Resource-use efficiency in maize production: the case of smallholder farmers in Ghana

Eficiencia en el uso de recursos en la producción de maíz: el caso de pequeños agricultores en Ghana

Frank Osei Danquah[1], He Ge[1]*, Lady Nadia Frempong[1], and Bright Asiamah Korankye[1]

ABSTRACT

This study aimed to evaluate the efficiency with which smallholder maize farmers use their input resources such as land, labor, capital, fertilizers, herbicides, pesticides, and improved seed in maize production. The study used the multi-stage sampling technique to collect cross-sectional data from 600 smallholder maize producers from the northern, Brong-Ahafo, eastern, and central regions of Ghana. This study employed the marginal value product (MVP) to marginal factor cost (MFC) ratio (MVP/MFC) of the input resources. The results revealed an increased return to scale, meaning smallholder maize farmers in the pooled sample and the studied regions should enlarge their production scale by about 3.2%, 2.2%, 7.6%, 6.8%, and 2.8%, respectively, to maximize productivity. The results also revealed that resource inputs like fertilizer, herbicides, pesticides, improved seed, and land were underutilized. Therefore, these resources need to be increased if smallholder maize farmers in the pooled sample want to be efficient in their production. Labor and capital were over-utilized and needed to be reduced to increase efficiency in the farmers' maize production.

Key words: pesticides, fertilizers, herbicides, improved seeds.

RESUMEN

El objetivo de este estudio consistió en evaluar la eficiencia con la que los pequeños agricultores de maíz utilizan sus insumos tales como la tierra, mano de obra, capital, fertilizantes, herbicidas, plaguicidas y semilla mejorada en la producción del maíz. Para ello se empleó una técnica de muestreo de multietapas con el fin de recolectar datos seccionales cruzados de 600 productores de maíz de las regiones del norte, Brong-Ahafo, oriente y centro de Ghana. Se empleó también el cociente entre el producto de valor marginal (PVM) y el factor de costo marginal (FCM) (PVM/FCM) de los recursos de ingreso. Los resultados obtenidos revelaron un aumento en el ingreso de retorno, lo que significa que los pequeños agricultores de maíz de la muestra y en las regiones mencionadas deberían aumentar su escala de producción en cerca de 3.2%, 2.2%, 7.6%, 6.8% y 2.8%, respectivamente, con el fin de maximizar la productividad. Los resultados mostraron también que los insumos tales como los fertilizantes, herbicidas, pesticidas, semillas mejoradas y la tierra fueron subutilizados. Por lo tanto, estos insumos deben incrementarse si los pequeños agricultores de maíz en la muestra quieren ser eficientes en su producción. El trabajo y el capital resultaron sobreutilizados y por lo tanto hay una necesidad de reducirlos con el fin de hacer más eficiente la producción de maíz por parte de los agricultores.

Palabras clave: pesticidas, fertilizantes, herbicidas, semillas mejoradas.

Introduction

Agricultural development is one of the most powerful tools for ending extreme poverty, boosting shared prosperity, and feeding a projected 9.7 billion people by 2050. Growth in the agricultural sector is two to four times more effective for raising incomes among the poorest compared to other sectors (World Bank, 2019). In Africa, agriculture remains the most feasible option for promoting economic growth, overcoming poverty, and improving food security. As a result, a very significant factor is needed to help sustain and increase agricultural productivity with improved agricultural production technologies and ensure good soil management. Agriculture is an important element in Ghana's economy; in the third quarter of 2019 agriculture contributed 7638.80 million Ghana cedis to the gross domestic product, an increase from the previous quarter (second quarter) that recorded 6464.36 million Ghana cedis (Ghana Statistical Service, 2018).

Maize is considered a vital food for about 1.2 billion people worldwide and is the most-produced cereal in the world. In

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[1] College of Management, Sichuan Agricultural University, Chengdu (China).
* Corresponding author: hege@sicau.edu.cn

2014, over 1,022 million t of maize were produced in more than 170 countries on about 181 million ha of land (Food and Agriculture Organization of the United Nations, 2016). The top producers were the United States of America with 361 million t, China with 216 million t, Brazil with 80 million t, and Argentina and Ukraine with 33 and 28 million t, respectively (Food and Agriculture Organization of the United Nations, 2016). In Africa, maize is graded as the cereal grain of greatest economic importance with wheat and rice ranking second and third, respectively (Thobatsi, 2009). In Ghana, maize accounts for over 50% of the total cereal (that includes maize, rice, sorghum, and millet) production, making it the most important staple crop (Ministry of Food and Agriculture, 2012). It is widely cultivated and serves as a major source of food and cash income for many people in Ghana (Tachie-Obeng, *et al*., 2010). Maize is the number one crop in terms of planted area (Ministry of Food and Agriculture, 2014). Total maize production in Ghana is carried out by about 70% of smallholder farmers (Ministry of Food and Agriculture, 2014). It is assumed that almost every household in Ghana's farming communities is directly or indirectly involved in maize or rice cultivation. Maize is used to prepare different kinds of food in Ghana; for example, porridge, *kenkey*, *banku*, and *tuo zaafi*. *Kenkey* is a traditional food mostly consumed by all the tribes and regions in Ghana. It is predominantly consumed by the Gas who live in the capital city of Accra. *Banku* is mostly eaten by the Fantes and the Ashantis, and *tuo zaafi* is the main food for the people in the northern region of Ghana.

