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# Technical Efficiency of Maize Production in the North West Region of Cameroon: A Stochastic Frontier Application on Small-Scale Farmers in Balikumbat Sub-Division

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# 카메룬 북서부 지역의 옥수수 생산의 기술적 효율성: 발리쿰바트 구획의 소규모 농부에 대한 확률론적 프론티어 적용

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**Abstract** Maize production is a major agricultural activity in the rural areas of Cameroon. Encouraged by a strong cultural and historic consumption habit for corn as a staple food in different forms, small-scale maize production in the North West Region of Cameroon plays a key role in food security. This study sampled 110 small-scale maize farmers in the Balikumbat Sub-Division. To examine the level of technical efficiency of small-scale maize production in the study area, we applied the Stochastic Frontier analysis through an Output-Oriented approach with the Cobb-Douglas Production function. An inefficiency model was used to identify the sources of technical inefficiency among the sampled farmers. The findings revealed that maize farmers in the study area were 52% technically efficient, with an abundant possibility of improving their output by 48% with the existing production technology. The findings also showed that 96% of the total variation in maize output was traceable to sources of technical inefficiency. The amount of seed used, the quantity of fertilizer, and the availability of farm labor all had a statistically significant effect on the technical efficiency of the activity. Moreover, technical inefficiency was negatively impacted by household size, farm size, training, and extension guidance; hence, these factors positively influenced the technical efficiency of farmers. Our results indicate there is room and a need to improve maize output in the study area using the current production technology.

**요 약** 옥수수 생산은 카메룬 농촌 지역의 주요 농업 활동이다. 다양한 형태의 주식인 옥수수에 대한 강력한 문화적, 역사적 소비 습관에 힘입어 카메룬 북서부 지역의 소규모 옥수수 생산은 이 지역의 식량 안보에 중요한 역할을 하고 있다. 이 연구는 Balikumbat Sub-Division의 소규모 옥수수 농부 110명을 표본으로 했다. 연구 지역에서 소규모 옥수수 생산의 기술적 효율성 수준을 조사하기 위해 Cobb-Douglas Production 함수를 적용한 Output-Oriented 접근 방식을 통한 확률적 프론티어 분석을 사용했다. 비효율율 모델은 표본 농부들 사이의 기술적 비효율의 원인을 식별하는데 사용되었다. 연구 결과에 따르면 연구 지역의 옥수수 농부는 기술적으로 52% 효율적이었고 기존 생산 기술로 생산량을 48%까지 향상시킬 수 있는 넓은 가능성이 있었다. 연구 결과는 또한 옥수수 생산량의 총 변동의 96%가 기술적 비효율의 원인으로 추적할 수 있음을 보여주었다. 사용된 종자의 양, 비료의 양, 농장 노동력의 가용성은 모두 활동의 기술적 효율성에 통계적으로 유의한 영향을 미쳤다. 기술 비효율은 가구 규모, 농장 규모, 훈련 및 확장 지도에 의해 부정적인 영향을 받았고 따라서 농민의 기술 효율성에 긍정적인 영향을 미쳤다. 따라서 현재 생산 기술로 연구 지역의 옥수수 생산량을 개선할 여지가 있으며 필요하다.

**Keywords :** Small-Scale Maize Production, Stochastic Frontier Analysis, Technical Efficiency, Production Technology, Technical Inefficiency

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## 1. Introduction

The Food and Agriculture Organization estimates that the world's population will reach 10 billion by 2050 from the current 7.9 billion inhabitants. This projected growth rate is owe to rapidly growing population witnessed across all the continents. While most countries are experiencing a rapid population growth, food production is not increasing at the same rate. Several economic, production and environmental challenges are accountable for low crop productivity. This therefore constitutes a wake- up called for the increase in food production and major policy formulation to sustain the productivity and efficiency of production systems. The Sustainable Development Goal number 1, places an important emphasis on agricultural productivity and efficiency. This may underline the main reasons behind the quest by scholars to constantly seek to measure and recommend policy strategies to stakeholders on ways of improving agricultural productivity and technical efficiency of production[1].

