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Measuring the Technical and Scale Efficiency of Smallholder Maize (*Zea mays*) Farmers in Cameroon: The Case of the Centre Region

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Authors' contributions

This work was carried out in collaboration between all authors. The author EEC designed the study, wrote the protocol, carried out the field study, managed the bibliographical research, carried out the statistical analysis and wrote the first version of the manuscript. Authors FDE and MNJR authors designed the study and approved the protocol and the bibliographical research. All authors read and approved the final manuscript.

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ABSTRACT

Urbanisation has led to the development of new markets, including that for cereals for human consumption, where maize cultivation has taken on an important role among smallholder producers in some countries, such as Cameroon. However, the cultivation of maize in the centre region of Cameroon raises several questions, including the efficiency of these farmers. This article presents the level and determinants of technical performance of smallholder maize farmers**.** The research method was based on field surveys. The study was carried out between September 2019 and December 2020 in the Centre Region of Cameroon. The research methods used included field work, field surveys through semi-structured interviews on 1060 (545 women and 515 men) maize

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farm managers who were selected in a reasoned method based on the file of the Ministry of Agriculture and Rural Development of Cameroon. Data from the study was analysed using Data Envelopment Analysis (DEA) method and the Tobit model allowed us to identify the determinants of the performance of these maize farms. The results show that the efficiency scores of the production and income outputs are 0.7773 and 0.6707, respectively, and provide evidence for the inefficiency of smallholder maize farmers in the Centre Region. Gender, cropping system, maize variety and number of treatments have a significant and positive influence on the productive efficiency of the farms while the only determinant that influences the income efficiency of the farmers is the maize variety used. Ultimately, smallholder maize farmers are not performing well in terms of both production and income. Value chain actors need to act on three main pillars around family farms: socio-economic characteristics (the place of women and education policy), the production system (access to quality seeds, and production techniques) and institutional factors (access to extension, financing and membership to a producer organization).

Keywords: Maize; technical performance; scale efficiency; Tobit; DEA.

ABBREVIATIONS

PARM	:	*Platform for Agricultural Risk Management*
INS	:	*National Institute of Statistics*
MINADER	:	*Ministry of Agriculture and Rural Development*
PO	:	*Peasant Organization*
CRSTE	:	*Constant Returns to Scale Technical. Efficiency*
VRSTE	:	*Variable Returns to Scale Technical Efficiency*

1. INTRODUCTION

Agriculture is one of the key sectors for achieving the global goal of poverty reduction and is a very important area for low-income countries, both in terms of its contribution to Gross Domestic Product and the number of people involved in this activity [1].

Despite its significant importance in economies, African agriculture continues to face several challenges such as the consequences of the 2008 food riots, the outbreaks of independence conflicts, terrorism and the Covid-19 pandemic. Of the 750 million people in sub-Saharan Africa, two-thirds (500 million) live in rural villages of less than 2,000 people, where agriculture and livestock farming remain the main occupations [2].

In Cameroon, the agricultural sector employs nearly 70% of the active population with a poverty rate of 37.5%, 55% of which represents the rural population [3]. Agriculture is therefore a major lever for ending famine, ensuring food security, improving nutrition and promoting sustainable agriculture. The results of a recent large-scale study on food security by the WFP [4]. show that nearly 10% of households in rural areas of Cameroon are food insecure due to insufficient food production.

This mismatch between agricultural production and population growth in Cameroon leads to increased hunger in rural areas. However, in these areas, agriculture is essentially based on small-scale farmers working on small plots of land for subsistence marked by the production of foodstuffs directly edible by family members [5-6]. In this type of agriculture, there are mainly food crops with a predominance of Cereals.

Cereals are one of the main sources of food, contributing nearly 50% of the total energy intake (kcal) of the diet. Indeed, cereals constitute the basis of the human diet in Cameroon, providing 36.2% of caloric intake and 40% of protein intake. Maize, which is one of the main cereal crops, contributes 19.5% and 22% of caloric and protein intakes respectively for the whole country. This shows its importance in the population's diet [7].

Maize (*Zea mays*) is a widely grown cereal in the world, in different agro-ecological zones. In general, the crop has about 50 species with different colours, tastes, content characteristics, shapes and grain sizes. In Cameroon, maize is the most important cereal crop. Common varieties grown in Cameroon include yellow, red and white species, with yellow and white being the most common varieties. The preference for white or yellow varieties depends on regional dietary habits and food preparation processes [5].