Maize production in Ghana has increased since the introduction of the fertilizer subsidy program (FSP) in 2008 as an intervention policy to counter the high fertilizer costs in 2007. Maize production in Ghana increased from 442 thousand t in 1969 to 2,760 thousand t in 2019, growing at an average annual rate of 8.33% (World Data Atlas, 2019). Despite the comprehensive cultivation and the importance of maize in the country, production is still low due to inefficient and inappropriate use of improved agricultural technologies. Due to the significance of this crop in Ghana, through the Ministry of Food and Agriculture (MOFA), the government has promoted modern technologies in agriculture in several ways (Nyamadzawo *et al*., 2013).

This study analyzed smallholder maize farmers' input resource-use efficiency in the study areas (i.e. northern, Brong-Ahafo, eastern, and central regions). Unlike the study by Abatania *et al*. (2012) that examined the resource and technical efficiency of one agro-ecological zone, this research covered all the agro-ecological areas of Ghana (Northern, Brong-Ahafo, Eastern and Central regions) in order to analyze the efficient use of input resources.

Materials and methods

Primary study area

The study was carried out in Ghana. Researchers collected primary data for this study from household surveys conducted in villages/communities selected from four regions (northern, Brong-Ahafo, eastern, and central regions) in Ghana from July to September 2019. These regions were purposively selected to cover all the agro-ecological zones and their maize production performance for the 2017-2018 farming seasons in Ghana.

The capital of the northern region is Tamale. In 2018, it had a population of about 3.576 million people and was ranked the fourth highest populous region in Ghana (EUROSTAT, 2018). More than 75% of the economically active population work in agricultural and agricultural-related jobs in this region. Maize, rice, sorghum, and millet, are mostly grown in the northern region.

The Brong-Ahafo region is located in the southern part of Ghana. The capital of the Brong-Ahafo region in Sunyani. The Brong-Ahafo region has a total population of 2,310,983, with an average growth rate of 2.2% compared to the national average of 2.4%. The area is ranked sixth in terms of population with 9.33% (EUROSTAT, 2018). Agriculture is the predominant activity, and many of the region's population are engaged in this sector. The main food crops are corn, yams, cassava, and some other root crops.

Koforidua is the capital of the eastern region. The eastern region has a population of about 2,633,154, and is ranked as the third most populous area of Ghana with 10.68% of the country's total population (EUROSTAT, 2018). The eastern part covers 19,323 km^2, about 8.1% of Ghana's total land area. Crops produced in this region include grains, such as wheat, corn, and barley. Additionally, field crops, such as cotton and tobacco, vegetables, fruits and nuts, and horticultural specialties, such as flowers and ornamental plants, are grown in this region.

Cape Coast is the capital of the central region. The central area has a population of about 2,201,863, and it is ranked the eighth most populous region in Ghana, recording a 8.93% of the country's total population (EUROSTAT, 2018). The main economic activity of the region is fishing and farming, and maize is the primary cereal grown here.

The central region contains many tourist attractions such as castles, forts, and beaches stretched along the region's coastline.

Sample size determination

This study used both primary and secondary data. The primary data was obtained through a cross-sectional survey conducted in Ghana's four regions (northern, Brong-Ahafo, eastern, and central regions) (Supplementary material 1). The study used the sample size formula (below) (Hashim, 2010) to determine the appropriate sample size (Eq. 1).

$$n = \frac{t^2 \times p \times q}{d^2} \tag{1}$$

where n is the sample size, t is the value for the selected alpha level of 0.025 in each tail, which is = 1.96, p is the proportion of the population engaged in maize production, q is the ratio of the people not involved in maize production, and d is the acceptable margin of error for the proportion being estimated = 0.05 (error researchers are willing to accept).

The Ghana Living Standard Survey reported that 49.1% of farmer households that cultivated staple and or cash crops were maize farmers (Ghana Statistical Service, 2018). Assuming a 95% confidence level and 5% margin of error, the sample size was calculated as follows:

$$n = \frac{1.96^2 \times 0.491 \times 0.509}{0.05^2} \tag{2}$$

The study followed Salkind and Rainwater (2003) recommendation of oversampling by 40%-60% to account for a low response rate. Therefore, this study's sample was increased by 56.2%, resulting in a sample size of 600 (Salkind & Rainwater, 2003).