In order to end hunger in Africa by 2025, the African Union's Malabo declaration on accelerated agricultural growth and transformation for shared prosperity and improved livelihoods puts agricultural- led growth at the center of its agenda achieving strategy [2]. Most African countries have their economy largely dependent on agriculture. With the enormous resource challenges the sector faces, small-scale agricultural production needs to be more efficient. To achieve this will entail maximizing available farm inputs or resources to achieve the best optimal output and farm yields that will improve productivity, food self-sufficiency and a decent livelihood for farmers[3]. Of the several crops whose productivity and technical efficiency measurement is constantly of importance to scholars, is maize which is grown across many agro-ecological zones of the world.

Maize (Zea May) is the most produced cereal in the world, widely grown in every continent except for the Antarctica. Many species exist with difference in color, textures, grain shape and sizes. Of the most common cultivated types, the white and yellow varieties are mostly preferred by consumers. The US, China and Brazil are the 3 top producers of corn in the world with the US producing about 383.94 million metric tons at the top of the list in 2021[4].

In Sub-Saharan Africa, maize is the most cultivated cereal covering about 24% of the total farmland allocated for crop production. Its consumption as a staple food accounts for over 30% of food caloric intake with a household food consumption expenditure ranging from 30% to 50% of the food budget [5].

In Cameroon, Maize has turned out to be a suitable preferred crop for household consumption as the frequency of consumption has greatly increased [6]. National demand is estimated at about 3 million tons with a national production of about 2.2 million tons as of April 2022, [7].

Of the 5 agro-ecological zones of that makes up the country, the crop is grown in all the zones covering the 10 regions of the country. However according to the Cameroon price bulletin report for 2021, the North West region is the main basin for maize and beans production in the country. Corn processed into different forms constitutes a major source of food for both inhabitants of the region and for animal feed.

Over the recent years, there has been a growing demand for corn for food, livestock feed and for biofuel feeds especially in high income countries. For most sub Saharan countries, maize is mostly grown for food consumption and for livestock feed [8]. The Organization for Economic Co-operation and Development (OECD) and Food and Agriculture Organization's (FAO) 2019 annual agricultural outlook attributes this growing demand to population dynamics and per-capita demand growth, justifying the rapid expansion on the surface area cultivated[9].

The definition of small-scale farming varies across different countries however, the general perception is that a small-scale farmer is one whose farm-size under exploitation is below 10 hectares of land.

### 1.1 Technical Efficiency Contextualized

Technical efficiency/inefficiency considering the current production context of the study area could be explained as follows; Maize farming in the study area uses a common and simple production system as observed in other agro-ecological zones in the country. Farmers prepare their farm lands before the start of the cropping season by clearing or ploughing the fields manually, chemically or mechanically depending the farm size. Local maize seeds from previous harvest or bought from shops are planted once the fields are prepared and rains have fully started. Chemical and organic fertilizers in varied quantities are used to maintain the fertility of the soil. The current fertilizer recommended dosage are 250kg/ha of N.P.K (20:10:10) and Urea (46% N). Regular field maintainance are done and the maize is harvested manually, dried and store locally for household consumption, marketing or processed to animal feed. As will be realized from the descriptive statistic of the farmers in the study area, the use of input resources under this current production system by the farmers, seemingly produces less maize than is estimated by previous national yield per hectare in the country. The use of available resources to obtain maximum yields in agricultural production has often been coined as technical efficiency.

By definition, technical efficiency is the effectiveness with which a given set of inputs/technology are used to produce an output. To use a farmer's language, a farm is said to be technically efficient when its uses its available inputs(Labor, seeds, fertilizer, chemicals etc) to reach its production frontier and produce its maximum output with the available resource at a given time. On the other hand, technical inefficiency is defined as when with a given amount of inputs or technology, the best possible or maximum output can not be produced. In agricultural production terms, a farm will be said to be technically inefficient, when it does not produce its expected maximum level of output(yield) using the available capital, labour and farm inputs at a given time[10].

### 1.2 Justification of the study

As basic economic principles hold, agricultural production resources are scare and hence the rational allocation of such resources to obtain maximum yield (efficiently) is increasingly of concern to farmers and scholars. The Covid-19 pandemic and unexpected crises in most countries have provoke the need for Cameroonian farmers to rethink on how best to maximize crop yield as a means of ensuring national food self -sufficiency. Meaningful increase in local production will not only limit reliance on the importation of basic staple foods but will increase farmers' income and wellbeing. As an important production zone in the North West Region, this study on the technical efficiency of small-scale farmers in the Balikumbat Sub-division will play an important role in providing information on the current maize production status of the zone and make recommendations from the findings to help improve local production in the zone, region and country at large. This study seeks as objectives;

1) To evaluate the technical efficiency of maize production in the study area.
2) To identify the factors that accounts for the technical inefficiency of maize production within the study area.