Despite its significant importance in food habits and the proliferation of its cultivation throughout the country, smallholders continue to have low yields (1.8 tons/hectare/year), although some benefit from support services [8-9]. Compared to the world average of about 5.5 tons/hectare/year. In 2017, annual maize production in Cameroon was estimated at 2,246,241 by FAOSTAT [10]. However, this production is still insufficient to meet the needs of the population, which forces the government to continue importing maize. In the first quarter of 2020 alone, the country imported 473 tons of maize, worth USD 542,994 [11].

In view of these statistics, it is important to question the effectiveness of maize farms in meeting the needs of the growing population. In Cameroon, as in most countries in sub-Saharan Africa, the question of the performance of maize farms is an important one in research. Several authors [12-15] [6] [5] [16] have analysed maize production systems to determine their technical and economic efficiency through econometric methods (parametric and non-parametric).

The present article aims to follow up on these analyses to understand the role of the family farm manager in the performance of the farm plots that he manages daily and to see the determinants of this performance.

2. MATERIALS AND METHODS

2.1 Geographical Location

The study was conducted in the 10 administrative divisions of the Centre Region of Cameroon. This Region has an estimated population of 3,098,044 inhabitants, including 1,552,362 men and 1,545,682 women according to the 2010 census. These inhabitants are essentially made up of the Béti and Bassa peoples, who are mixed in the towns and in some rural areas with immigrants from the East, West, North and abroad.

The reasons for choosing this location are numerous. It is important to note that the Centre Region is the third largest maize production area with 193,201 tons in 2010. Apart from its production capacity, this Region was chosen for three main reasons. Firstly, the Centre Region is the most populous in the country with 19% of the national population. Secondly, maize plays an important role in the dietary habits of the population and is therefore grown in all the administrative units of the region. Finally, the Centre Region is the seat of institutions and therefore benefits from the presence and proximity of institutions that provide support and advice to producers.

2.2 Hydrography and Climate

The Centre Region belongs to the Sanaga basin. This important river drains a basin of about 65,000 km^2 at Nachtigal, with an average annual flow of 1,200 m^3/s. The basin is subject to a tropical transitional regime. Floods begin in July and peak in October. The rapid recession in November and December is followed by a regular drying up during the first three months of the year. The main tributary of the Sanaga is the Mbam, enlarged by the Noun. It drains a basin of 42,300 km^2 with an average annual flow of 750 m3/s. The regime of this watercourse is very similar to that of the river.

The Centre Region belongs to the forest zone with bimodal rainfall. It is subject to a sub-equatorial Guinean type climate with four seasons: The short dry season (mid-June to mid-August); the long dry season (mid-November to mid-March); the short rainy season (mid-March to mid-June); and the long rainy season (mid-August to mid-November).

The rainfall in this agro-ecological zone varies between 1500 and 2000 mm/year. This hydrography and climate make it possible to produce maize over two agricultural seasons in the Centre Region.

2.3 Study Population

The study population is made up of all the maize producers in the Centre Region identified by the deconcentrated services of the Ministry of Agriculture and Rural Development. Among these producers, the analysis unit was the head of the farm because it is the latter who controls resources and plans operations.

2.4 Sampling and analysis technique

According to official figures from the Ministry of Agriculture and Rural Development for the

Centre region, 142,957 maize farmers were counted in the divisions during the 2019 agricultural season. A sample of 1,060 heads of family farms was used for this study with a confidence level of 95% and a margin of error of 3%. The sample was divided into administrative divisions using a proportionality coefficient k equal to 0.0074 in order to have the number of people to be interviewed per territorial division (see Table 1).

The respondents were selected using a reasoned and random approach in which the starting point was the services of the divisional delegation of agriculture and the respondent n+1 was identified by the snowball method where saturation was considered when the number of people to be surveyed was reached according to Table 1.

