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Resource use efficiency among maize farmers in Ghana

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Abstract

Background: Despite the enormous importance of maize in Ghana, maize farmers in the country continue to experience low yields, making Ghana self-insufficient in the production of the crop. For maize farmers to be helped to increase productivity, the focus should not only be on whether or not they have adopted productivity-enhancing technologies, but it is necessary to carefully examine whether they are even making maximum use of the technologies or inputs available to them. This study analysed resource use efficiency for Ghana's maize farms.

Methods: The data used were obtained through a cross-sectional survey of 576 maize farmers in the Northern Savannah, Transitional, Forest and Coastal Savannah zones of Ghana using structured questionnaire. Descriptive statistics, stochastic frontier analysis and the ratio of marginal value product to marginal factor cost were the methods of analysis employed.

Results: The results showed that generally, maize farmers in Ghana were inefficient in their use of resources available to them. Fertilizer, herbicide, pesticide, seed, manure and land were underutilized, while labour and capital were overutilized by the farmers. The results further showed that maize farmers in Ghana exhibit increasing returns to scale, indicating that the famers can increase their output by increasing the use of some of the key resources.

Conclusion: Incentives and strategies aimed at encouraging farmers to optimize the use of fertilizer, herbicide, pesticide, seed, manure and land are recommended to ensure improved maize productivity in Ghana. Currently, incentives and strategies could take the form of better management by government of the current fertilizer subsidy programme and efficient input distribution through farmer-based organizations to ensure easy access by farmers.

Keywords: Efficiency, Maize, Productivity, Resource use, Stochastic frontier

Background

Accounting for over 50% of total cereal production in Ghana, maize is the most important staple crop in the country. With a greater proportion of maize supply going into food consumption in Ghana, an increase in its productivity is undoubtedly crucial for achieving food security in the country. As a major constituent of livestock and poultry feed, the productivity and development of the poultry and livestock industries depend on the maize value chain. In the medium term, the demand for maize is expected to grow at an annual rate of 2.6% [18]. Despite the enormous importance of maize in Ghana, maize farmers in the country continue to experience low yields, making Ghana self-insufficient in the production of the crop [20]. For maize farmers to be helped to increase productivity, the focus should not only be on whether or not they have adopted productivity-enhancing technologies, but it is necessary to carefully examine whether they are even making maximum use of the technologies or inputs available to them. This will convince stakeholders in the maize subsector that the improved inputs they may have planned to introduce to the farmers will be utilized efficiently to help boost maize production in the country. Therefore, it is important to determine the efficiency of resource use in maize production in Ghana so that government and individuals interested in investing in maize production in Ghana will know the levels at which production inputs should be employed in order for them to

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achieve desired yields [30]. This is because apart from studies conducted by [3, 28] on resource use efficiency in maize production in Ghana, no other economic study has considered the subject in the country even though it has been done for other crops [5, 16, 21, 30, 31], making literature on resource use efficiency in maize production in Ghana very limited. The findings of [3] showed that there was limited use of fertilizers, weedicides and improved seeds by maize farmers in the Asamankese district of Ghana. Also, the results of the work of [28] revealed that maize farmers in the Nkoranza area of Ghana overutilized labour and underutilized fertilizer and seeds.

However, resource use efficiency in maize production is common in other parts of the world, especially neighbouring Nigeria. Jirgi et al. [13] in a study on the profitability and resource use efficiency in maize production in Kontagora Local Government Area, Niger State, Nigeria, found that farm size, labour and fertilizer were overutilized, while capital inputs were underutilized. Gani and Omonona [8] studied the resource use efficiency among small-scale irrigated maize producers in Northern Taraba State of Nigeria. The empirical results showed that fertilizer, seeds, labour and land were underutilized, whereas water (the key variable) was overutilized. Taiwo et al. [29] also analysed the efficiency of resource use in hybrid and open-pollinated maize production in Giwa LGA of Kaduna State, Nigeria. The findings were that fertilizer and insecticides were underutilized, whereas seeds, labour and herbicides were overutilized. In a similar study, [15] conducted a study on the resource use efficiency in quality protein maize (QPM) production in Kaduna State, Nigeria. In this study, the results showed that whereas fertilizer, family and hired labour were overutilized, land and seeds were underutilized. The allocative efficiency analysis by [25] in a study on the resource use efficiency of maize (*Zea mays* L.) production in Sri Lanka showed that profitability can be increased by increasing land, seed and fertilizer as well as reducing use of agrochemicals and labour. The findings of the work of [2] in resource use efficiency in maize production under traditional and improved technology in Western Ethiopia revealed the mean technical, allocative and economic efficiencies under improved technology to be estimated at 74, 82 and 61%, respectively, while the corresponding results under the traditional technology were 92, 80 and 73%, respectively. Hasan [12] studied the economic efficiency and constraints of maize production in the northern region of Bangladesh and found that farmers in the study area had scope to increase maize productivity by attaining full efficiency through reallocating the resources. Zongoma et al. [32], studying resource use efficiency in maize production among small-scale farmers in Borno State in Nigeria, observed that maize production can be improved if resources like fertilizer, labour and farm size are adequately utilized. Sanusi et al. [27], in optimization of resource use efficiency in small-scale maize production in Niger State, Nigeria, reported underutilization of inputs such as land, improved seed, fertilizer and capital items.

