able to produce higher yields since they can be physically healthy enough and strong. However, Bhavan and Maheswaranathan (2012) found farmers' age haven't any significant effect on yield in Batticaloa. According to Table 3, the smallest household had one member while the largest had 7 members among the respondents.

Table 3: Mean age and household size

Variable	Mean	Std. Dev.	Min	Max
Age	47.2	12.97784	28	74
Household Size	3.93	1.281216	1	7

Source: Researcher's calculation

Maize Farming Inputs

The main farming inputs considered to this study are explained by Table 4. According to this table respondents utilized different amount of human labour hours, land, seed, fertilizer and tractor as inputs per acre. As shown in table 4 an average of 3169.5 kg per acre of maize was yielded from by using an average of 1.7-acre land, 31.5 hours of work force, 2.64 hours of tractor duration, 8.5kg of seed and 71.5 kg of fertilizer. Further, all farmers were utilized hybrid maize seeds only for their cultivation.

Table 4 Production inputs for maize farming

Variable	Mean	Min	Max
Yield (kg/acre)	3169.5	600	12000
Land (Acre)	1.7	1	5
Labour (Hours)	31.5	23.7	69.6
Duration of tractor (Hours)	2.64	1.5	10.5
Quantity of seed (kg/acre)	8.5	5	25
Fertilizer (kg/acre)	71.5	50	250

Source: Authors' calculation using STATA, 10

Empirical results from the stochastic frontier analysis

It elaborates on the results obtained from the econometric analysis of the stochastic production frontier of the Cobb-Douglas functional form. It initially explains the results from the estimation of the production frontier function on the significant parameters with effect of maize yield. Secondly, it further analyses the results from the technical efficiency prediction to improve the maize yield.

The stochastic frontier production function was used to determine the factors which influence the maize production among farmers in the study area. According to Table 4.4, out of five variables, log of labour hours and log of land size and log of fertilizer are significant while remaining variables such as log of seed quantity and log of tractor hours are insignificant in this model.

The coefficients of each variable represent the elasticity of maize yield with respective inputs which means percentage changes occur in output as a result of 1 percent change in input. In this line, coefficient of labour hours 0.63 reflects that as the labor hours increased by 1 percent, it will lead to producing 0.63 percent of more output of maize while keeping remaining other inputs are constant. Similarly, coefficient of land size 0.65 represents that as the cultivated land size increased by 1 percent, it will increase the output by 0.65 percent remaining other inputs are constant.

This finding revealed that farmers are currently cultivating below the optimal land scale in maize production in this area as increase in area would increase the maize production. However, land resource management must be considered carefully since arable land scarcity greatly affects the next generation.

The relationship between land size and maize production in this study was similar to the study made by Khan et al. (2010) on maize farming in Bangladesh and Baruwa and Oke (2012) in their study on cocoa yam in Nigeria. In contrast, a study by Chirwa et al. (2008) mentioned that land size negatively influences the maize yield in Malawi.

Table 5: Estimated inputs results using stochastic frontier production function

Variables	Coefficient	Standard Error	P > Z
Constant	5.215747	.7703958	0.00
Ln land (size)	.6597102	.3518519	0.031
Ln labour (hours)	.6379482	.2538963	0.012
Ln seed (quantity)	.0417357	.2692137	0.808
Ln Fertilizer (quantity)	.0767906	.0590471	0.003
Ln Tractor (hours)	-.2222446	.2692137	0.409

Source: Authors' calculation using STATA, 10

Moreover, the coefficient of fertilizer was 0.07 which is also statistically significant and positively influences the maize production. The remaining other variables including use of tractor for maize farming and use of seeds were insignificant. However, a study by Kibaara (2005) indicated that agricultural mechanization was statistically significant in a study of the technical efficiency of maize production in Kenya where households that used tractors for land preparation increased their technical efficiency by 26 percent.

Estimation of variance parameters using stochastic production frontier

It is indeed necessary to identify the variance parameters which are useful to measure both efficiency and inefficiency among the maize farmers in the study area in order to identify the determinants of the production factor in the study area. Further, the findings would be useful to enhance maize production in the future.