Since the start of the Covid-19 pandemic, the prices of locally produced maize has been on a rise as production has been negatively affected by the increase in price of fertilizers and improved imported seeds and other inputs. Analyzing the technical efficiency and source of inefficiency to help identify how farmers can achieve maximum maize yield in Balikumbat is therefore the main motivation for this study.

The measurement of technical and economic efficiency is therefore primordial in the measurement of agricultural productivity. According to Nshimizu and Fare [11,12], the measurement of productivity had often not paid much attention to the existence of technical inefficiencies faced in the production chain. With this observation, Grosskopf [13], noted that not paying attention to technical inefficiencies when measuring productivity leads to the ignorance of technical changes and if researchers upheld this, policy recommendations made to stakeholders will be flawed. The appropriate measurement of technical efficiency is therefore of high importance considering the limited available farming resources in both quantity and quality in the study area. One other very importance need for this study is the fact that little or none of such a study has been conducted in the study area even though the area constitutes a very important maize market for both the North West and West Region.

## 2. Methodology

### 2.1 Study Area and Data Collection

This study was carried out in Balikumbat, Balikumbat Sub-Division of the Ngoketunjia Division of the North West Region. The Balikumbat Sub-Division comprises of 5 villages which are Balikumbat, Bafanji, Bamunkumbit, Baligashu and Baligansin. Balikumbat is the administrative headquarters of the Sub-Division and has an estimated population of 44512 inhabitants for which about 90% are small-scale farmers as estimated by the 2021 Council Development Plan report. It has a very fertile land and serves as a food production basin for many cereals, vegetables and nuts. Maize production is a principal agricultural activity in the study area, encouraged by the fact that the main traditional meal of the village is 'fufu' corn (maize powder porridge) and vegetable. Maize is consumed through other forms such as drinks or food from roasted, fried and boiled or processed into animal feed.

Through a multistage sampling approach, 4 main maize growing zones were identified with the help of some baseline information from some existing farmers' cooperative in the area. The zones were; the Ngohti zone, Munanji/Munchu zone, Ngwayit zone and the Njugoru zone. A total of 110 small-scale maize farmers were sampled through the administration of questionnaires. The sampled farmers were distributed as follows, Ngohti zone (n= 25), Munanji/Munchu zone (n=30), Ngwayit zone, (n=25), Njugoru zone, (n=30). Primary data from the sampled farmers constituted the main primary data used in the study with some secondary data gotten from online sources. The data variables collected ranged from the socioeconomic characteristics of the farmers to the maize farming related inputs and outputs factors. Some of these variables are described on Table 1.

### 2.2 Measurement of Technical Efficiency

Agricultural literature highlights two main methods used in the measurement of technical efficiency, the DEA (Data Envelopment Analysis) method and the Stochastic Frontier Analysis method. The DEA technique for technical efficiency measurement is a nonparametric approach that was first introduced in 1957 by Farell and later simplified [14]. This technique however has been criticized by some scholars for its total attribution of production shortfalls to inefficiency. The stochastic frontier analysis is popular for technical efficiency measurement and seems most preferred by some scholars due to its ability to identify and distinguish deviations from the production frontier caused by inefficiency in a given data set from that attributed to measurement error and external factors[15]. The Stochastic Frontier model was introduced many years ago[16,17], and the model has since been used across different economic analysis by several scholars around the world.

Small-scale farmers in Balikumbat rarely keep records of farming transaction especially as most of them produce maize just for household consumption. With this consideration and the fact that some external factors besides the production factors could be responsible for inefficiency of maize production, estimation will be bias if it were to assume that all deviations from the production frontier are attributed to technical inefficiency. Therefore to ensure a more appropriate and unbiased estimation of technical efficiency, this study used the Stochastic Frontier Analysis technique for the measurement of Technical efficiency in the study area [18].