Apart from the limited literature on the subject of resource use efficiency in maize production in Ghana, to the best of our knowledge, no study has analysed resource use efficiency in any crop at the national level for Ghana, making literature on resource use efficiency in agricultural production at the national level in Ghana limited. This article analyses the resource use efficiency of maize farmers in Ghana which is very important for policy makers in their design of policies aimed at improving resource use efficiency and consequently productivity in Ghana.

Methods

Study area

The study was conducted in the four main agro-ecological zones of Ghana, namely Northern Savannah, Transitional, Forest and Coastal Savannah zones. The Northern Savannah zone is located along the north-eastern corridor of the Northern Region with a total land area of about 125,430 km^2. The tropical continental climate and Guinea Savannah vegetation type are seen in this area. The Transitional zone, which is located around the middle portion of the Brong-Ahafo Region and the northern part of Ashanti Region, covers a total land area of about 2300 km^2. The climate of the place is the wet semi-equatorial type, while the vegetation is the Savannah woodland and a forest belt. The Forest zone, covering an area of about 135,670 km^2, is floristically divided into rain forest and semi-deciduous forest. The climate of the place is the semi-equatorial type, while the vegetation is semi-deciduous forest zone with clay, sand and gravel deposits. The Coastal Savannah occupies about 20,000 km^2 and comprises the Ho-Keta Plains, the Accra Plains and a narrow strip tapering from Winneba to Cape Coast.

Data collection

Farm-level primary data on maize production for the 2014 cropping season were collected from 576 maize farmers using structured questionnaire. The study used [4]'s sample size determination formula in the determination of the appropriate sample size. That is

$$n = \frac{t^2 (p)\,(q)}{d^2} \quad (1)$$

where $n =$ sample size, $t =$ value for selected alpha level of 0.025 in each tail $= 1.96$, $p =$ proportion of population engaged in maize production activities, $q =$ proportion of population who do not engage in maize production activities, and $d =$ acceptable margin of error for proportion being estimated $= 0.05$.

According to the Ghana Living Standard Survey Report of the Fifth Round (GLSS 5), 41.5% of households who harvested staple and/or cash crops in the last twelve months before September 2008 were maize farmers [9]. Assuming 95% confidence level and 5% margin of error, the sample size was calculated as follows:

$$n = \frac{1.96^2 \times 0.415 \times 0.585}{0.05^2} = 373$$

These procedures result in the minimum returned sample size. If a researcher has a captive audience, this sample size may be attained easily. However, since many educational and social research studies often use data collection methods such as surveys and other voluntary participation methods, the response rates are typically well below 100%. Salkind [26] recommended oversampling by 40–60% to account for low response rate and uncooperative subjects. The sample size was therefore increased by 54.5% to correct all probable anomalies that might occur, increasing the sample size to 576 maize farmers.

Multi-stage sampling technique was employed in the study. Two districts/municipalities were purposively selected in the first stage from each agro-ecological zone based on total maize production by Ghana's districts/municipalities [24]. The second stage consisted of random sampling of nine (9) villages from each of the sampled districts. Finally, the third stage comprised a random sample of eight (8) maize farmers from a list of maize farmers in each of the villages with the help of agricultural extension agents. The data collected consisted of detailed information on the socio-economic characteristics of the farmers, their inputs, outputs as well as prices of inputs and outputs.