Table 6 Estimation of variance parameters

Variables	Coefficient	Standard Error
Sigma-v	.0572715	.0125919
Sigma-u	.2736035	.0316474
Sigma square (σ2)	.0781389	.0170352
Lambda	4.777308	.0367173
Log likelihood	11.173286	
Wald chi squared	1568.27	
Chi bar squared	50.3	

Source: Researcher's calculation

Table 4.5 represents the estimation of variance of parameters produced stochastic production frontier using exponential distribution method. Moreover, value of sigma u is higher than the sigma v which shows the presence of the inefficiency and the value of lambda is equaled to 4.77 which also further shown the presence of the technical inefficiency among the maize farmers in the study area. The value of log likelihood ratio test of chi bar squared distribution is equaled to 50.33 which is significant at 5 percent level and confirms the presence of the inefficiency effects.

Hypotheses Testing

Two hypotheses such as (1) the absence of inefficiency effects in maize production in the study area and (2) absence of joint effect of the considered socio-demographic, economic and institutional factors on the inefficiency component were formulated and statistically tested for this study.

According to Coelli et al. (2005) for the half-normal and the exponential models, the null hypothesis that the absence of inefficiency effects involves one parameter often noted as sigma ($\sigma\mu$). The parameter represents the variance related to the inefficient effects in the stochastic frontier model. As the variance inefficiency effects is concerned, Batesse and Coelli (1995) specified another parameter gamma (γ) which is associated to the two error terms of the stochastic frontier functions. The parameter γ measures the output deviation from the frontier caused by inefficiency effects and it equals to $\sigma^2_\mu / (\sigma^2_v + \sigma^2_\mu)$ where σ^2_μ and σ^2_v respectively stand for the variances related to inefficiency and statistical noise.

The first hypothesis testing was conducted to check if these effects were statistically significant. Findings in Table 4.7 showed that the calculated chi-squared values ($\chi 2$) for the estimated model exceeded the critical values from the statistical table which lead to the rejection of the first null hypothesis. Hence, there is an inefficiency effect in maize production in the study area.

The second hypothesis stated that there is no joint effect of age, household size, maize farming experience, education level, use of credit in maize farming, farm income and visit of extension agent were not significant. Table 4.7 showed that this hypothesis was rejected based on the value of chi-statistics which exceeded the critical values. This leads to the conclusion that the joint effect of the seven variables was significant.

Table 7: Tests of hypotheses in the estimated models

Hypotheses	Null hypotheses	Log Likelihood	Chi-Square statistics	Critical Value	Decision
Hypothesis 1	H0 = 0	11.17	50.33	0.00491	Reject H0
Hypothesis 2	H0 = 0	31.3	64.91	3.9×10^{-18}	Reject H0

Source: Estimated using Kodde and Palm (1986)

Technical efficiency levels among maize farmers

As per the results shown in Table 4.8, the mean value of TE was estimated to 78 percent with a range from 25 percent to 98 percent. Further, majority of 42 percent of respondents recorded the technical efficiency of 61-90 percent and 37 percent of respondents had 91-100 percent of technical efficiency. 21 percent of respondents recorded below 40 percent of technical inefficiency which means still farmers in the study area utilized the resources inefficiently in the production process though many of the farmers have improved the technical efficiency.

Table 8 Frequency Distribution of Technical efficiency values

Technical Efficiency (%)	Frequency	% of Total
0-30	1	1
31-60	20	20
61-90	42	42
91-100	37	37
Total	100	
Mean TE	.7881593	
Minimum TE	.25561	
Maximum TE	.9828878	

Source: Researcher's calculation

Determinants of Technical Inefficiency

Technical inefficiency was calculated using farmer's experience, farmer's education, family size, age, extension services, farm income and credit assistance and error term (u). The results from Table 4.9 suggest that, coefficient of all variables such as farmer's experience, farmer's education, family size, age, extension services, farm income and credit assistance were found statistically significant in the inefficiency model of maize farmers whereas the coefficient for farmer's experience, farmer's education, farm income and credit assistance in the inefficiency model were negative and reduce the technical inefficiency or increase technical efficiency of the production.

The coefficient for experience of farmers was negative and it reflects that by adopting new techniques, knowledge and skills would improve the efficiency level, although age is a negative relation in productivity. On the other hand, when age is getting old, old farmers may be denied to adopt better techniques due to that technical efficiency might be low. An increase in a year of experience in maize seed production will increase TE by 0.02 percent, which is significant at five percent level of significance. Farmers having more years of experience are better placed to acquire the knowledge and skills necessary for choosing appropriate new farm technologies over time. They can manage the field effectively and allocate the resources wisely. Experience in farming tends to increase farmers' capacity to do better. Hence, they influence TE positively and significantly.