## 2.3 Technical Efficiency Measurement using Stochastic Frontier Analysis

Technical efficiency measurement with a cross- sectional data set such as that used in this study within a production context can be modeled as output-oriented or input-oriented[19]. This study used the output-oriented approach with an inefficiency model considered. The stochastic production frontier model used considering the output-oriented technical inefficiency model can be simplified as below.

$$Y_i=f(x_i;\beta)e^{\varepsilon i} \quad (1)$$

$$\varepsilon_i = v_i - u_i,\ v_i \sim N(0,\sigma^2),\ u_i \sim F \quad (2)$$

In the above formula, y denotes a scalar of maize output of the i-th farmer as a vector of inputs and $f(x_i;\beta)$ is the deterministic kernel in the production frontier used in this study. The error term, $\varepsilon_i$ is represented by (v) and (u), which handles the exogenous shocks and measurement error and a non-negative technical inefficiency term respectively and considered to be independent.

As earlier stated this study used the Cobb-Douglas functional form with the production frontier model parameterized as below;

$$\ln Yi = \ln\beta_0 + \sum_{k=1}^{n} \beta_{ki} \ln X_{ki} + v_i - u_i \quad (3)$$

where by, $u_i$ is the log difference between the maximum and the actual output(maize) produced. This implies that $u_i$ X 100% will give the percentage by which actual maize output of the farmers in Balikumbat can be increased while maintaining current inputs if maize production were to be fully efficient. This could also be interpreted to give the percentage of output lost due to technical inefficiency[20].

## 2.4 Estimation Method

Three different distribution methods can be used in estimation, the half- normal distribution, the exponential distribution and the truncated distribution proposed by Stevenson [21]. The half-normal distribution seemed common but has been proven to be inherently restrictive as its inflexibility limits the exploration of alternatives. The truncated-normal distribution on the other hand allows for the inefficiency distribution to have a non zero model [20,22]. The estimation method used in this study is therefore the truncated normal distribution considering that the one step approach of analysis chosen as analytical approach can't be used for the half-normal distribution or the exponential distribution.

Assuming a particular distribution for the inefficiency component (u), a maximum likelihood technique is used to estimate Eq. (3) and a Truncated-Normal distribution, ($u \sim N^{+}$) is used[17].

According to the estimation method of Aigner [16], with an independence assumption between u and v, the lambda parameterization of the above model gives a log-likelihood function for our chosen Truncated-Normal distribution as done by Kumbhakar and Lovell [19], as follows

$$\ln L = \text{constant} - H \ln \sigma - H \ln \varphi (\mu/\sigma_u) + \Sigma \ln \varnothing (\mu/\sigma\lambda - \varepsilon_i \lambda/\sigma) - \frac{1}{2} \Sigma (\varepsilon_i + \mu)/\sigma)^2 \quad (4)$$

In which, $\sigma = (\sigma_u^2 + \sigma_v^2)^{1/2}$, $\lambda = \sigma_u/\sigma_v$, and $\sigma_u = \lambda\sigma / + \lambda^2$ are variance parameters with $\varnothing$ being the standard normal cumulative distribution function. H represent the total number of farmers, with any non-negative value attributed to $\lambda$ as it approaches zero. $\sigma_u$ turn towards zero as $\sigma_v$ approaches infinity.

The maximization of the log-likelihood function estimates the coefficient and parameters of the model and the conditional means are used to get the technical inefficiency as proposed by Jondrow [23]. Following on the proposed estimator of Battese and Coelli [24], the technical efficiency of the farmers can be calculated as defined from Eq. 4, where;

$$\text{Technical efficiency} = E[\exp(-\hat{U}_i) | \varepsilon] \quad (5)$$

## 2.5 Determination of the Sources of Technical Inefficiency

The second objective of this study was to determine the effects of exogenous variables, on technical inefficiency of the maize farmers in the study area. Inefficiency effects are commonly estimated with the use of 2 approaches, the one -step procedure and the two- step procedure. In the two step procedure, the inefficiency scores are estimated and then regresses in a second step on a vector of exogenous variables believed to be responsible for the inefficiency. This approach, has however been criticized by scholars as biased and argued that the model estimated is miss-specified[24]. Based on the above argument and undesirable statistical properties of the two- step approach, the one-step procedure is mostly preferred for use in determining the exogenous effects on efficiency. The one step procedure handles the biased raised in the two step procedure and in a single estimation procedure, estimates the factors influencing inefficiency alongside those of the stochastic frontier function.

Following the approach employed by Caudill and Ford[25], this study applied the one-step procedure with a parameterize variance of the inefficiency distribution as follows;

$$\sigma_{ui}^2 = \exp(Zi\delta) \quad (6)$$

In which, $\sigma_{ui}^2$, denotes the variance of technical inefficiency, z is the vector of explanatory variables while $\delta$ represent the vector of the inefficiency effects.