Data analysis

Descriptive statistics were used to summarize the socio-economic characteristics as well as quantities of inputs and outputs of the respondents. Also, the stochastic frontier production function was employed to analyse the determinants of maize output. Aigner et al. [1, 17] independently proposed the stochastic frontier production function. According to them, the stochastic frontier production function is defined by;

$$y_i = f(x_i; \beta) + e_i \quad \text{where } i = 1, 2, \ldots, N \tag{2}$$

$$e_i = v_i - u_i \tag{3}$$

where y_i represents the level of output of the ith maize farmer; $f(x_i; \beta)$ is an appropriate production function of vector, x_i of inputs for the ith maize farmer and a vector, β of parameters to be estimated. e_i is an error term which comprises two components, v_i and u_i. v_i is a random error with zero mean, $N(0; \sigma^2 v)$, and is specifically associated with random factors like measurement errors in production as well as weather factors that the maize farmer cannot control and it is assumed to be symmetric and independently distributed as $N(0; \sigma^2 v)$, random variables and is independent of u_i. Conversely, u_i is a *non-negative* truncated half normal, $N(0; \sigma^2 v)$, random variable and is linked to farm-specific characteristics, which leads to the ith maize farm not achieving maximum production efficiency. u_i is therefore linked to the technical inefficiency of the maize farm and ranges from zero to one. However, u_i may have other distributions like exponential and gamma. N is the number of maize farmers that took part in the cross-sectional survey. Technical efficiency of a maize farmer is the ratio of observed output to the frontier output, given the quantity of resources employed by the farmer. Technical inefficiency therefore refers to the margin with which the level of output for the farmer falls below the frontier output.

$$\text{Technical efficiency} = \text{TE}_i = \frac{y_i}{y_i^*} \tag{4}$$

where $y_i^* = f(x_i; \beta)$, highest predicted value for the ith farm

$$\text{TE}_i = \text{Exp}\,(-u_i) \tag{5}$$

$$\text{Technical inefficiency} = 1 - \text{TE}_i \tag{6}$$

The stochastic frontier production function can be estimated by the maximum likelihood estimation (MLE) technique. The technique makes use of the specific distribution of the disturbance term and is more efficient than corrected ordinary least squares [11]. Diagnostically, the generalized likelihood ratio test was used to determine whether the Cobb–Douglas or translog functional form fits the data collected from the maize farmers in this study better. The test allows evaluation of a restricted model with respect to an adopted model. The statistic associated with this test is defined as:

$$\lambda = -2\left[\ln \frac{L(H_0)}{L(H_1)}\right] = -2[\ln L(H_0) - \ln L(H_1)] \tag{7}$$

where $L(H_0)$ and $L(H_1)$ are the log-likelihood values of the adopted and the restricted models, respectively. The test statistic λ has approximately a Chi-square distribution with a number of degrees of freedom equal to the number of parameters (restrictions), assumed to be zero in the null hypothesis. When λ is lower than the corresponding critical value (for a given significance level), the null hypothesis cannot be rejected. The main hypothesis tested here is to find out whether the Cobb–Douglas functional form is an adequate representation of the maize production data collected, given the specification of the translog functional form. The test results showed that the translog functional form was more appropriate. Therefore, the translog functional form was adopted in this study. Theoretically, the stochastic frontier translog production function is specified as:

$$\ln y_i = \beta_0 + \sum_{k=1}^{m} \beta_k \ln x_{ki} + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \beta_{kj} \ln x_{ki} \ln x_{ji} + v_i - u_i \tag{8}$$

where ln is natural logarithm, y_i is total output, x_i is vector of inputs, and ij are positive integers ($i \neq j$). β is a vector of parameters to be estimated, and v_i and u_i have been defined above. The inefficiency model is also specified as:

$$u_i = \delta_0 + \sum_{m=1}^{N} \delta_m z_i \tag{9}$$

where z_i is a vector of farmer characteristics and δ is a vector of parameters to be estimated. STATA provides a joint estimation of the parameters in the stochastic frontier production function and those of variables in the inefficiency model as well as variance parameters. Empirically, the following stochastic frontier translog production function was estimated.