The negative sign of farmer's education indicates that number of years of schooling will reduce the technical inefficiency as increases the years of school. Further, it is believed that role of education would help to understand the maize farming techniques and management and lead to increase the efficiency. Similar findings made by Awudu and Richard (2001) in their study on technical efficiency during economic reform in Nicaragua found that education increases the efficiency. A study by Seyoum et al. (2000) on technical efficiency among maize farmers in Ethiopia found that more educated adopt new technology and increase efficiency.

Table 9: Inefficiency effect model

Variables	Coefficient	Standard Error	P > Z
Constant	6.416642	.0002625	0.000
experience (years)	-.0205691	3.75e-06	0.000
education (years)	-.0369951	3.65e-06	0.000
family size (numbers)	.013609	3.54e-06	0.000
age (years)	.0485412	6.16e-06	0.000
extension services visit (numbers)	.0029684	1.98e-06	0.000
farm income (amount)	-.0166489	.0000179	0.000
credit assistance (amount)	-.042454	9.02e-06	0.000

Source: Researcher's calculation

Though the family size was statistically significant in this model, they were negative in the productivity in this study. The positive relationship between the technical inefficiency and extension contacts could be led to the negative relation in the productivity. Similar findings were made by the study of Tijani (2006) and Ezeth et al. (2012). In contrast, Nchare (2007) and Muhammad-Lawal et al. (2009) found that positive relation between the productivity in their studies on coffee production in Cameroon and technical efficiency of youth participation in agriculture.

Further, the coefficient of farm income and credit assistance in the inefficiency model reveal that these may be used to purchase additional farming inputs and helps to improve the risk tolerance capacity for the maize farmers in the study area and thereby they increase the efficiency of the maize production whereas extension service negatively corelated with the maize productivity

Empirical findings of TE indicated that the farmers achieved 78 percent of technical efficiency in maize production on average and It suggested that maize farmers in thestudy area still has to improve their farming efficiency by 22 percent from its present level and this variation has arisen from differences in production factors, demographic characteristics and institutional factors rather than random error. 37 percent of them were being operated at more than 91 percent of technical efficiency.

The stochastic frontier production function is applied to identify the impact of each input on maize production and its results showed that log forms of the inputs such as land size, labour hours and fertilizer significantly affected the maize production in the model. Hence, it is important to make understand the government and farmer organizations to work collectively to ensure proper planning of land use, and optimal usage of fertilizer and labour.

Further, the results of inefficiency model revealed that farmer's experience, farmer's education, farm income and credit assistance were negatively influencing the technical inefficiency in the study. Therefore, efficiency improvement can be ensured firstly by motivating the experienced farmers to be involved in maize farming and then secondly capacity development of farmers must be improved by conducting training, and sharing experience among maize farmers.

Moreover, greater efforts must be taken by the financial institutions and banks focusing on credit accessibilities for small scale farmers which tend to stimulate the current levels of efficiency and productivity of maize farmers in the future. Additional farm income from the maize farming makes higher efficiency in production and increases risk tolerance.

Recommendations

The findings of this research study indeed bring some benefits for maize farmers to increase the TE in their production in future. Therefore, the following implications are recommended based on the findings of the study to uplift the maize production in KPN. Focus on pioneering effective institutional arrangements with collaboration of GOSL and NGOs that would enhance the positive influence of access to credit used where maize farmers are able to raise the required funds. Based on the findings, both formal and informal education would have a huge impact on attaining higher efficiency levels in maize production in the study area. Therefore, this can be done through farmer forums and on farm practical demonstrations. Further, provision of non-formal agricultural education could be a supplement to formal education. Focus on comprehensive land consolidation plan which may help to increase maize production and hence improve efficiencies in the study area. Also, fertilizer subsidy programme for maize farmers enables to increase the production in the study area. This study only evaluated the technical aspects of production efficiency of maize production. Based on the study, optimal usage of farming inputs is only identified. Therefore, the study recommends an assessment of allocative efficiency and economic efficiency of maize production which would be a comprehensive study to specify the inputs in the maize production in the study area. It is vital to streamline local hybrid seed production program to ensure the availability of high-quality seeds to farmers at an affordable price.