## 2.6 Empirical Model Specification

Most scholars on the use of stochastic frontier analysis for the measurements of technical efficiency commonly makes use of either the Cobb-Douglas production function or the Translog production function[26]. While some scholars have argued that any of the choices made of the functional form used doesn't affect the measurement of Technical Efficiency, the Cobb-Douglas functional form has been widely used as a simpler and self -dual approach for the measurement of technical efficiency in most studies carried out in agricultural production economics[27]. Considering the objective of this study and the data variables surveyed, this study uses the Cobb-Douglass functional form and is specified as follows;

$$\ln Y_i = \beta_0 + \beta_1 \ln seed + \beta_2 \ln fertilizer + \beta_3 \ln chemicals + \beta_4 \ln labour + v_i - u_j \quad (7)$$

Where lnYi is the total output /maize yield in kilograms/ha (in natural log) produced for the season. The natural log of seeds, denoted by lnseed is the total quantity of seeds used in kilograms (kg/ha in natural log) for maize production. The natural log of fertilizer denoted by lnfertilizer, is the total amount of fertilizer used for maize production in kilograms(kg/ha). The natural log of chemicals denoted by lnchemicals, is the total amount of herbicide and or insecticides used in litters(L/ha) for maize production.

The variables selected for the production function above represents the key characteristics of maize farming in the study area. It's important to note that the choice of seeds used by the farmers either local, improved or hybrid are of importance in total yield obtained by the respective farmers even though the survey didn't categorized the seed variable. The fertilizer component in their farming represent both synthetic and or organic manure used by the farmers. The labor force used is mostly family household labor and hired labor from the time of land preparation right to the time of harvesting. The above inputs are considered just for the production of maize and not for other crops which the farmers cultivate in a season. Some scholars on technical efficiency measurement have preferred explanatory variables expressed in monetary Units of each variables while some considered these variables measured in quantity or volume Units[18]. This study considered the inputs values in Kg/ha for seeds, fertilizer and yield while labor was measured in man- days of labor and chemicals in L/ha.

## 2.7 Measurement of Technical Inefficiency

To examine the different factors and extent to which exogenous factors affects the technical efficiency of farmers in the study area, the technical inefficiency component of the model chosen is simplified as follows

$$\sigma^2_{ui}=\exp(\delta_0+\delta_1 z_{gender}+\delta_2 z_{marietal}+\delta_3 z_{edu}+\delta_4 z_{HHsize}+\delta_5 z_{croptype}+\delta_6 z_{exp}+\delta_7 z_{farmsize}+\delta_8 z_{training}+\delta_9 z_{extvisits}) \quad (8)$$

Where $\sigma^2_{ui}$ denotes the variance of the technical inefficiency, the $\delta$'s represent the inefficiency effects; z(gender) is the gender of the farmer expressed as a dummy variable, z(marietal) denotes the marital situation of the farmer, z(edu ) is the educational status of the farmer, z(HHsize) denotes the total number of people in a farming household, z(croptype) denotes cropping system if mono culture with just maize or mixed farming involving many crops on the same farm in the studied season. z(exp) denotes the number of years spent in maize farming by a farmer, z(farmsize ) denotes the exact farm size used for maize in the studied season, z(training ) denotes if the farmer received any formal training on maize farming during the last 2 seasons and uses a dummy variable for a Yes or No response, z(extvisits ) denotes the visits of extension workers to the farm's field during the last 2 farming seasons and uses a dummy variable form for a Yes or No response

Table 1. Description of co-variates used in the inefficiency model

| Variable name | Description | Measure |
|---|---|---|
| Gender | Male or female farmer | Binary |
| Age | Age of farmer | continuous |
| Marital status | | continuous |
| Education | Education attained | continuous |
| HHsize | Number of people in a farming household | continuous |
| croptype | Types of cropping system | Binary |
| Experience | Years spent in maize farming | |
| Training | Organized training sessions | |
| Extension | Extension visits and guidance to farmers | |