Sampling technique and size

A multi-stage sampling technique was used in this study. The first was to select four regions (northern, Brong-Ahafo, eastern and central regions) in Ghana to cover all the agro-ecological zones. After that, four districts/municipalities were randomly selected from each of the four selected regions. In the next stage, three villages or communities were randomly selected from each of the four districts/municipalities. For the last step, a random selection was performed by picking every K^{th} (sampling interval) farmer in a list, where k was obtained by dividing the population of smallholder maize farmers in the village by the sample size.

Method for estimating the efficiency of resource use in maize production

For maize farmers to be efficient in their use of production resources, these resources should be used in a manner such that their marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfect competition, according to Tambo and Gbemu (2010). Consequently, the resource use efficiency parameter was calculated using the ratio between the MVP of inputs and the MFC. According to Fasasi (2006) and Goni *et al.* (2007), the efficiency of resource use can be calculated as follows:

$$RE = \frac{MVP}{MFC} \tag{3}$$

where RE is the resource efficiency coefficient, MVP is the marginal value product, and MFC is the marginal factor cost of inputs.

$$MFC = P_x \tag{4}$$

where P_x is the unit price of the input, say X.

$$MVP_x = MPP_x \times P_y \tag{5}$$

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

Taking into consideration the translog production function (Eq. 5)

$$\beta_x = \frac{\delta 1nY}{\delta 1nX} = \frac{\delta Y}{\delta X} \times \frac{X}{Y} \tag{6}$$

$$MPP_x = \frac{\delta Y}{\delta X} = \beta_x \frac{Y}{X} \tag{7}$$

where MPP_x is the marginal physical product of input X and is a measure of input X's technical efficiency, and β_x is the output elasticity of input X.

Hence,

$$MVP = \frac{\delta Y}{\delta X} \times P_y = \beta_x \frac{Y}{X} \times P_y \tag{8}$$

where Y represents the value of the output, X represents the value of the input and P_y represents the unit price of the output.

The MVP of a particular input resource is consequently computed by the product of output elasticity of that input, the ratio of mean output to mean input values, and the unit output price. The MFC of input was attained from the data composed on that input's unit price.

To decide whether or not an input is used efficiently, we used the following convention. If r=1, it implied the input was used efficiently, r>1 meant the input was underutilized, so the output would be increased if more of that input were employed. Finally, r<1 means that the input is over-utilized, so both the production and profit would be maximized if less input were utilized (Eze & Okorji, 2003).

Results and discussion

Socio-economic characteristics of farmers

Table 1 below shows that the pooled sample revealed that most maize farmers in the study area are males (449) representing 74.8%, compared to 151 females representing 25.2%. Male dominance in maize farming runs through all the four regions of the study. These results can be attributed to the fact that most Ghana people perceive farming to be an occupation for men and not women. This result was in agreement with the work of Sadiq *et al.* (2013), who found a dominance of male maize farmers of 67% compared to 33% of female maize farmers in the studies of profitability and production efficiency of small-scale maize production in the Niger State of Nigeria. The result also showed the average age of 46 years with a minimum age of 18 and a maximum of 79 years (Tab. 1). The majority of the farmers were between 18 and 40 years, while very few farmers were above 60. This result means most maize farmers in Ghana are young, a fact that may affect productivity. This result was consistent with the studies by Ojiako and Ogbukwa (2012) who found a mean age of 44.8 years for farmers (Tab. 1).

Most of the maize farmers had a junior high school and senior high school education. The average number of schooling for maize farmers was five years. This result can be attributed to the fact that most educated youths wish to work in offices and see farming as a job for school dropouts in Ghana. This result agrees with the studies by Oladejo and Adetunji (2012) who also found that most maize farmers in the Oyo State of Nigeria (82.3%) had received formal education. The studies revealed that many maize farmers (56.9%) did not belong to farmer associations. This result was probably obtained because maize farmers in Ghana do not see the benefits of such farmer associations or because there are no farmer groups in the study areas.

The average household size of maize farmers in Ghana was seven people (Tab.1) with a range of 1 to 37 people. These results were consistent with the study of Oladejo and Adetunji (2012), who found an average household size of 8 among maize farmers in the Oyo state of Nigeria. The average years of experience for maize farmers in the pooled sample was 14 years, meaning farmers interviewed in the study areas have spent much time in maize cultivation. The studies show that a slight majority of farmers had no access to extension with a percentage of 54.5% compared to 45.5% of farmers who had access to extension services, and an average number of visits of 3 (Tab. 1). Generally, there was poor extension contact with maize farmers, and this could affect their adoption of improved farming practices.