$$\begin{aligned}\ln \mathrm{OUTPUT}_i = {} & \beta_0 + \beta_1 \ln \mathrm{SED}_i + \beta_2 \ln \mathrm{FET}_i + \beta_3 \ln \mathrm{PET} + \beta_4 \ln \mathrm{MAN}_i + \beta_5 \ln \mathrm{LAD}_i \\ & + \beta_6 \ln \mathrm{LAB}_i + \beta_7 \ln \mathrm{HEB}_i + \beta_8 \ln \mathrm{CAP} + \beta_9 \ln(\mathrm{SED})_i^2 + \beta_{10} \ln(\mathrm{FET})_i^2 + \beta_{11} \ln(\mathrm{PET})_i^2 \\ & + \beta_{12} \ln(\mathrm{MAN})_i^2 + \beta_{13} \ln(\mathrm{LAD})_i^2 + \beta_{14} \ln(\mathrm{LAB})_i^2 + \beta_{15} \ln(\mathrm{HEB})_i^2 + \beta_{16} \ln(\mathrm{CAP})_i^2 \\ & + \beta_{17}(\ln \mathrm{SED} \times \ln \mathrm{FET})_i + \beta_{18}(\ln \mathrm{SED} \times \ln \mathrm{PET})_i + \beta_{19}(\ln \mathrm{SED} \times \ln \mathrm{MAN})_i \\ & + \beta_{20}(\ln \mathrm{SED} \times \ln \mathrm{LAD})_i + \beta_{21}(\ln \mathrm{SED} \times \ln \mathrm{LAB})_i + \beta_{22}(\ln \mathrm{SED} \times \ln \mathrm{HEB})_i \\ & + \beta_{23}(\ln \mathrm{SED} \times \ln \mathrm{CAP})_i + \beta_{24}(\ln \mathrm{FET} \times \ln \mathrm{PET})_i + \beta_{25}(\ln \mathrm{FET} \times \ln \mathrm{MAN})_i \\ & + \beta_{26}(\ln \mathrm{FET} \times \ln \mathrm{LAD})_i + \beta_{27}(\ln \mathrm{FET} \times \ln \mathrm{LAB})_i + \beta_{28}(\ln \mathrm{FET} \times \ln \mathrm{HEB})_i \\ & + \beta_{29}(\ln \mathrm{FET} \times \ln \mathrm{CAP})_i + \beta_{30}(\ln \mathrm{PET} \times \ln \mathrm{MAN})_i + \beta_{31}(\ln \mathrm{PET} \times \ln \mathrm{LAD})_i \\ & + \beta_{32}(\ln \mathrm{PET} \times \ln \mathrm{LAB})_i + \beta_{33}(\ln \mathrm{PET} \times \ln \mathrm{HEB})_i + \beta_{34}(\ln \mathrm{PET} \times \ln \mathrm{CAP})_i \\ & + \beta_{35}(\ln \mathrm{MAN} \times \ln \mathrm{LAD})_i + \beta_{36}(\ln \mathrm{MAN} \times \ln \mathrm{LAB})_i + \beta_{37}(\ln \mathrm{MAN} \times \ln \mathrm{HEB})_i \\ & + \beta_{38}(\ln \mathrm{MAN} \times \ln \mathrm{CAP})_i + \beta_{39}(\ln \mathrm{LAD} \times \ln \mathrm{LAB})_i + \beta_{40}(\ln \mathrm{LAB} \times \ln \mathrm{HEB})_i \\ & + \beta_{41}(\ln \mathrm{LAD} \times \ln \mathrm{CAP})_i + \beta_{42}(\ln \mathrm{LAB} \times \ln \mathrm{HEB})_i + \beta_{43}(\ln \mathrm{LAB} \times \ln \mathrm{CAP})_i \\ & + \beta_{44}(\ln \mathrm{HEB} \times \ln \mathrm{CAP})_i + v_i - u_i\end{aligned} \tag{10}$$

where OUTPUT is output of maize, measured in kilogramme per hectare (kg/ha), and it is the dependent variable; SED is quantity of seed used, measured in kilogramme per hectare (kg/ha); LANDSZ is area of land cultivated with maize, measured in hectares; LAB is quantity of labour employed in maize production, measured in man-days; CAP is capital used in maize farm, measured as depreciated charges on farm tools and implements in Gh¢; FET is quantity of fertilizer used in maize production, measured in kilogrammes per hectare (kg/ha); MAN is quantity of manure used in maize production, measured in kilogrammes per hectare (kg/ha); PET is quantity of pesticides used in maize production, measured in litres per hectare (L/ha); and HEB is quantity of herbicides used in maize production, measured in litres per hectare (L/ha).

According to [14, 30], for maize farmers to be efficient in their use of production resources, their resources must be used in such a way that their marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfect competition. Therefore, the resource use efficiency parameter was calculated using the ratio of MVP of inputs to the MFC. According to [7, 10], the efficiency of resource use is given as:

$$r = \frac{\mathrm{MVP}}{\mathrm{MFC}} \tag{11}$$

where r = efficiency coefficient, MVP = marginal value product, and MFC = marginal factor cost of inputs.

$$\mathrm{MFC} = P_x \tag{12}$$

where P_{x_i} = unit price of input, say x

$$\mathrm{MVP}_x = \mathrm{MPP}_x \cdot P_y \tag{13}$$

where y = mean value of output, x = mean value of input employed in the production of a product, MPP_x = marginal physical product of input x, and P_y = unit price of maize output.

If β_x = output elasticity of input x.

From the translog production function (Eq. 6),

$$\beta_x = \frac{\partial \ln Y}{\partial \ln X} = \frac{\partial Y}{\partial x} \cdot \frac{x}{Y}$$

$$\text{MPP}_x = \frac{\partial Y}{\partial x} = \beta_x \frac{Y}{x} \tag{14}$$

$\text{MPP}_x =$ marginal physical product of input X.