Source, author's definition, 2022

# 3. Results and Discussion

### 3.1 Descriptive statistics

Analyzing the data set collected from the survey painted a clear picture of the essential characteristics of small-scale maize farmers in Balikumbat. Of the 110 farmers sampled, 54.5% were female while 45.5% were male indicating woman as those mostly in the activity. The youthful population of the sampled size represented 39% of the sample within the age ranges of 20 to 35 years while the mid age group between 36 to 50 years was 45% presenting the largest group of the farmers, with about 16% representing farmers with above 50 years of age. This goes without saying that the youths within the study area are less interested in the activity as compare to the mid-aged adults in the area. Majority of the farmers were married while a less number were still single or divorced. In terms of educational status, 42% of the farmers had attended just primary school while about 36% had attended secondary or higher education. Those who had never been to school represented less than 5% of the sampled farmers. This clearly indicates that most farmers in Balikumbat can read and write a trait that could be very useful in the application of training lessons or extension guidance in the community if trainings and extension visits were regularly organized. For other production-related variables sampled, 66% of the farmers were observed to practice mixed farming, meaning their maize was cultivated alongside other crops like groundnuts, beans or some related vegetables crops on the same farm area. On the other hand, about 44% of the farmers cultivated maize as a single crop on specific farm land. Majority of the farmers, about 55% had been in the maize cultivation activity for more than 15 years indicating a wide experience in the activity. Given that agricultural cooperatives and other groups are common in the area owe to its rice cultivation history that seems more organized, 61% of the maize farmers reported to belong to farming groups even though about 90% of them indicated not have receive any assistance of any kind from the groups for maize production. The average farm size in the study area was 0.5ha with a majority of the farmers owning small maize plots for which the minimum was 0.1ha (1000 square meter) and the largest farmers cultivating on 3ha. The average amount of seeds, and fertilizers used were 5.6kg and 127kg/ha respectively. Just about 3.5 L/ha of herbicides on average were said to be used. An average of 30 man-days of labor were spend by farmers on maize farming with a very good portion of the labour force being farm household members. The total average quantity of maize output was 978kg/ha, which is believed to be below the estimated 2.3 tons/ha indicated by the FAO as national average yield for the country[6]. This comparatively low output in maize production in the study area justifies the very importance of such a study to identify the reasons for low productivity and make recommendations for improvements of technical efficiency of maize production in the study area.

### 3.2 Technical efficiency and production function of maize production

The average technical efficiency of the small scale maize farmers in Balikumbat was found to be 52%, indicating that the farmers are operating 48% below their maximum output potential. This also implies that with the current production technology within the surveyed area, 48% of maize potential yield is lost due to technical inefficiency. Within sampled farmers, the least technically efficient group of the farmers operated at 14.4%, indicating to be cultivating maize at about 83% below their maximum potential capacity. The most efficient group of farmers operated at 97.7% of their potential indicating a good technical efficiency in maize production using the same production technologies. This clearly shows a wide existing gap between the least efficient and the most efficient group of farmers hence there is a possibility for most of these least efficient farmers to improve their maize yield. The representative distribution of the technical efficiency is as shown below on Table 2;

Table 2. Distribution of efficiency levels within the sampled farmers

| Range of efficiency scores | Frequency | Percentage |
|---|---|---|
| 0.10-0.49 | 60 | 54.5 |
| 0.50-0.79 | 30 | 27.3 |
| 0.80-0.97 | 20 | 18.2 |
| Total | 110 | 100 |

Source: Author's computation, 2022.

The table clearly shows that a majority of the maize farmers operate at less than 50% of their maximum potential. About 27.3% of the other farmers operated at an efficiency less than 80% their maximum capacity and the rest 18.2 % of the farmers operated at an efficiency range of 80% to 97% with the existing production technology. The technical efficiency can be better summarized as shown on the table below;

Table 3. Summary of calculated technical efficiency

| Variable | Obs(n) | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Technical efficiency | 110 | .5190031 | .2583274 | .1447577 | .9774644 |

Source: Author's computation, 2022

## 3.3 Estimated impact of maize production function

The production function of the maize farmers was defined by the key factors considered for the growing of maize in the study area. The key variables retained for this function were total yield of maize harvested in kg as the main dependent variable while the quantity of seeds, fertilizer used and man-days of labour used, were all designated as the independent variables. Worthy of note is the consideration of farm size not as a key production factor given that access to farm land in the study area is not a challenge to most of the farmers based on their ability and desire to get farm land, as such this variable may not be of any key challenge to maize farmers. However farm size is rather consider as one of the independent variables when checking out on sources of technical inefficiencies as will be seen later.