Our results revealed that smallholder maize farmers who were not beneficiaries of non-governmental organizations (NGOs) were slightly fewer compared to those who enjoyed some benefits: 48.2% for non-beneficiaries against 51.8% beneficiaries in Ghana. Also, our results revealed that very few maize farmers benefited from government subsidies with a percentage of 28.3% compared to 71.7% non-beneficiaries. For instance, the northern region recorded 63.9% of smallholder maize farmers enjoying government subsidies against 36.1% of the smallholder maize farmers who do not enjoy government subsidies. This result could be traced to the fact that the standard of living in the northern region of the country is low compared to other areas. For that matter, most smallholder maize farmers in this region are less able to afford to purchase improved production technologies to boost their productivity. Therefore, the government helps smallholder maize farmers in this region by subsiding enhanced production technologies. A meagre percentage recorded for maize farmers who had access (26.3%) as compared to 73.7% with no access to credit for the pooled sample. This trend runs through all the study regions. Low percentages of farmers have access to credit recording, 22.2%, 30.6%, 15.4%, and 37.2% for the northern region, Brong-Ahafo region, eastern region, and central region, respectively.

Resource use efficiency by maize farmers in Ghana

The return to scale parameters in Table 2, calculated as the sum of individual production input elasticity, showed an increase. This means that maize production in Ghana (northern, Brong-Ahafo, eastern and central regions) was a production function. The return to scale values for the pooled sample and the northern, Brong-Ahafo, eastern, and central regions were recorded as 3.268, 2.229, 7.594, 6.804, and 2.841, respectively (Tab. 2). These results suggest that smallholder maize farmers in the pooled sample (northern,

TABLE 1. Descriptive statistics of the characteristics of the interviewed maize farmers.

Variables	Pooled sample				Northern region				Brong-Ahafo region				Eastern region				Central region			
	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD
Age (years)	18	79	45.84	11.24	18	79	47.13	10.62	22	73	44.70	12.16	19	78	46.1	11.07	25	70	45.41	17.67
Education (years)	0	18	6.20	4.76	0	16	4.10	6.03	0	18	7.21	3.76	0	17	9.08	4.01	0	16	4.426	1
Experience (years)	1	54	13.68	11.81	1	54	19.41	12.34	1	48	11.8	11.27	1	45	8.81	7.45	1	50	14.73	2.01
Household size	1	37	7.14	5.32	1	37	8.92	5.76	1	29	6.67	5.18	1	22	6.90	3.81	1	18	6.08	2.01
Extension visit	0	17	2.84	4.56	0	6	1.31	1.61	0	11	2.83	2.12	0	10	1.01	2.41	0	17	6.24	0
	Freq.		**%**		**Freq.**		**%**		**Freq.**		**%**		**Freq.**		**%**		**Freq.**		**%**	
Gender																				
Male	449		74.8		109		75.7		101		70.1		131		84.0		108		69.2	
Female	151		25.2		335		24.3		43		29.9		25		16.0		48		30.8	
Total	600		100		144		100		144		100		156		100		156		100	
Member of farmer's group																				
Yes	180		30.0		62		43.1		46		31.9		25		16.0		47		30.1	
No	420		70.0		82		56.9		98		68.1		131		84.0		109		69.9	
Total	600		100		144		100		144		100		156		100		156		100	
Government subsidy																				
Yes	170		28.3		92		63.9		30		20.8		27		17.3		21		13.5	
No	430		71.7		52		36.1		114		79.2		129		82.6		135		86.5	
Total	600		100		144		100		144		100		156		100		156		100	
Beneficiary of NGOs																				
Yes	289		48.2		98		68.1		74		51.4		48		30.8		69		44.2	
No	311		51.8		46		31.9		70		48.6		108		69.2		87		55.8	
Total	600		100		144		100		144		100		156		100		156		100	
Access to credit																				
Yes	158		26.3		32		22.2		44		30.6		24		15.4		58		37.2	
No	442		73.7		112		77.8		100		69.4		132		84.6		98		62.8	
Total	600		100		144		100		144		100		156		100		156		100	

NGO_s - non-governmental organizations, Min - minimum, Max - maximum, M - mean, SD - standard deviation, Freq. - frequency.

Brong-Ahafo, eastern, and central regions) should enlarge their production scale by about 3.2%, 2.2%, 7.6%, 6.8%, and 2.8%, respectively, because of the scale elasticity recorded by them for maximizing productivity given their disposable resources (Tab. 2). The results revealed that smallholder maize farmers in Ghana could increase their maize output using more of the mentioned resources (fertilizer, pesticides, herbicides, improved seed, land, labor, and capital). This result agrees with Saura-Calixto *et al.* (2007), who report that farmers could increase their output by increasing the quantity of fertilizer, seed, labor, and cultivated land size. The increasing returns to scale finding agree with those of Uchegbu (2001) and Ajibefun (2002), even though they contradict the conclusions of Obasi (2007).

TABLE 2. Input elasticity.