Therefore

$$\text{MVP} = \frac{\partial Y}{\partial X} \cdot P_y = \beta_x \frac{Y}{X} \cdot P_y \tag{15}$$

Marginal value product (MVP) of a particular input is therefore calculated by the product of output elasticity of that input, the ratio of mean output to mean input values and the unit output price. On the other hand, marginal factor cost (MFC) of an input was obtained from the data collected on the unit price of that input. To decide whether or not an input was used efficiently, the following convention was followed in this study. If

$r = 1$, it implies the input was used efficiently.

$r > 1$, it implies the input was underutilized and therefore both output and profit would be increased if more of that input is employed.

$r < 1$, it implies the input is overutilized and therefore both output and profit would be maximized if less of that input is employed [22].

Returns to scale were calculated by the sum of the output elasticities of the various inputs.

$$\text{Returns to scale} = \sum_i \frac{\partial \ln Y}{\partial \ln X_i} = \sum_i \beta_i \tag{16}$$

where Y is output, X_i are inputs and β_i are output elasticities.

Results

Descriptive analysis

Table 1 presents the socio-economic characteristics of maize farmers interviewed in the study. Table 2 also presents the descriptive statistics of farmers' characteristics and quantities of inputs used and outputs obtained. The results showed that 77.4% of maize farmers in the sample are males, while 22.6% are females. The ages of the respondents ranged from 18 to 78 years with a mean age of 45.2 years (Table 2). Also, Table 1 shows that majority of the respondents (56.9%) are within the age bracket of 18–45 years. The results of educational level of the farmers presented in Table 1 show that 35.9% of maize farmers interviewed received no formal education and 34.7% got to middle school, junior secondary school (JSS) or junior high school (JHS). Table 2 also shows that, on average, maize farmers in Ghana have 6 years of schooling.

For the sampled maize farmers who had access to extension service, the average number of times extension agents visited them was calculated to be 3 times (Table 2). Also 75.7% of maize farmers in the sample did not belong to any farmer association as against 24.3% that were members of farmer associations (Table 1). In fact, most of the respondents considered in this study had no maize production credit from any financial source, be it formal or informal. For example, 82.5% of the farmers never received credit from any financial source. With a mean of 7.61, the household size ranged from 2 to 34 (Table 2). Also, Table 2 shows that on average, the respondent farmers had 14.07 number of years of experience in maize farming. The mean maize output recorded in the study was 1.8 Mt/ha, and the mean quantity of labour used was 69.07 man-days. Finally, the mean farm size cultivated was estimated to be 2.862 ha.

Table 1 Socio-economic characteristics of maize farmers

Variable	Frequency	%
Sex		
Male	446	77.4
Female	130	22.6
Total	576	100
Age group (years)		
18–45	328	56.9
46–60	180	31.2
Greater than 60	68	11.8
Total	576	100
Educational level		
No formal education	207	35.9
Primary school	84	14.6
Middle school/JSS/JHS	200	34.7
SSS/SHS	69	12
Training college/tertiary	16	2.8
Total	576	100
Association membership		
No	436	75.7
Yes	140	24.3
Total	576	100
Access to credit		
No	475	82.5
Yes	101	17.5
Total	576	100

Source: Survey, 2015

Appropriateness of stochastic frontier translog production function

The results of the generalized likelihood ratio test for data collected from the study area showed that at least one of the interaction terms is statistically different from zero (Table 3). Table 4 also presents the variance parameters for the stochastic frontier production function for

Table 2 Descriptive statistics of farmers' characteristics and quantities of inputs and outputs

Variable	Minimum	Maximum	Mean	Standard deviation
Age (years)	18	78	45.15	11.61
Education (years)	0	18	5.96	4.976
Experience (years)	1	50	14.07	10.83
Farm size (ha)	0.2	70	2.862	12.71
Number of plots	0.4	50	1.579	2.164
Extension visits	0	26	2.727	4.833
Fertilizer (kg/ha)	0	225	125	190
Herbicide (L/ha)	0	12.5	5.164	7.445
Pesticide (L/ha)	0	11	0.111	0.889
Seed (kg/ha)	15	24	18	17
Labour (man-days/ha)	9	1096	69.07	97.16
Manure (kg/ha)	0	625	29.25	272.7
Capital (Gh¢)	40	2500	558	766
Size of household	2	34	7.611	4.719
Output (Mt/ha)	0.01	2.03	1.8	1.2