Table 1. Sample of the study

Divisions	Population	Sample
Haute Sanaga	8 350	62
Lékié	1 346	10
Mbam et Inoubou	44 295	328
Mbam et Kim	73 805	547
Mefou et Afamba	1 686	13
Mefou et Akono	2 615	19
Mfoundi	1 910	14
Nyong et Kellé	798	6
Nyong et Mfoumou	328	3
Nyong et So'o	7 824	58
Total	**142 957**	**1 060**

To determine the performance (technical efficiency) of farms, the DEA model was used with the Win4DEAP2 software to estimate farm efficiency scores. Developed by Charnes, Cooper and Rhodes [17], this model has constant yields and assumes convexity of the whole production. We assume that there are *n* Farms, each of which consumes variable quantities of *m* inputs to produce quantities of *s* outputs.

Specifically, the $Farm_j$ consumes quantities X_{ij} of input *i* and produces quantities $Y_{rj}$of output r. We assume $X_{ij} \geq 0 \; et \; Y_{rj} \geq 0$ and further on, we assume that each $Farm_j$ has at least one positive input and a positive output value.

The form of the DEA ratio, which gives the relative efficiency of $Farm_j$ presented by Charnes, Cooper and Rhodes is a ratio of outputs to inputs employed for each $Farm_j$ (j=1,2,...,n). Thus, for a farm $Farm_0$, the equation amounts to maximising the efficiency ratio such that:

$$Max_{u,v}\; h_0 = \frac{\sum_{s}^{r=1} U_r Y_{r^0}}{\sum_{m}^{i=1} V_i X_{i0}} \qquad (1)$$

Of course, without further constraints equation 1 is unbounded. For each operation the mathematical programming problem can be stated as follows:

$$Max_{u,v}\; h_0 = \frac{\sum_{s}^{r=1} U_r Y_{r^0}}{\sum_{m}^{i=1} V_i X_{i0}}$$

Under the condition that (U/C)

$$\frac{\sum_{s}^{r=1} U_r Y_{rj}}{\sum_{m}^{i=1} V_i X_{ij}} \leq 1 \; where \; j = 1 \; to \; n \qquad (2)$$

$$U_r\,, U_r \geq 0 \;\forall\; r = 1 \; to \; s;\; i = 1 \; to \; n$$

This form gives the possibility of an infinite number of solutions; if (u^*, v^*) is optimal $(\alpha u^*, \alpha v^*)$ is also optimal for α>0. A transformation had been developed by Charnes et al [17] that can remedy this problem. We assume $\sum_i v_i x_{i0} = 1$, the equivalent program obtained where (u, v) are changed by (μ,v) is :

$$Max\; z_0 = \sum_r \mu_r y_{r0}$$

$$\begin{cases} U/C \; \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0 \\ \sum_i v_i x_{i0} = 0 \\ \mu_r, v_i \geq 0 \end{cases} \qquad (3)$$

For which the dual problem is:

$$\theta^* = Min\; \theta$$

$$\begin{cases} U/C \; \sum_j \gamma_j x_{ij} \leq \theta x_{i0} \\ \sum_j \gamma_j y_{rj} = 0 \\ \gamma_j \geq 0 \end{cases} \qquad (4)$$

Considering the dual theorem of linear programming we have $z^* = \theta^*$; therefore, either model can be employed [18] θ is a scalar that represents the technical efficiency score of each $Farm_j$ and γ a constant called the multiplier. The $Farm_j$ for which $\theta^* < 1$ are inefficient, while the $Farm_j$ for which $\theta^* = 1$ are frontier points.

Banker, Charnes and Cooper [19] proposed a model that allows for the VRS assumption, as the

CRS assumption is only appropriate if the operator operates at an optimal scale. They introduce a new variable in the CCR model, which allows to distinguish the pure technical efficiency. The problem becomes:

$$Max\ h_0(u,v) = \sum_r \mu_r y_{r0} + C_0$$

$$\begin{cases} U/C\ \sum_i v_i x_{i0} = 1 \\ \sum_r u_r y_{rj} - \sum_i v_i x_{ij} - C_0 \leq 1 \\ \mu_r, v_i \geq 0 \end{cases} \quad (5)$$

The heads of the farms surveyed are 1060 (n=1 to 1060), producing two outputs: the quantity of maize and the income of the farm using the following inputs: area, quantity of seed, quantity of fertiliser, value of pesticides, quantity of labour, depreciated value of infrastructure + transport and handling. Each group uses K inputs (k=1 to 6) to produce 1 output (m=1). In this particular case, the aim is to determine the level of technical efficiency of maize farms. This can be done either according to an input or output orientation. But in the case of this work, the calculation of the technical efficiency will be done according to the output orientation (it is a question of minimizing the inputs to obtain a maximum level of outputs).