Variables	Elasticity				
	Pooled sample	Northern region	Brong-Ahafo region	Eastern region	Central region
Fertilizer	0.476	0.529	0.587	0.669	0.933
Herbicides	0.178	0.436	0.745	0.660	0.019
Pesticides	0.004	0.003	0.007	0.002	0.012
Improved seed	0.724	0.019	1.251	0.162	0.921
Land	1.146	0.134	3.554	4.245	0.122
Labor	0.246	0.894	0.587	0.765	0.743
Capital	0.494	0.214	0.424	0.301	0.031
Scale of elasticity	3.268	2.229	7.594	6.804	2.841

Table 3 presents the marginal productivities that revealed that maize farmers in the pooled sample and all the regions (northern, Brong-Ahafo, eastern and central regions) used land more efficiently than other resources (fertilizer, herbicides, pesticides, improved seed, labor, capital). This result implied that if maize farmers had cultivated more land, it would have likely led to a rise in maize output by 1103 kg, 4369 kg, and 1408 kg among maize farmers in the pooled sample and the Brong-Ahafo and eastern regions, respectively (Tab. 3). Similarly, maize farmers in the northern region were more efficient in using herbicides to control weeds in their maize crops compared to the other regions. The results also revealed that maize farmers in the central region were more efficient in using labor in their maize production than the other regions. The results of the northern region suggest that if maize farmers had used more herbicides, the maize output would have increased by 157 kg (Tab. 3). The output of maize in the central region would have also increased by 40.3 kg if maize farmers had increased their use of labor in maize production (Tab. 3). The results revealed an inefficient use of capital in the pooled sample and all the four regions (northern, Brong-Ahafo, eastern, and central regions). It recorded the lowest MPP of 2.53, 0.69,1.99,1.04, and 0.34, respectively (Tab. 3). These results also corroborate the research work conducted by Saura-Calixto *et al.* (2007).

Considering the technologies available to maize farmers and the inputs and output prices, resource use efficiency would be achieved at a level where the MVP is equal to the MFC. The resource can only be used efficiently if the compared MVP and the MFC are the same. The results revealed that the ratios of the MVP to the MFC for maize farmers in the pooled sample were greater than one for the use of fertilizer, herbicides, pesticides, seeds, and land with values of 2.7, 9.5, 7.0, 18.2, and 35.6, respectively (Tab. 3). The ratios for the use of labor and capital were found to be less than one with values of 0.8 and 0.2, respectively (Tab. 3). These results imply that maize farmers in Ghana were not efficient in allocating their resources (fertilizer, herbicides, pesticides, seed, land, labor, and capital). The above means that maize farmers in Ghana underutilized fertilizer, herbicide, pesticide, seed, and land, while labor and capital were over-utilized. In general, maize output could have been increased if more underutilized inputs like fertilizer, herbicides, pesticides, seed, and land were used.

TABLE 3. Marginal value product to marginal factor cost ratio across the various regions in Ghana.

Variable	Pooled sample				Northern region				Brong-Ahafo region				Eastern region				Central region			
	MPP	MVP	MFC	R	MPP	MVP	MFC	R	MPP	MVP	MFC	R	MPP	MVP	MFC	R	MPP	MVP	MFC	R
Fertilizer	3.9	3.8	1.4	2.7	2.6	1.94	1.6	1.2	5.4	4.8	1.4	3.4	5.6	6.3	0.6	10.5	10.4	10.6	0.87	12.2
Herbicide	94.5	91.8	9.7	9.5	157	124	10.4	12.0	642	584	8.3	70	140	165	8.4	19.6	11.8	11.9	11.4	1.04
Pesticide	74.6	72.5	10.4	7.0	76	60.4	0.7	86.2	166	151	0.9	168	54.1	63.7	0.114	559	10.5	10.6	0.3	35.3
Seed	54.4	52.7	2.9	18.2	1.50	1.29	3.8	0.3	118	109	2.4	45	7.65	9.1	2.9	3.1	32	32.3	2.9	11.1
Labor	9.9	9.6	12	0.8	26.4	21	7.3	2.9	32	28.4	18.9	1.5	18.4	21.8	10.4	2.1	40.3	40.6	11.6	3.5
Land	1103	1078	30.3	35.6	117	92.1	14.2	6.5	4369	3975	47.3	84	1408	1669	28.27	59.0	21.3	21.5	32.4	0.66
Capital	2.53	2.46	12.8	0.2	0.69	0.57	0.05	13.8	1.99	1.9	12.9	0.1	1.04	1.06	13.39	0.08	0.34	0.35	13.7	0.02

MPP - marginal physical product, MVP - marginal value product, MFC - marginal factor cost, R - efficiency coefficient.

In contrast, labor and capital could have been reduced. This result agrees with the work of Chiedozie *et al*. (2010), who report similar results in their study that fertilizer, land, and pesticides were underutilized.