With the Cobb-Douglas production function subjected to a one-step approach with a truncated normal distribution, the results of this study revealed that about 96% of the variance in maize yield was attributed to technical inefficiency. The total maize output of the maize farmers were positively significantly affected by the quantity of seeds used and the quantity of fertilizers used. The Seeds variable was statistically significant at 5% and fertilizer used was statistically significant at 5%. However, between both production variables, the quantity of fertilizers used by the farmers had a greater positive significant effect on the technical efficiency of the farmers as indicated by its larger constant value of 0.029 as against the 0.026 for the seed variable at 5% statistically significant. The positive constant values for fertilizer indicates that increasing fertilizer use by 100% increases total maize yield by about 29% mean while increasing the quantity of seed used by 100% increases total maize yield by about 26%. This interpretation is considering the existing production technology while holding other inputs constant. This result reflects that of Shamsudeen[28], who found that seed and fertilizer both positively significantly affected the maize output of farmers in Northern Ghana.

The labor variable was observed to be statistically insignificant at 5% level with a negative coefficient indicating effect on the total amount of maize produced by the farmers. A similar result was reported by of Gershom[29] who found that all classical inputs positively had a significant effect on maize output in Zambia except for labor and fertilizer. This may be attributed to the fact that mostly household labour is used by small-scale farmers who hardly keep a clear record on the exact number of man days spent for cultivation and the quality of labor may not positively impact total maize yield. This could be different from large scale farmers who may mostly depend on hired labour and mechanization and hence keep track on their cost or ensure quality work is done by the hired labor force Its important to note that keeping good records on number of days spend for labor ensures a good data which could influence results.

Table 4. Maximum likelihood estimates of the stochastic frontier production function of the sampled farmers

| Variables | Coefficient | Std Error | P>Z |
|---|---|---|---|
| Lnseed | .26296 | .0628 | 0.000 |
| Lnfertilizer | .29006 | .0940 | 0.002 |
| Lnlabour | -.17652 | .1058 | 0.095 |
| _Cons | 6.24082 | .4542 | 0.000 |
| Inefficiency variation($\sigma$_u ) | 0.131 | | |
| Noise variation ($\sigma$_v ) | 0.004 | | |
| Signal -to-noise ratio($\lambda$ ) | 0.967 | | |
| Observations | 110 | | |
| Loglikelihood | -14.61 | | |

Note: Lnoutput is the dependent variable and P value is at 1% significance level
Source: authors' analysis

## 3.4 Determinants of technical inefficiencies sources

The sources of technical inefficiencies were identified using the specified model component of the stochastic frontier approach earlier explained. The technical inefficiency was considered as the dependent variable (Mu) while the independent variables considered were as specified on Table 1. The summary of the analytical results are as follows;

Table 5. Maximum likelihood estimates of the inefficiency model

| Variable | Coefficient | Std.error.z | P value |
|---|---|---|---|
| Gender (dummy) | .80839 | 0.97 | 0.332 |
| Marital status | .10473 | 1.80 | 0.072 |
| Educational status | .10254 | 1.82 | 0.069 |
| Household size | -.04907 | -0.87 | 0.386 |
| Crop type | -.04290 | -0.48 | 0.635 |
| Experience | .07768 | 1.18 | 0.238 |
| Farm size | -2.2879 | -8.35 | 0.000 |
| Training | -.10170 | -0.51 | 0.609 |
| Extension visit | -.07620 | -0.36 | 0.720 |
| constant | 1.3982 | 4.28 | 0.000 |

source:Author's results, 2022.

The general inefficiency model is statistically significant at 1% indicating the data set fits for the analysis. The result shows the different co-variates that are sources of technical inefficiency for maize production in the sampled area. Household size of the farmers was observed to have a negative relationship (-.049) on their technical inefficiency even though it's not statistically significant. This suggests that the number of people in a farming household positively affects their maize production output and efficiency. The household size represent the active labor force used for maize cultivation. This agrees with the findings on technical efficiency of maize farmers in Oyo state of Nigeria[30], which identified households with more family members to be more technically efficient than those with less family members.