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Table 2 below shows the variables used to calculate the technical efficiency scores.

The dependent variable will be censored by keeping the numbers zero in the sample. The censored Tobit model used to explain inefficiency is specified as follows.

If Y represents the efficiency level of any firm $\boldsymbol{Y_i}$, the model can be written as follows:

$$\begin{cases} Y_i = \beta X_i + v_i \\ with \begin{cases} Y_i = Y_i^*\ if\ 0 \leq Y_i^* \leq 1 \\ Y_i = 0\ if\ no \end{cases} \end{cases} \quad (6)$$

In this relationship, Y_i^* is assumed to depend on a number of explanatory variables grouped in the vector X_i , not incorporated in the performance calculation and whose effects are grouped in the vector β. Y_i is the combination of the value predicted by the deterministic component of the model βX_i and a residual whose value varies randomly for each firm. However, it is assumed that the variable Y_i^* is not directly observable, but rather the continuous, zero-bounded variable Y_i is observed. Assuming that the errors are normally distributed, the estimation of the above model will involve maximising the log likelihood function as follows:

$$Log\ L = \sum_{i=1}^{n} Log\ \left[1 - \emptyset X_i {}^{\beta}/_{\delta}\right] + \sum_{i=1}^{n} Log\left(\frac{1}{\sqrt{2\pi\delta}}\right) - \frac{\sum_{i=1}^{n}(Y_i X_i \beta)^2}{2\delta^2} \quad (7)$$

Where n is the number of observations, and δ is the standard deviation. The application of this model requires an appropriate choice of explanatory variables used for the analysis of the determinants of firm performance.

Table 2. Variables of the technical efficiency

Variables	Measures	Description
Output		
Production and Incomes	In USD	Quantity of maize produced / income
Inputs		
Total area	In m²	Total area of the farm
Seed	In USD	Expenditure on seed
Fertilizer	In USD	Expenditure on fertilizer
Pesticide	In USD	Pesticide purchase expenditure
Labour	In USD	Expenditure on labour
Handling/Transport	In USD	Expenditure on handling

The empirical model of the analysis is as follows:

$$Perf_i = \beta_0 + \beta_1 SE_i + \beta_2 VT_i + \beta_3 VI_i + \varepsilon_i \quad (8)$$

Where $Perf_i$ represents economic performance, SE_i the matrix of socio-economic variables (age, gender, education level, marital status, household size, main activity, land ownership and type of labour), VT_i the matrix of technical variables (seed type, type of production system, fertilisation, respect of spacing, variety, phytosanitary treatment and Number of seeds per packet), VI_i the institutional variables (source of funding, access to extension, membership of a PO) and ε_i the error term.

Table 3 presents the study variables subdivided into dependent and independent variables.

3. RESULTS AND DISCUSSION

In this study, the technical efficiency (performance) of the small farmers will be analysed using maize production on the one hand and farmer's income as the main output on the other. This will lead to a double objective of analysing the management of inputs to achieve better maize production on the one hand and better income on the other.

The descriptive statistics of the variables that allowed the analysis of the efficiency scores are contained in Table 4 below. With regard to outputs, it is noted that the 1060 farms produce an average of 1,063 kg of maize. In addition, the average income of the farmers is USD 159.37.

As for inputs, the results show that farmers produce on average on an area of 11 526.204 m². In terms of land rental, farmers spend an average of US$14.10. Labour costs are estimated to an average of USD 58.18. Regarding expenditure on fertilizer consumption, the results show that farmers spend an average of USD 13.39 on fertilization. Expenditure on seed purchase is estimated at an average of US$3.42. Handling and transport costs are estimated to an average of USD 3.24.

The analysis of the performance of maize farms in the Centre Region was carried out using the DEA method. The analysis shows that the CRSTE efficiency scores are equal to the VRSTE. The analysis of the distribution of efficiency scores (performance) was analysed at two levels. Firstly, the distribution of efficiency scores by division is analysed and secondly, the distribution of efficiency scores by farm manager and farm characteristics is analysed.