Source: Survey, 2015

Table 3 Results of hypotheses test for the model used

Restriction	$L(H_0)$	λ	χ^2	Decision
$H_0 : \beta_{ij} = 0$	−98.2	38.2	23.3	Rejected
$\delta_m = 0$	−148.7	28.4	10.1	Rejected

Critical values are at 5% significance level and are obtained from χ^2 distribution table. $L(H_0)$ = log-likelihood function, λ = test statistic, β_{ij} = parameters in the square and cross terms and δ_m = parameters in the inefficiency term

Table 4 Variance parameters for the stochastic frontier production function

Variable	Parameter	Standard error
Sigma squared $\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.72206*	0.006
Gamma $\gamma = \sigma_u^2/\sigma^2$	0.999999***	0.046
Lambda $\lambda = \sigma_u/\sigma_v$	3,764,018***	0.009
Log-likelihood	−246.316	
Number of farmers	548	
Wald	3.1×10^{10}***	
Mean VIF	1.2519	
Breusch–Pagan stat	0.5664	

Source: Survey, 2015

The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5%, and * is significant at 10%

maize farmers in the sample. The values of γ (0.999999), λ (3,764,018) and σ^2 (0.72206) for the study are quite high and significant at 1, 1 and 10%, respectively (Table 4). The Wald Chi-square statistic (3.1×10^{10}) for the study is significant at the 1% level. Also, the mean variance inflation factor (VIF) calculated was small and the Breusch–Pagan (BP) test was not significant.

Determinants of output and resource use efficiency by maize farmers in Ghana

The results of the stochastic frontier translog production function analysis for maize farmers revealed that whereas fertilizer, herbicides, pesticides and land inputs had significant positive effects on the output of maize, labour input had a significant negative sign (Table 5). Table 6 also presents the production elasticities of these inputs. The elasticities are 0.485, 0.177, 0.003, 1.145 and 0.245 for fertilizer, herbicide, pesticide, land and labour inputs, respectively. Also, the return to scale calculated for the respondents was 3.327 (Table 6). Considering the technologies available to farmers as well as inputs and output prices, resource use efficiency was determined at the level where marginal value product (MVP) was equal to marginal factor cost (MFC). That is, a resource is efficiently utilized if its marginal value product and marginal factor cost are the same. Table 6 presents the ratios of the MVP to MFC for the maize farmers interviewed. The results revealed that the ratios were greater than unity (1) for fertilizer, herbicide, pesticide, seed, manure and farm size. The ratios for labour and capital were, however, found to be less than unity. The adjustments in marginal value products (MVPs) for optimal resource use (% divergence) by the maize farmers presented in Table 7 show that, for resources to be efficiently utilized, more than 70.3% increase in fertilizer, 89.6% rise in herbicide, 86% increase in pesticide, 94.7% increase in seed, 99.9% increase in manure and 97.2% increase in farm size would be required. On the other hand, quantities of labour and capital would be expected to decline by 20.8 and 81.7%, respectively.

Discussion

It could be inferred from the results on gender distribution of the respondents that maize production in Ghana is dominated by males. This could be attributed to the crucial roles women performed in the domestic and economic life of society which reduced the time available for maize production. This comprises the unmeasured non-economic activities, such as child care, cooking and cleaning, performed by females in the household. This finding corroborates those of earlier studies [3, 32] and implies that, generally, maize production is dominated by males. The age distribution and the mean age also show that the sampled maize farmers are relatively young. This condition may have a positive influence on the efficiency of input utilization in maize production.