Table 4 shows MVPs adjustments for optimal resource utility (% divergence) by maize farmers in Ghana. The result from the pooled sample indicates that for resources to be efficiently utilized, there should be an increase of more than 70.4%, 89.7%, 86.3%, 94.6%, and 97.4% for fertilizer, herbicide, pesticide, seed, and land, respectively, to ensure a higher maize output (Tab. 4). However, labor and capital were over-utilized. Therefore, these inputs need to be decreased by 20.9% and 81.9%, respectively, for efficiency in maize productivity to be ensured (Tab. 4). In the northern region, for optimal resource utilization by farmers to be achieved, there should be an increase in fertilizer, herbicides, pesticides, labor, land, and capital of 21.8%, 91.9%, 99.4%, 66.5%, 84.7%, and 94.5%, respectively. In comparison, the quantity of seed would be expected to be reduced by 66.8% to ensure optimization (Tab. 4). The optimal resource use adjustment by maize farmers in the Brong-Ahafo region also revealed that for an optimal resource to be achieved, there should be an increase of 73.3% of fertilizer, 98.7% of herbicide, 99.6% of pesticide, 97.8% of seed, 33.4% labor, and 98.8% of land. In comparison, capital needs should be reduced by 85.9% for optimal output levels to be achieved (Tab. 4). For maize farmers in the eastern region, an increase of 90.5%, 95%, 99.8%, 68.9%, 52.4%, 99.3%, and 98.3% for fertilizer, herbicide, pesticide, seed, labor, and land, respectively, as well as a decrease in capital input of 90.8% would be required for optimal resource use to be achieved (Tab. 4). Optimal adjustment regarding optimal use of resources by maize farmers in the central region requires an increase of 91.9%, 3.9%, 99.3%, 91.8%, and 71.4% in fertilizer, herbicides, pesticides, seed, and labor, respectively. In comparison, land and capital need to be decreased by 33.8% and 98.4%, to ensure resource-use efficiency optimization for increasing maize production (Tab. 4). This result agrees with the studies of Chiedozie *et al*. (2010) and Wongnaa *et al*. (2012), who obtain similar results in their studies on resource use efficiency. Our results suggest a significant divergence from the optimal levels of pesticides (underutilized) in all the agro-ecological zones compared to any other input resources. The divergence of pesticide use from the optimal levels was greater in the eastern region, whereas that of land was greater in the Brong-Ahafo region of Ghana (Fig. 1).

TABLE 4. Adjustments in marginal value products (MVP) for optimal resource use (% divergence).

Variable	Pooled sample		Northern region		Brong-Ahafo region		Eastern region		Central region	
	EG	% D	EG	% D	EG	% D	EG	% D	EG	% D
Fertilizer	2.7	70.4	0.43	21.8	3.6	73.3	5.8	90.7	9.67	91.9
Herbicide	82.3	89.7	113.9	91.9	574.8	98.7	155.7	95.2	0.46	3.9
Pesticide	62.4	86.3	59.8	99.4	149.3	99.6	63.4	99.7	10.8	99.3
Seed	49.8	94.6	2.42	66.8	104.8	97.8	6.4	68.8	29.7	91.8
Labor	2.5	20.9	13.8	66.5	9.45	33.4	11.31	52.5	28.8	71.4
Land	1037.8	97.4	78.1	84.7	3927.92	98.8	1630.8	98.2	10.89	33.8
Capital	10.64	81.9	11.4	95.4	10.99	85.7	12.6	90.9	13.56	98.4

EG - efficiency gap, D - divergence from optimal level.

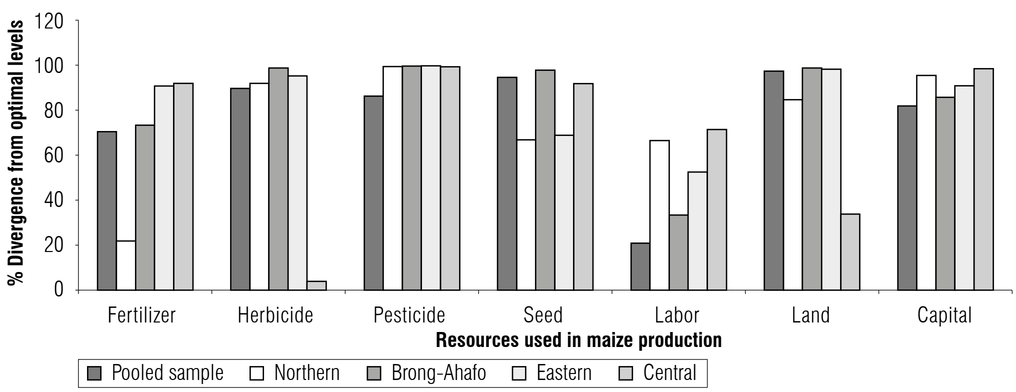

FIGURE 1. Adjustment in marginal value of products for optimal resource use.

In the northern region, the results for the ratios of the MVP and MFC were greater than one for the use of fertilizer, herbicide, pesticide, labor, land, and capital with values of 1.2, 12.0, 86.2, 2.9, 6.5 and 13.8, respectively, while the use of seed was found to be less than one with a value of 0.3 (Tab. 3). This result means that fertilizer, herbicide, pesticide, labor, land, and capital were underutilized by maize farmers in this region, while seed was over-utilized. The maize output in the northern region could be increased if more underutilized inputs like fertilizer, herbicide, pesticide, labor, land, and capital were used. At the same time, the quantity of seed should be reduced.