Table 5 presents the distribution according to the divisions of the Centre Region. Overall, the table shows that the average efficiency scores of all 1060 farms in the Centre Region are equal to 0.7773 for productive efficiency and 0.6707 for income efficiency. Overall, these results would imply that maize farms in the Centre region are not efficient in terms of production and income as they use 78% and 68% of their capacity respectively. These results corroborate those of Mbarga et al [6] who find that maize farmers in the Centre region are less performant. The results of the productive performance analysis show that the three best performing divisions are Nyong-Ekelé (0.8216), Nyong et So'o (0.8011) and Mbam et Kim (0.7910). In terms of income performance analysis, the three best performing departments are Mefou and Afamba (0.7584), Nyong and Mfoumou (0.725) and Nyong and So'o (0.7177).

Table 6 shows the distribution of efficiency scores according to operator and farm characteristics. The analysis of this table will be done in two steps. Firstly, we will interpret the distribution of productive performance and secondly, we will interpret the distribution of income performance.

With regard to the distribution of productive efficiency scores, the analysis of the gender variable shows that men (0.7813) perform better than women (0.7735). As for the marital status variable, we note that married people (0.7815) outperform single people (0.7728), widowers (0.7671) and divorced people (0.7447). Regarding the educational level variable, farmers with secondary education (0.7804) outperform those with primary education (0.7768), higher education (0.7756) and no education (0.7708). Regarding membership to a farmer's organization (FO), we note that farmers who are members of an FO (0.779) perform better than those who are not members (0.7769). In terms of land ownership, farmers who are not landowners (0.7865) outperform landowners (0.7766). In terms of fertilizer use, fertilizer users perform worse (0.7726) than non-users (0.7799). In terms of agricultural training, farmers who have received agricultural training perform better (0.7946) than those who have not received agricultural training (0.7788). With regard to the source of finance, farmers whose main source of finance is microfinance/banking (0.7905) outperform those whose main source of finance is self-financing (0.7804) and tontine (0.7611).

Table 3. Dependent and independent variables

Variables	Items	Description
Dependent variables		
Technical Efficiency	Technical Efficiency	Continuous variable between 0 and 1
Independent variables		
Age		dummy variable =0 if 15-25 years old, =1 if 26-35 years old, =2 if 36-45 years old, =3 if 46-55 years old, =4 if 56-70 years old, =5 if over 70 years old
Sex		dummy variable: =1 if male; 0=female
Education level		dummy variable: =0 if no level; =1 primary; =2 secondary; =3 higher
Marital status		Dummy variable =0 if married, =1 if single, =2 if widowed, =3 if divorced
Household size		Continuous variable measuring Number of residents in the household
Main activity		Dummy variable =0 if agricultural, =1 if livestock, =2 if education, =3 if fishing, =4 if hunting, =5 if student, =6 if civil servant, =7 if defence force, =8 if other.
Land ownership		Dummy variable: =1 Yes; 0=No
Type of labour		dummy variable: =0 if family, =1 if employee, =2 family and employee, =3 other to be specified
Type of seed		Dummy variable: =0 if other; =1 if hybrid; =2 if composite.
Cropping system		Dummy variable: =0 if mono-crop, =1 mono-crop and fruit, =2 polyculture with other species.
Use of fertiliser		Dummy variable: =1 Yes; 0=No
Respect of spacing		Dummy variable: =1 Yes; 0=No
Phyto-sanitary treatment		Dummy variable: =1 Yes; 0=No
Deseeding		Dummy variable: =1 Yes; 0=No
Number of seeds		Continuous variable measuring Number of seeds
Source of funding		Dummy variable: =1 if self-financing, =1 if tontine, =2 if microfinance/banking.
Access to extension		Dummy variable: =1 Yes; 0=No
Membership in a PO		Dummy variable: =1 Yes; 0=No

Table 4. Descriptive statistics of effectiveness analysis variables

Variable	Frequency	Mean	Standard deviation
Outputs			
production	1,060	1,063	272,836
income	1,060	159.37	509.05
Inputs			
area	1,060	11,526	14,925
rental	1,060	14.10	0.11
labour	1,060	58.18	235.36
fertilizer	1,060	13.39	72.28
seed	1,060	3.42	18.97
handling/transport	1,060	3.24	21.53