Table 5 Maximum likelihood estimates of stochastic frontier production function

Variable	Coefficient	Standard error	Variable	Coefficient	Standard error
Constant	6.141105		ln PET × ln CAP	0.0054***	0.00166
ln FET	0.035808*	0.019983	ln PET × ln HEB	−0.032***	0.00901
ln HEB	0.28478***	0.083703	ln SED × ln LAB	−0.0435**	0.020435
ln PET	0.009152**	0.00412	ln SED × ln MAN	−0.011104	0.019845
ln SED	0.025144	0.016284	ln SED × ln LAD	−0.164***	0.034314
ln LAB	−0.2874***	0.076363	ln SED × ln CAP	−0.005622	0.007020
ln MAN	−0.0047556	0.004164	ln SED × ln HEB	0.0464***	0.01499
ln LAD	0.72564***	0.14299	ln LAB × ln MAN	0.0258***	0.008313
ln CAP	−0.04421	0.030529	ln LAB × ln LAD	0.0408982	0.015034
ln FET × ln FET	−0.0075***	0.001945	ln LAB × ln CAP	−0.009154	0.009142
ln PET × ln PET	0.008695	0.017164	ln LAB × ln HEB	−0.104***	0.010646
ln HEB × ln HEB	−0.0376***	0.011096	ln MAN × ln LAD	0.0119***	0.022958
ln SED × ln SED	−0.0975***	0.00871	ln MAN × ln CAP	0.0020805	0.002654
ln LAB × ln LAB	−0.01556**	0.00757	ln MAN × ln HEB	0.01491**	0.005952
ln MAN × ln MAN	−0.00523**	0.002116	ln LAD × ln CAP	0.0130063	0.008294
ln LAD × ln LAD	0.017689	0.02085	ln LAD × ln HEB	−0.006***	0.001830
ln CAP × ln CAP	−0.0099***	0.00264	ln CAP × ln HEB	−0.004569	0.001371
ln FET × ln PET	0.03589***	0.010018	ln FET × ln CAP	−0.002860	0.002089
ln FET × ln HEB	−0.002079	0.00348	ln PET × ln SED	−0.0037**	0.001425
ln FET × ln SED	0.006614	0.005298	ln PET × ln LAB	0.0005474	0.000422
ln FET × ln LAB	−0.003543	0.002891	ln PET × ln MAN	0.0056727	0.006087
ln FET × ln MAN	−0.00449**	0.002187	ln PET × ln LAD	0.0008757	0.003021
ln FET × ln LAN	0.002772**	0.002519			

Source: Survey, 2015

The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5%, and * is significant at 10%

Table 6 Input elasticities and ratio of marginal value product to marginal factor cost

Variable	Elasticity	MPP	MVP	MFC	*r*
Fertilizer	0.485	3.8	3.7	1.1	3.4
Herbicide	0.177	94.4	91.6	9.5	9.6
Pesticide	0.003	74.4	72.2	10.1	7.1
Seed	0.734	54.1	52.5	2.8	18.7
Labour	0.245	9.8	9.5	12	0.79
Manure	0.045	193	187	0.01	15,558
Land	1.145	1101	1068	30.4	35.2
Capital	0.493	2.43	2.36	12.9	0.18

Source: Survey, 2015

MPP = marginal physical product, MVP = marginal value product, MFC = marginal factor cost, *r* = efficiency coefficient, scale elasticity = 3.327

Table 7 Adjustments in MVPs for optimal resource use (% divergence)

Variable	Efficiency gap	% divergence from optimal levels
Fertilizer	2.6	70.3
Herbicide	82.1	89.6
Pesticide	62.1	86
Seed	49.7	94.7
Labour	2.5	20.8
Manure	186.69	99.9
Land	1037.6	97.2
Capital	10.54	81.7

Source: Survey, 2015

This could be the result of the believe that young farmers easily accept new agricultural technologies and innovations thereby making them use appropriate input mix in their production. This is similar to the finding on age distribution by [3] that reported that majority of maize farming population are below 40 years. According to the study, the young farming population may have positive implications on productivity because it is believed that the younger the farming population, the more productive the labour is and consequently higher outputs are obtained. The results on education compare well with the findings of [32] that also reported a 37.4% lack of formal education among small-scale maize farmers in Nigeria.

The implication is that some level of inefficiency in input utilization is possible among maize farmers since education is expected to have a positive effect on efficiency [28]. With high levels of farming experience, the productivities and efficiencies of maize farmers in Ghana are expected to be on the higher side since experienced farmers could predict appropriate husbandry practices for efficient maize production. The high level of farming experience is expected as it is in line with the findings of [32] that also reported that 80.9% of the sampled maize farmers have at least 11 years of experience. The finding on access to agricultural extension service by the farmers is an indication of poor provision of extension service to the farmers. This may prevent farmers from using their resources efficiently. The few number of farmers that joined farmer-based organizations could have an adverse effect on the resource use efficiency of maize production in the study area since extension agents normally disseminate information on good agricultural practices through farmer-based organizations. Poor access to credit by the respondent farmers is a potential source of resource use inefficiency in maize production since credit allows farmers to acquire efficiency-enhancing inputs such as fertilizer, labour, pesticides and herbicides. With maize production being a labour-intensive activity, the results on household size show that the respondents have some source of labour which could enhance their resource use efficiencies. The results on maize yield imply that average maize yield for the farmers is relatively lower than the estimated potential yield of 6.0 Mt/ha for Ghana [19]. The relatively small farm sizes recorded in the study imply that most maize production activities in Ghana are on a small scale.