In the Brong-Ahafo Region, the ratios of the MVP and MFC were greater than 1 for fertilizer, herbicide, pesticide, seed, labor, and land with values of 3.4, 70, 168, 45, 1.5, and 84, respectively, while the only input with a ratio less than one was capital 0.1 (Tab. 3). The implication of this is that fertilizer, herbicide, pesticide, seed, labor, and land were underutilized, while only capital was over-utilized. Therefore, maize farmers in the Brong-Ahafo region could have increased their outputs if inputs like fertilizer, herbicide, pesticide, seed, labor, and land were increased while capital was reduced.

In the eastern region, the MVP and MFC ratio was greater than one for fertilizer, herbicides, pesticides, seed, labor, and land with values of 10.5, 19.6, 559, 3.1, 2.1, and 59.0, respectively. The capital ratio of MVP and MFC was less than one (0.08) (Tab. 3). This means capital was over-utilized while fertilizer, herbicides, pesticides, seed, labor, and land were underutilized by maize farmers in this region. Therefore, if maize farmers had increased their use of fertilizer, herbicides, pesticides, seed, labor, and land and decreased the amount of capital, then it is likely that their maize output would have increased.

The MVP and MFC ratios calculated for maize farmers in the central region were greater than one for fertilizer, herbicide, pesticide, seed, and labor, recording 12.2, 1.04, 35.3, 11.1, 3.5, respectively. Simultaneously, land and capital were found to be less than one, recording 0.66 and 0.02, respectively (Tab. 3). This result indicates that fertilizer, herbicide, pesticide, seed, and labor were underutilized, while land and capital were over-utilized. Maize farmers in the central region of Ghana could have increased their outputs if more of such inputs like fertilizer, herbicide, pesticide, seed, and labor were used while land and capital were reduced. The studies of Chiedozie *et al.* (2010) also reported similar results.

Conclusion

For maize farmers in Ghana to be efficient in their use of resources, fertilizer, herbicides, pesticides, improved seed, and land should be increased because of these resources' underutilization. On the other hand, labor and capital need to be decreased since they were overutilized. In the northern region, we found that for maize farmers to be optimal in their productivity levels, there should be an increment in fertilizer, herbicide, pesticide, labor, land, and capital. At the same time, the quantity of seed should be decreased. For maize farmers in the Brong-Ahafo region to be optimal in their maize production, fertilizer, herbicides, pesticides, seed, labor, and land need to be increased while capital should be reduced. All the other resource inputs, including fertilizer, herbicide, pesticide, improve seed, labor, and land should be increased for optimal productivity levels in the eastern region. Finally, in the central region, inputs such as fertilizer, herbicide, pesticide, seed, and labor should be increased to ensure optimal resource use, whereas land and capital should be reduced. Based on the results obtained, the researchers recommend that the government and other stakeholders subsidize the price of input resources like fertilizer, herbicides, pesticides, and improved seed to enable farmers to increase their use. Extension offices should also encourage farmers to use the underutilized resources and advise them to reduce over-utilized resources like capital.

Author's contributions

FOD formulated the research goals and aims, created the visualization, wrote the original draft, and reviewed and edited the manuscript, HG provided all the resources needed for this study and also supervised all the writing, LNF applied the statistical techniques and software to analyze data and BAK developed the methodology for this study and was responsible for data curation.

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SUPPLEMENTARY MATERIAL 1. Survey questionnaire.

Farmers Interview Schedule.

I am FRANK OSEI DANQUAH from Sichuan Agricultural University, China. I am currently researching how improving production technology enhances maize farmers' economic efficiency in Ghana. The information provided will be treated with a high level of confidentiality.

Questions are addressed to farmers, preferably the household heads or decision-makers in the household.

A. IDENTIFICATION

A1. Enumerator's Name:____ Phone No.____

A2. Respondent's Name: ____ Phone No.____

A3. Date of interview: ___ /___/

A4. Region (Please tick)

1. Northern region
2. Brong-Ahafo region
3. Eastern region
4. Central region

A5. Which district/Municipality is the farmer located in ____

A6. Area Operated (Farm Location) ____

A7. Description of operational area
Urban = 0   Rural = 1

B. DEMOGRAPHIC CHARACTERISTICS AND SOME SOCIAL CULTURAL PRACTICES.

B1. Gender:____ Male = 1   Female = 0

B2. Age of the respondent (years)
18-45 years = 1;   46-60 years = 2;
above 60 years = 3

B3. Educational Level:
No formal education=1; Primary education=2
Secondary education =3; Tertiary education = 4

B4. Actual number of years spent in school
(if formally educated)____

B5. Marital status:____
Single = 0   Married = 1

B6. How many people do you have in your household ____

B7. How many years of farming experience ____

B8. Approximately how many non-formal trainings have you attended in the past five (5) years:
None = 1; 1-5 times = 2; 6-10 times = 3;
more than 10 times = 4

B9. What is the total farm size you own (acres)____

B10. How many plots of lands do you own____

B11. How much of your land is used for maize cultivated (acres)____

B12. Are you currently a member of any farmer's group or local association in the village?
No = 0   Yes = 1

B13. Are you a beneficiary of any subsidies from the government?
Yes = 1   No = 0

B14. Do you hold a formal land title or registration to the whole or part of your land?
Yes = 1   No = 0

B15. How did you get access to the land you are cultivating?