Crop type defined as the mono culture (just maize planted) or mixed cropping system (maize planted alongside other crops on the same farm) was observed to have a negative relationship on the technical inefficiency of the farmers. This suggests that a cropping system selected by a farmer greatly affects the technical efficiency of the maize produced on that same farm plot. Even though the specific group interaction of mono culture and mixed cultivation on technical inefficiency wasn't examined in details in this study, base on the number of farmers in the study area who responded to practice mixed farming in the data collected during the cultivation season, one could suggests that the mixed cropping system practiced by the farmers has a positive relationship on their technical efficiency of maize production as it influences maize yield, reduces weeds and labor cost. Some of these other crops fertilized the soil when planted with nitrogenous building crops. This result agrees with the findings of Eloundou[31], who identified cropping systems in the Centre Region of Cameroon to have a positive impact on the technical efficiency of small scale farmers.

The farm size used by the farmers was observed to have a negative effect on their technical inefficiencies. This implies that it affects technical efficiency positively and was statistically significant at 1%. Farmers with larger farm sizes showed more efficiency than those of small farms. For every additional farm land used for maize cultivation, the total yield of maize harvested increased by 2.2%. perhaps farmers with larger farms invest more in fertilizer and labor and consequently gets a better output per unit area cultivated than farmers with smaller farm sizes who produce mainly for household consumption hence feel reluctant to invest more on farm inputs. This result doesn't agrees with the findings of some scholars who have identified farm size to have a negative impact on technical efficiency as observed by Ajapnwa [18]. They argued that due to limited use of resource by small scale farmers, managing or increasing farm size leads to less efficiency.

Training on maize cultivation techniques and the frequency of agricultural extension officer's visit to the field during the season were observed to both have negative effects on the technical inefficiency of the farmers. This means that farmers who attended trainings prior to the start of a maize farming season or received extension visits were less technically inefficient than those who didn't attend trainings or extension visits. Even though the descriptive result of this study suggest that a majority of the farmers didn't receive any training nor received extension workers on their farm for guidance these variables didn't have a statistical significant effects on technical inefficiency. Apart from these above mentioned variables and their role on technical efficiency, the rest of other variables such as the gender of the farmers, the marital status of the farmers, their educational levels and number of years of experience, didn't have a statistical significant effect on the level of technical inefficiency of the farmers.

## 4. Conclusion and Recommendation

Maize production remains a very vital source of food and income for small-scale farmers in the Balikumbat Sub-Division. This study estimated the levels of technical efficiency of the farmers in the study area while examining the sources of technical inefficiency of the farmers. Through an output-oriented approach, stochastic frontier analysis was used in a one-step approach with Truncated-normal distribution to examine the technical efficiency and inefficiency of maize production in the study area. Being mindful of some of the limitations of this study that allowed for some strong assumptions on the distributional and functional form of the data parameters, the findings however gave a clear representative view on the input and output relationship of maize production in the study area. Going by the current production technology in Balikumbat with the amount of fertilizer, seeds used and labor used, farmers harvest a maximum yield of about 1ton per hectare which is far below the estimated average yield per hectare in the rest of the country. Based on the analyses done in this study, if farmers were to maintain this current production technology, maize output can be increased by 48% corresponding to about 920kg of maize per hectare. Therefore from the results presented in the previous sections, a few recommendations can be made to improve and increase maize yields and technical efficiency in the study area.

(1) From an academic and research view point, this study will recommend that further research is carried on the impact of the types of seeds used by farmers on the productivity of maize in the study area. Farmers are greatly encouraged to use improved maize seeds in the right dosage to increase their output. The use of fertilizers in the right quantity and timing is encouraged to boost yields and hence technical efficiency as was proven from the results gotten. (2) Improving on the sources of technical efficiency will equally require the government or local stakeholders to help farmers gained more practical knowledge through trainings on maize cultivation and enforcing regular field visits by agricultural extension agents in the study area. Increasing the active labor force either from hired labor or household labor should be encouraged to enhance technical efficiency. Increasing access to more farmland will be encouraged with the hope of investing more in seeds, labor and fertilizer to get better yields, from the larger farms. (3) Finally the study area as indicated from the descriptive statistic has existing farmer's associations and maize farmers are greatly encouraged to pull resources together through such groups to gain access to fertilizers and maize seeds.

Conclusively, most of these recommendations agrees with the existing efforts of the Ministry of Agriculture and Rural Development to increase local food production in the North West region. The collective role of the farmers, government and development partners if well harnessed will not only ensure that farmers in Balikumbat are better efficient but will equally promote increased food production in the region and country.

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