Regarding the distribution of income efficiency scores, analysis of the gender variable shows that women (0.6992) outperform men (0.6406). For the marital status variable, married people (0.6786) outperform divorced people (0.6754), widowers (0.6732) and single people (0.6556). About the educational level variable, farmers with no education (0.6928) outperform those with primary (0.6707), secondary (0.6689) and tertiary (0.6509) education. Regarding membership to a farmers' organization (FO), we note that farmers who are members of an FO (0.6403) perform less well than non-members (0.6806). Regarding land ownership, we note that farmers who own land (0.6751) perform better than those who do not (0.6153). In terms of fertilizer use, fertilizer users (0.6108) perform worse than non-users (0.7035). In terms of agricultural training, farmers who have received agricultural training (0.6292) perform worse than those who have not received agricultural training (0.6778). About the source of financing, farmers whose main source of financing is self-financing (0.6884) perform better than those whose main source of financing is microfinance/banking (0.6078) and tontine (local saving) (0.5864).

Table 5. Distribution of efficiency scores by department

Divisions	Technical efficiency: production	Technical efficiency: income
Haute-Sanaga	0,7733	0,6645
Lékié	0,6986	0,5323
Mbam et Inoubou	0,7536	0,6241
Mbam et Kim	0,7910	0,6967
Mefou et Afamba	0,7885	0,7584
Mefou et Akono	0,7535	0,6623
Mfoundi	0,7838	0,6460
Nyong et kélé	0,8216	0,5558
Nyong et Mfoumou	0,7366	0,725
Nyong et So’o	0,8011	0,7177
General	**0,7773**	**0,6707**

Table 6. Analysis of the distribution of efficiency scores according to operator and farm characteristics

Divisions	Technical efficiency: production	Technical efficiency: income
Gender		
Female	0.7735	0.6992
Male	0.7813	0.6406
Marital status		
Married	0.7815	0.6786
Single	0.7728	0.6556
Widowed	0.7671	0.6732
Divorced	0.7447	0.6754
Level of education		
Not in school	0.7708	0.6928
Primary	0.7768	0.6707
Secondary	0.7804	0.6689
Higher	0.7756	0.6509
Membership of a PO		
No	0.7769	0.6806
Yes	0.779	0.6403
Land ownership		
No	0.7865	0.6153
Yes	0.7766	0.6751
Use of fertiliser		
No	0.7799	0.7035
Yes	0.7726	0.6108
Agricultural training		
No	0.7788	0.6778
Yes	0.7946	0.6292
Source of funding		
Self-financing	0.7804	0.6884
Tontine (Local saving)	0.7611	0.5864
Microfinance/banking	0.7905	0.6078

An analysis of the correlation between the variables in the Table 6 shows that the correlation coefficients between the variables are low. This would mean that there is no multi-collinearity between the dependent variables in the study.

The analysis of the determinants of the productive efficiency of maize farms in the Centre Region was carried out using the Tobit model (Table 7). For this purpose, 18 independent (explanatory) variables were selected. These variables can be classified into three groups, namely: socio-economic characteristics (age, gender, level of education, marital status, household size, main activity, land ownership and type of labour), technical characteristics (type of seed, type of production system, fertilization, respect of spacing, variety, phyto-sanitary treatment and number of seeds per pocket) and institutional characteristics (source of financing, access to extension, membership to a PO).

The overall significance analysis shows that we have to reject the hypothesis that "all coefficients are zero" because the likelihood ratio (LR) is statistically significant at 1% with the Chi2 test. Thus, the model is globally significant (Acceptable and validated) and the signs of the coefficients can be taken into account.

The results of the Tobit model indicate on the one hand that gender (Sex), cropping system (crop sys), maize variety (variety) and number of treatments (no of treatment) have a significant and positive influence on the productive efficiency of maize farms in the Centre Region. On the other hand, it is noted that marital status (status), household size (size), fertiliser use (fertiliser use), thinning of plant (thinning) and source of finance (funding) have a significant negative influence on the productive efficiency of maize farms in the Centre Region.

On the other hand, the results show that age (age), level of education (edu), membership in a farmer's organization (op membership), salary (salary), ownership of land (ownership), labour force (Mo), number of seeds (no of seed) and agricultural training (forma) do not have a significant influence on the productive efficiency of maize farms in the Centre Region.