References

Addai, K. N., and Owusu, V., (2014). Technical efficiency of maize farmers across various agroecological zones of Ghana. *Journal of Agriculture and Environmental Sciences, 3*(1), 149-172.

Abdi Tumuri, Debela Geleta & Getachew Sime (2024) Technical efficiency of maize production and their determinants among smallholder farmers in Ethiopia: a case study in Sidama Region. *Cogent Food & Agriculture, 10*(1), 1-10.2392045, DOI: 10.1080/23311932.2024.2392045

Ali, S., and Khan, M., (2014). Technical efficiency of wheat production in District Peshawar, Khyber Pakhtunkhwa, Pakistan. Sarhad Journal of Agriculture, 30(4): 433- 441.

Amarasinghe, S.T.C., and Weerahewa, J., (001). An assessment of technical efficiency of potato production. Tropical Agricultural Research, 13, 292-300.

Aschalew Shiferaw Belete (2020). Analysis of technical efficiency in maize production in Guji Zone: stochastic frontier model. *Agriculture & Food Security, 9*(15), 2-15. https://doi.org/10.1186/s40066-020-00270-w

Awoniyi, O. A., and Bolarin, T. O., (2007). Production Efficiency in Yam based enterprise in Ekiti State, Nigeria. *Journal of Central European Agriculture, 4*, 626 – 635.

Awudu, A., and Richard E., (2001). "Technical Efficiency during Economic Reform in Nicaragua: Evidence from Farm Household Survey Data." Economic Systems, 25, 113- 125.

Ayodeji D. Kehinde, Temitope O. Ojo and Abiodun A. Ogundeji (2024). Impact of participation in social capital networks on the technical efficiency of maize producers in Southwest Nigeria. *Agriculture & Food Security, 13*(12), 2-19. https://doi.org/10.1186/s40066-023-00464-y

Baruwa, O.I., and Oke, J.T.O., (2012). Analysis of the technical efficiency of small-holder Cocoyam farms in Ondo State, Nigeria. *Tropicultura*, *30*(1), 36-40.

Basnayake, B.M.J.K., and Gunaratne, L.H.P., (2002). Estimation of technical efficiency and its determinants in the tea small holding sector in the mid country wet zone of Sri Lanka. *Sri Lankan Journal of Agricultural Economics,4*(1), 137-150.

Battese, G.E., and Coelli, T.J., (1995). A model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics. 20,* 325- 332.

Battese, G. E., Sohail, J., Malik, H., and Manzoor A.G., (1996). An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan. *Journal of Agricultural Economics, 47* (1): 37-49.

Bempomaa Acquah HD. (2014). Technical efficiency analysis of maize production: Evidence from Ghana. *Applied Studies of Agribusiness Community. 8*(2–3):73–9.

Belete, A., Dillon, J., and Anderson, F., (1991). Development of Agriculture in Ethiopia since the 1975 Land Reform. *Agricultural economics. 6,* 159-175.

Binam, J.N., Tonye, J., Wandji, N., and Nyambi, G., (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food policy, 29*(5):531-45.

Boyce, J.K., (1987). Agrarian impasse in Bengal: Institutional constraints to technological change. Oxford: Oxford University Press.

Bhavan, T. and Maheswaranathan, S., (2012), Technical Efficiency of Paddy Farmers in Batticaloa District of Sri Lanka, Sri Lanka Economic Research Forum, International symposium, University of Colombo.

Carter, M.R., and Wiebe, K.D., (1990). Access to capital and its impact on agrarian structure and productivity in Kenya. *American journal of agricultural economics, 72,* 1146-1150.

Central Bank Report of Sri Lanka, 2020. Retrieved from. https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/statistics/otherpub/ess_2020_e1.pdf

Coelli, T.J., (1996). A guide to frontier version 4.1: A computer program for stochastic frontier production and cost function estimation. Mimeo, Department of Econometrics, University of New England.

Coelli, T.J., (2005). An introduction to efficiency and productivity analysis.2nd Ed. Springer Science & Business Media, Inc., New York, USA.

Cornia, G. A., (1985). Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries. *World development*, *13*(4), 513-534.

Chirwa, E. W., Kumwenda, I., Jumbe, C., & Chilonda, P., (2008). Agricultural growth and poverty reduction in Malawi.

Davidova, S., Gorton, M., and Fredriksson, L., 2010. Semi-subsistence farming in Europe: Concepts and key issues. Background paper prepared for the seminar 'Semi- subsistence farming in the EU: Current situation and future prospects.