1. I bought
2. I inherited it from my parents
3. Its parts of my family properties
4. Other (Specify) ____

B16. If yes, what kind of subsidy was that____

B17. Are you a beneficiary of any NGO program?
Yes = 1   No = 0

B18. If yes, what is the name of the NGO ____

B19. What was the form of benefits given to you?
Farming =1; Paying of your ward school fees = 2; Construction of house for you = 3; Financial Support = 4; Others (Please specify) = 5

B20. Has any agricultural extension officer visited you?
No = 0   Yes = 1

B21. If yes, how many times? 1 = last year; 2 = two years ago; 3 = three years ago; 4 = beyond three years.

B22. Have you received any credit for your farming?
Yes = 1   No = 0

B23. What was your total capital at the beginning of the production season? Gh¢____

B24. What was the amount of credit you accessed last year in any Gh¢____

B25. Have you engaged in other income generation activities apart from maize farming previous year?
Yes = 1 No = 0

B26. If yes, which of the following were you engaged in (Select only one)
1. Artisan (carpentry, fitting, dressmaking, etc.)
2. Trading
3. Food processing
4. By day labourer
5. Public servant
6. Others (please specify)

B27. Which of the improved production technologies would you like to adopt
1. Fertilizer use
2. Pesticides use
3. Herbicides use
4. Improved seed use
5. Combination of all the technologies

B28. Which one of the following groups of improved production technologies did you employ in your maize production last year? Please tick.
1. Improved seeds + fertilizer use + pesticide use + herbicide use + other soil fertility management practices
2. Some of the technologies mentioned in (1) above but not all
3. Only one of the technologies mentioned in (1) above

B29. Did you use fertilizer on your maize farm?
Yes / No

B30. If yes, why did you apply it on your maize farm ____

B31. Did you use Pesticides on your maize farm?
Yes / No

B32. If yes, why did you apply it on your maize farm ____

B33. Did you use Herbicides on your maize farm?
Yes / No

B34. If yes, why did you apply it on your maize farm ____

B35. Did you use the improved seed in your maize farm?
Yes / No

B36. If yes, why did you apply it on your maize farm ____

B37. Approximately how many minutes does it take you from your house to your farm? ____

B38. Around how many kilometres do your cover from your house to your farm?____

B39. Why did you plant the variety of maize seeds you planted last year?
1. It was very cheap
2. It was the only one available
3. It was the only known variety to me
4. That was what customers preferred
5. It is high yielding
6. Others (please specify)

B40. What is your source of labour for your maize farming?
1. Family members
2. Hired Labour
3. Friends
4. Others

C. OUTPUT OF MAIZE

C1. The output of maize for all land cultivated and the selling price.

Year	Season	Total maize farm size (Acres)	Total output		Selling price (Gh¢/Bag)
			No. of bags	Weight (kg)	
2016	Major				
	Minor				
2017	Major				
	Minor				
2018	Major				
	Minor				

C2. Did you make a profit by selling your maize?
Yes = 1 No = 0

C3. What do you think about the level of yield on your farm for the past three farming seasons?
1 = Increased 2 = Decreased 3 = No change

C4. If there is an increase, what might be the cause ____

C5. What do you perceive to be the cause for the decrease, if any____

C6. According to you, what is the food security status in your household?
1 = Not sufficient 2 = Sufficient

D. RESOURCE OR INPUT USED IN PRODUCTION OF MAIZE

D1. Indicate whether the following input was used in your maize farm last year and indicate the quantity used, cost per unit, and the total cost per acre.

No.	Variable input	Quantity used	Unit cost (GH¢)	Total cost (GH¢)
1	**Fertilizer (Kg)**			
2	**Pesticides (L)**			
3	**Herbicides (L)**			
4	**Improved seed (kg)**			
Labour (person-days)				
a	Land clearing			
b	Sowing			
c	Falling of trees			
d	Others (indicate)			

E. SUMMARY OF UNIT PRICE OF THE KEY PRODUCTION ITEMS

No.	Production variable	Cost/price GH¢
	The average price of maize per kg	
	The average cost of rented land per hectare	
	The average price of seed per kg	
	Average price per fertilizer per kg	
	The average price of herbicides per litre	
	The average price of pesticides per litre	
	The average price of labour per person-day	