The interpretation of the fixed effects of the variables with a significant influence is presented below:

Sex (Gender) has a positive and significant influence at the 10% threshold. This result would mean that compared to women, being a man increases the probability of the farmer to be successful by 0.0093%. This result is contrary to that of Mango et al. [20] in Zimbabwe.

Cropping System (crop sys) exerts a positive influence on performance and is significant at 5%. This means that compared to those who practice monoculture, practicing polyculture increases the probability of performing by 0.0057%. These results are consistent with those obtained by Wang et al. [21].

Corn Seed Type (variety) has a positive sign and is significant at 1%. This would mean that compared to those using traditional seeds, using hybrid and composite seeds increases the probability of performing by 0.0086%. This result is in line with those found by Omondi et al. [22].

The Number of Treatments (no of treatment) exerts a positive and significant influence at the 10% threshold on farm performance. This result means that increasing the number of treatments increases the probability of being successful by 0.0059%. This result is similar to that of Jjagwe et al. [23]

Matrimonial Status (Status), has a negative sign and significant at 5%. This result would mean that compared to married individuals, being single reduces the probability of being successful by 0.0075. This result corroborates that of the study by Mbarga et al [6] conducted among 105 maize farms in the Centre Region of Cameroon.

Household Size (Size), has a negative and significant influence at the 10% level. This result would mean that increasing the size of the household reduces the probability of the farmer to be efficient by 0.0066%. This result corroborates that of Mango et al. [20] which shows that increase in household size reduces the probability of maize farms in Zimbabwe to be efficient.

Fertiliser use (Fertiliser use), has a negative sign and significant at 10%. This result means that compared to those who do not use fertilizer, using fertilizer reduces the likelihood of performing well. This result corroborates the findings of Yamoah et al. [24].

Thinning has a negative and significant influence on performance at the 10% level. This result would mean that practising thinning reduces the probability of being successful by 0.0091%.

The Source of Financing (Funding) has a negative and significant influence at the 10% level. This result means that not self-financing reduces the probability of being successful by 0.0114%. This result corroborates that of the study by Mbarga et al. [6] conducted among 105 maize farms in the Centre Region of Cameroon.

Table 8 below presents the analysis of the determinants of income efficiency of maize farms in the Centre Region. For this purpose, we estimated a Tobit model using the Maximum Likelihood method, relating the technical efficiency scores to 18 explanatory variables. The latter are the same as those used in the previous analysis.

The overall significance analysis shows that we must reject the null hypothesis (H0) "all coefficients are zero" because the likelihood ratio (LR) is statistically significant at 1% with the Chi2 test. Thus, the model is globally significant (Acceptable and validated) and the signs of the coefficients can be considered.

The results of the Tobit model indicate on the one hand that only the maize variety (variety) has a significant and positive influence on the income efficiency of maize farms in the Centre Region. On the other hand, it is noted that sex (gender), marital status (status), labour force (labour), number of treatments (no of treatment), source of finance (funding) exert a negative and significant influence on the productive efficiency of maize farms in the Centre region.

The interpretation of the fixed effects of the variables with a significant influence is presented below:

The type of corn seed (Variety) has a positive sign and is significant at 1%. This would mean that compared to those using traditional seeds, using hybrid and composite seeds increases the probability of performing by 0.0338%. This result is in line with those found by Omondi et al. [22].

Sex (Gender) has a negative and significant influence at the 10% level. This result would mean that compared to women, being a man reduces the operator's probability of performing by 0.00341%. This result is in line with Mango et al. [20] in Zimbabwe.

Table 7. Determinants of the productive efficiency of maize farms in the Centre region

Variables	Coefficient (dy/dx)	Student (p-value)
Sex	0.0093	1.74 (0.083)*
Age	0.0005	0.25 (0.802)
Status	-0.0075	-2.04 (0.041)**
Edu	0.0014	0.46 (0.645)
PO membership	0.0073	1.23 (0.218)
Sized	-0.0066	-1.90 (0.058)*
Crop sys	0.0057	2.56 (0.011)**
Treatment	0.0157	1.00 (0.195)
Principal_activity	0.0008	0.86 (0.317)
Land ownership	-0.0019	-0.21 (0.831)
Labour	0.0015	0.56 (0.574)
Fertiliser use	-0.0114	-1.81 (0.071)*
Thinning	-0.0091	-1.75 (0.080)*
Variety	0.0086	3.12 (0.002)***
No of treatments	0.0059	1.80 (0.072)*
No of seeds	0.005	0.11 (0.914)
Funding	-0.0114	-1.89 (0.059)*
Training	0.0133	1.52 (0.128)
Number of observations	844	
LR chi2 (18)	48.86	
Prob>chi2	0.0001	
Pseudo R^2	-0.0235	