The significance of the likelihood ratio test makes the translog production function an appropriate fit for the data, and therefore, the rather popular but inflexible Cobb–Douglas functional form should be rejected. The high γ value for maize farmers in the study area indicates the presence of technical inefficiencies among the sampled farmers, making the stochastic frontier production function an appropriate model for the study. The value of λ shows that the one-sided error term U dominates the symmetric error term V, so variation in actual maize output comes from differences in farmers' specific factors rather than random variability, hence the need for the inclusion of an inefficiency term in the production function and hence once again the appropriateness of the stochastic frontier production function for this study. Also, the significance of the values of λ and σ^2 implies good fit and the correctness of the specified distributional assumption. The Wald Chi-square results also show that the model was jointly significant and that the inputs jointly explain the variations in maize output. The small mean VIF indicates the absence of multicollinearity in the model [6], and also, the insignificance of the Breusch–Pagan (BP) test reveals safety of heteroskedasticity.

For maize farmers in the study area, the elasticity values show that a 1% rise in the levels of fertilizer, herbicide, pesticide and land has the effect of increasing output levels by 0.485, 0.177, 0.003 and 1.145%, respectively. This finding corroborates the results of [10, 22]. However, the significant negative effect of labour could be the result of excess labour supply by the farm household.

The returns to scale calculated for maize farmers in the study area reveal increasing returns to scale for the farmers which imply that maize production in Ghana during the 2014 rainy season was in stage one of the production function. The results suggest that maize farmers in Ghana could enlarge their production scale by about 3.3% on average, in order to adequately expand productivity, given their disposable resources. That is, Ghanaian maize farmers can increase their maize output by employing more of the resources (fertilizer, herbicide, pesticide, seed, labour, land, manure and capital) employed in maize production. This finding is in agreement with the results of some studies on resource use efficiency in maize production in Ghana and other parts of the world [3, 27–29], even though it disagrees with the findings of [23].

The marginal productivities revealed that maize farmers in the study area utilized land more efficiently vis-à-vis the other resources. This suggests that if more lands were cultivated, it would have led to an increase in maize output by 1101 kg among the farmers in the study area. This result is in line with the findings of similar studies conducted by [3, 25, 27–29, 32].

The results on resource use efficiency for maize farmers in the study area suggest that the farmers were not efficient in the allocation of any of the resources available to them. That is, fertilizer, herbicide, pesticide, seed, manure and land were underutilized, while labour and capital (farm tools) were overutilized. Maize output in Ghana could therefore increase if more of such inputs like fertilizer, herbicide, pesticide, seed, manure and land were employed, while quantities of labour and capital were reduced. The aforementioned results are also in consonance with the results obtained by similar studies on resource use efficiency in maize production conducted in Ghana and other countries [3, 25, 27–29, 32]. The results on divergence from optimal levels of resource use show great divergence from optimal levels of use of manure (underutilized) than any other input. This is followed closely by divergence from optimal levels of use of land. Sienso et al. [25, 27, 28, 32] obtained similar results in their resource use efficiency studies in maize production.

Conclusion

Generally, for optimal use of resources in maize production in Ghana, quantities of fertilizer, herbicide, pesticide, seed, manure and land should be increased while labour as well as capital (farm tools and equipments) should be reduced. Incentives and strategies aimed at encouraging farmers to use more fertilizer, herbicide, pesticide, labour, manure and land are recommended for resource use efficiency to be achieved by the farmers. Currently, incentives and strategies could take the form of better management by government of the current fertilizer subsidy programme and efficient input distribution through farmer-based organizations to ensure easy access by farmers. Also, extension officers should encourage maize farmers to join farmer-based organizations (FBOs) in places where there are established ones by presenting to the farmers the benefits of joining such organizations. In places where there are no established ones, extension officers should assist maize farmers to team up and form such organizations. This is because information on agricultural technologies and the right input mix is normally disseminated through farmer associations, and therefore, farmers who belong to such associations will more likely have knowledge of suggested technologies and appropriate input mix than those who are not members of such associations. The Agricultural Development Bank (ADB) should also live up to its mandate to ensure easy acquisition of loans by farmers. Acquired loans will be used to purchase required production inputs. Farmers, especially those in farmer-based organizations, are also encouraged to form their own informal credit schemes with which they can help one another.

Abbreviations

BP: Breusch–Pagan; FBO: farmer-based organizations; GLSS: Ghana Living Standards Survey; GSS: Ghana Statistical Service; JHS: junior high school; JSS: junior secondary school; MFC: marginal factor cost; MPP: marginal physical product; MVP: marginal value product; MLE: maximum likelihood estimation; MiDA: Millennium Development Authority; MOFA: Ministry of Food and Agriculture; SRID: Statistics, Research and Information Directorate; VIF: variance inflation factor.

Authors' contributions

DAV was responsible for designing the study and data collection. CAW conceived the idea and was responsible for analysis of the data as well as preparation of the manuscript. RA provided technical advice in formulation of the research objectives and the review of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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