Didace, K., 2006. The effect of land factors and management practices on rice yieldsDung, D., 2013. The spatial distribution of poverty in Sri Lanka

Esham, M., (2009). A comparative study of farmers–agribusiness linkage in Sri Lanka. *American-Eurasian Journal of Agricultural and Environmental Science*, *6*(5), 591-599.

Esham, M., Usami, K., Kobayashi H., and Matsumura, I., (2005). Determinants of Farmers' Participation in Farmers-Agribusiness Linkage and Its Implication for Income Distribution in Sri Lanka Case Study of Hybrid Maize Production. *Journal of Rural Problems*, *41*, 200-205.

Ezeh, C. I., Anyiro, C.O., and Chukwu, J.A., (2012). Technical efficiency in poultry broiler production in Umuahia capital territory of Abia State, Nigeria. Greener Journal of Agricultural Sciences, 2(1), 001-007.

Food and Agricultural Organization of the United Nations. FAO, (2021). Agricultural production data, Food and Agriculture Organization of the United Nations. Retrieved from. https://www.fao.org/srilanka/news/detail-events/fr/c/1437490.

Gautam, H., and Jeffrey A., (2003). Access to Credit, Plot Size and Cost Inefficiency among Smallholder Tobacco Cultivators in Malawi. *Agricultural Economics, 29*, 99- 109.

Getachew, W., (2018). Technical Efficiency of Barley Production: The Case of Smallholder Farmers in Meket District, Amhara National Regional State, Ethiopia. 1(2), 42-48.

Goyal, S.K., Suhag, K.S., and Pandey, U.K., (2006). An Estimation of Technical Efficiency of Paddy Farmers in Haryana state of India. *Indian Journal of Agricultural economics*. *61*(1), 109-121.

Hasnain, M. N., Hossain, M. E., and Islam, M. K., (2015). Technical efficiency of Boro rice production in Meherpur District of Bangladesh: A stochastic frontier approach. *American journal of agriculture and forestry*, *3*(2), 31-37.

Hopper, W.D., (1965). Allocation efficiency in a traditional Indian agriculture. Journal of farm economics, 29: 175-398.

Kalirajan, K. S., (1985). Types of education and agricultural productivity: A quantitative analysis of Tamil Nadu maize farming. Journal of development studies, 21:232-41.

Khan, A., Huda, F. A., and Alam, A., (2010). Farm household technical efficiency: A study on maize producers in selected areas of Jamalpur district in Bangladesh. *European Journal of Social Sciences*, *14*(2), 262-271.

Kibaara, B.W., (2005). Technical Efficiency in Kenyan's Maize Production; An Application of the Stochastic Frontier Approach. An MPhil Thesis, Colorado State University.