Table 8. Determinants of income efficiency on maize farms in the Centre Region

Variables	Coefficient (dy/dx)	student (p-value)
Sex	-0.0341	-1.90 (0.058)*
Age	0.0063	0.80 (0.426)
Status	-0.0226	-1.83 (0.068)*
Edu	0.0098	0.95 (0.343)
Membership	0.0073	0.37 (0.714)
Size	-0.0091	-0.78 (0.436)
Crop sys	0.0016	0.22 (0.830)
No Treatment	0.0144	0.36 (0.721)
Act_principal	0.0025	0.86 (0.391)
Ownership	0.0198	0.65 (0.518)
Labour	-0.0467	-5.20 (0.000)***
Fertiliser use	-0.0300	-1.42 (0.156)
Thinning	0.0038	0.22 (0.826)
Variety	0.0338	3.66 (0.000)***
No of treatment	-0.0294	-2.68 (0.008)***
No of seeds	-0.02669	-1.53 (0.127)
Funding	-0.0900	-4.45 (0.000)***
Training	-0.0268	-0.92 (0.358)
Number of observations	844	
LR chi2 (18)	123.00	
Prob>chi2	0.0000	
Pseudo R^2	4.2773	

The matrimonial status (Status), has a negative sign and significant at 10%. This result would mean that compared to married individuals, being single reduces the probability of being successful by 0.0226%. This result corroborates that of the study by Mbarga et al. [6] conducted among 105 maize farms in the Centre Region of Cameroon.

Labour (labour), has a negative and significant sign at 10%. This result means that compared to those using family labour, using hired labour reduces the probability of performing by 0.0467%. This result corroborates the results of Ephraim's [25] work on 156 maize farms in southern Malawi.

The number of treatments (no treatment) has a negative and significant influence at the 1% level on farm performance. This result means that increasing the number of treatments reduces the probability of being successful by 0.0295%. This result is similar to that of Jjagwe et al. [23].

Source of financing (funding) has a negative and significant influence at the 1% level. This result means that not being self-financing reduces the probability of being successful by 0.0900%. This result corroborates that of the study by Mbarga et al. [6] carried out on 105 maize farms in the Centre region of Cameroon.

4. CONCLUSION

The aim of this article was to present the level of technical efficiency of small-scale maize producers in the Central Region of Cameroon from the point of view of production and income. But also, to analyse the determinants of this performance. After the field surveys, it was found that small-scale maize farmers in the Centre Region are not technically efficient. The efficiency scores of the production and income outputs are 0.7773 and 0.6707 respectively. To achieve the desired level of productive performance, these producers must reduce the use of inputs (seed, fertilizer, pesticides, labour, handling/transport) by 22.27%, while for an optimal level of performance in terms of income, these small producers must reduce the use of inputs by 32.93%.

In the analysis of the determinants of technical efficiency, it was shown that certain socio-economic factors have a significant and positive influence on the level of productive efficiency of maize farmers, such as the gender of the head of the farm, but also certain technical factors relating to the control of the production itinerary, such as the cultivation system, the variety of maize grown and the number of phyto-sanitary treatments. Furthermore, only the variety of maize used on the farm has a significant and positive influence on the level of income of the farm managers.

The results of this study can inspire policy makers to improve the support provided to stakeholders in the maize value chain. Thus, it can be recommended that development agents provide technical support to small-scale maize producers in the choice and use of good seeds, in mastering the application of fertilizers and in better disseminating the benefits of crop diversification on the plots of land using a well-reasoned method. In addition, in order to increase the income of maize producers, it is important to rethink the land policy in order to facilitate access to women and young people, as it has been shown that gender has a positive influence on increasing production.

CONSENT

The 1,060 respondents gave their verbal consent for the collection and publication of results for academic purposes only.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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