Kibirige, D., (2013). Impact of human dimensions on smallholder farming in the

Eastern Cape Province of South Africa (Doctoral dissertation, University of Fort Hare).
Kimenyi, S.M., (2002). Agricultural, economic growth and poverty reduction. Nairobi: Kippraa.
Kiplangat, J., (2003). Does agricultural extension have a new beginning because of ICTs? Reflection on experience in Sub-Saharan Africa. Keynote paper, presented at the 6th Consultative Expert meeting on CIA`s observatory on ICTs. Wageningen University, Netherlands. Sept 23-25.
Lana, M.A., Eulenstein, F., Schlindwein, S.L., (2017). Erratum to: Yield stability and lower susceptibility to abiotic stresses of improved open - pollinated and hybrid maize cultivars.
Mapila, M. A. T. J., (2011). Rural livelihoods and agricultural policy changes in Malawi. Agricultural Innovations for Sustainable Development. In: Manners, G. and Sweetmore, A., (Editors). Accra-Ghana, CTA and FARA, 3, 190-195.
Masterson, T., (2007). Productivity, technical efficiency and farm size in Paraguayan agriculture. The Levy Economics Institute. Working paper, 490, 1-36. New York, USA.
Mardiyah Hayati, Adi, D., Mohammad Wahyu Firdaus, None Fatahullah, & Aulia Adetya. (2024). Evaluation of technical efficiency traditional agriculture among smallholder maize farmers in East Java. *E3S Web of Conferences, 499,*1- 6. https://doi.org/10.1051/e3sconf/202449901026
Mehmood, Y., Rong K., Arshad, M., and Bashir M K., (2017). Do liquidity constraints influence the technical efficiency of wheat growers: Evidence from Punjab, Pakistan? The Journal of Animal and Plant Sciences, 27, 667–679.
Michael, O. F., (2011). Measuring technical efficiency of yam farmers in Nigeria: Astochastic parametric approach. *Agricultural Journal, 6*(2), 40-46.
Muhammad-Lawal, A., Omotesho, O.A., and Falola, A., (2009). Technical of youth participation in agriculture: A case study of the Youth-in –Agriculture Programme in Ondostate, south-western Nigeria. *Nigerian Journal of Agriculture, Food and Environment, 5*(1), 20-26.
Mukole Kongolo 2021 Technical Efficiency and Small Scale Maize Producers in Mwanza Region: A Stochastic Frontier Analysis. *Asian Journal of Agriculture and Food Sciences, 9* (3), 111-119.
Nchare A., (2007). Analysis of factors affecting the technical efficiency of Arabica Coffee Producers in Cameroon. *African Economic Research Consortium Research Paper* 163.
Nieuwoudt, W.L., (1990). Efficiency of Land Use. Agrekon, 29: 210-215.
Oberhauser, A.O., (1993). An industrial restricting and women’s homework in Appalachia: Lessons from West Virginia, at South-eastern Geographer 33: 23-43.
Obwona, M., (2006). Determinants of technical efficiency differentials amongst small- and medium-scale farmers in Uganda: a case of tobacco growers, AERC research paper 152, Nairobi: African Economic Research Consortium.
Osim, O. O. and Oniah, M.O. (2023). Technical Efficiency in Maize Crop Production by Small-Scale Farmers in Central Agricultural Zone of Cross River State,

Nigeria. *European Journal of Agriculture and Forestry Research, 11*(1), 13-23,

Ogolla, B.D., and Mugabe, J. W., (1996). Land tenure system and natural resource management. In land we trust: Environment, private property and constitutional change. Juma, C. and J.B. Ojwang: 79-120. Nairobi, Kenya initiatives publishers.

Resource Profile, District Secretariat, Batticaloa, 2020. Resource Profile, Koralaippattu North, Batticaloa, 2020.

Rudra, B. S., Wen-Chi, H., Pai-Po, L., and Yam, B. T., (2016). Determinants of inefficiency in vegetable farms: Implication for improving rural household income in Nepal. *American Journal of rural development. 4*(5), 105-113.

Sapkota, M.; Joshi, N.P, (2021) Factors Associated with the Technical Efficiency of Maize Seed Production in the Mid-Hills of Nepal: Empirical Analysis. *Int. J. Agron*, 2(1), 1–8.

Seyoum, E.T., Battese, G.E., and E.M. Fleming., (2000). Technical efficiency and productivity of maize producers in Eastern Ethiopia: A case study of farmers within and outside the Sasakawa-Global 2000 project. Agricultural economics, 19: 341-348.

Seyoum. E. T, G. A., (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: A study of farmers within and outside the Sasakawa- Global 2000 Project. *Agricultural economics, 19*, 341-48.

Sibiko, K. (2012). Determinants of Common Bean Productivity and Efficiency: A Case of Smallholder Farmers in Eastern Uganda. MSc Thesis, Egerton University.

Shantha, A.A., Asan, A.B.G.H., and Bandara, R.A.G., (2012). Efficiency and managerial ability of paddy farming under minor irrigation conditions: a frontier production function approach. *The Journal of Agricultural Sciences,7*(3), 145-158.

Surinder C., (2011). Project Feasibility Report on Maize Processing in Himachal Pradesh Surinder: Surinderchugh (Roll Number: 25) EPDGCFM 2010 –12.

Tchale, H., (2009). The efficiency of smallholder agriculture in Malawi. AFJARE, 3: 2.

Thiam, A., Bravo-Ureta, B. E., and Rivas, T. E., (2001). Technical efficiency in developing country agriculture: A meta-analysis. Agricultural Economics, 25(2-3), 235-243.

Tijani, A.A., (2006). Analysis of the technical efficiency of maize farms in Ijesha land of Osun State, Nigeria. *Agrekon,* 45(2), 127-135

Yiadom-Boakye, E., Owusu-Sekyere, E., Nkegbe, P. K., and Ohene-Yankyera, K., (2013). Gender, resource use and technical efficiency among rice farmers in the Ashanti Region, Ghana.