Discovery Agriculture

Determinants of maize production efficiency: A stochastic frontier analysis across farm scales in Southwest, Nigeria

Tolulope Seun Olubunmi-Ajayi[1*], **Olanrewaju Peter Oladoyin**[2], **James Adebayo**[3], **Olabimpe Banke Akintuyi**[1]

To Cite:
Olubunmi-Ajayi TS, Oladoyin OP, Adebayo J, Akintuyi OB. Determinants of maize production efficiency: A stochastic frontier analysis across farm scales in Southwest, Nigeria. *Discovery Agriculture* 2024; 10: e19da1593
doi: https://doi.org/10.54905/disssi.v10i22.e19da1593

Author Affiliation:
[1]Department of Agricultural and Resource Economics, Federal University of Technology, Akure, Ondo State, Nigeria
[2]Department of Agricultural Economics, Adekunle Ajasin University, P. M. B.001, Akungba-Akoko, Ondo State, Nigeria
[3]Department of Electrical and Electronics, University of Ibadan, Ibadan, Nigeria

[*]**Corresponding Author**
Department of Agricultural and Resource Economics, Federal University of Technology, Akure, Ondo State,
Nigeria
Email: tolulopeolubunmiajayi@gmail.com

Peer-Review History
Received: 28 May 2024
Reviewed & Revised: 01/June/2024 to 26/August/2024
Accepted: 30 August 2024
Published: 07 September 2024

Peer-Review Model
External peer-review was done through double-blind method.

Discovery Agriculture
pISSN 2347-3819; eISSN 2347-386X

DISCOVERY SCIENTIFIC SOCIETY

ABSTRACT

This study investigates the determinants of maize production efficiency in different farms in South Western Nigeria using stochastic frontier analysis. Primary data collected through a well-structured questionnaire was used for the study. A sample of 240 maize farmers was randomly selected for the study. The findings reveal significant differences in technical, allocative, and economic efficiency between small, medium, and large maize farms. Smallholder farmers showed the highest variability in efficiency, mainly due to limited access to resources and suboptimal use of inputs. Medium-scale farms have demonstrated a moderate level of efficiency, benefiting from better management practices and resource allocation. Large farms showed consistently high efficiency and emphasized the advantages of economies of scale. Key determinants of maize production efficiency identified in this study include herbicide rate, labour, seed, and farm size, with fertilizer use showing mixed effects. The result further shows that age, education, farm size, farming experience, and access to credit significantly affect allocative efficiency across scales. The study highlights the need for targeted interventions to increase resource efficiency, improve access to agricultural inputs, and promote the adoption of good agricultural practices at all scales of maize production. This research provides valuable insights for policymakers and agricultural stakeholders, highlighting the importance of addressing inefficiencies and promoting technological innovation to increase maize productivity in the field. By improving efficiency, farmers can achieve higher yields, increase food security, and contribute to the economic development of the region.

Keywords: Efficiency, maize, production, scale economies, stochastic frontiers, Nigeria

1. INTRODUCTION

Maize is crucial for households, industries, and the broader economy in Nigeria. Despite its significance, maize production has not met the necessary levels to fulfill the country's food and industrial demands. Over the past two decades, yield increases have been marginal, primarily due to an expansion in the harvested area rather than improved productivity (Olubunmi-Ajayi et al., 2023). This indicates a production shortfall that threatens food security and economic stability. In Nigeria, maize is a major food staple, predominantly cultivated through subsistence farming methods. The region's maize output remains low, largely because farmers lack sufficient knowledge of optimal resource allocation. Empirical studies Ado et al., (2007), Olubunmi-Ajayi et al., (2023) highlight that many developing countries, including Nigeria, grapple with high poverty levels exacerbated by rapid population growth and limited agricultural resources, such as arable land.

Improving maize yields is imperative for enhancing food security and the livelihoods of rural households. Efficient resource utilization is essential for achieving this goal, as it can significantly boost productivity and contribute to halving hunger (Amos, 2007; Olutumise et al., 2023). Smallholder farmers in Nigeria face high inefficiencies – technical, economic, and allocative – due to limited access to resources, lack of information on efficiency, and low levels of literacy. This inefficiency hinders their ability to engage in commercial production and use resources efficiently, ultimately reducing productivity. The current adverse economic conditions further strain rural households, impacting both their living standards and maize production. Land productivity has been declining, particularly in areas where population growth and non-agricultural activities compete for land resources (Babatunde et al., 2007).

Enhancing the productivity of smallholder farmers is critical for economic development, as it provides employment and promotes equitable income distribution (Bravo-Ureta and Evenson, 1994; Olubunmi-Ajayi et al., 2023). The inability to achieve increased productivity in Nigeria's maize sector raises questions about the efficiency of resource use among maize farmers. If inefficiency is identified, it necessitates an examination of the role of technological innovation and policy factors in this situation. Addressing these policy questions could justify additional investment in maize production and the advancement of agricultural technology. Thus, efficiencies and scale economies are pivotal for agricultural productivity and income generation among maize-based farming households. However, the nexus between scale economies and productivity in Nigeria remains underexplored.

While some studies have examined agricultural productivity, limited research focuses specifically on scaling the maize farming households in this region. Existing literature often overlooks the nuanced dynamics of sole maize farming in Nigeria, emphasizing general agricultural productivity and management strategies. Comprehensive research is needed to investigate the influence of efficiencies and scale economies on maize production efficiency within this context. Again, studies examined the efficiency of large and medium corn-based production. For example, Ogunjimi et al., (2014) focused on technical efficiency and constraints among medium-sized maize production enterprises in Oyo State. Research has examined farm size, efficiency, and economies of scale, suggesting that medium-sized farms tend to be more efficient.

However, there is a research gap regarding small-scale maize farmers who use basic implements for their operations. Therefore, it is necessary to assess the technical efficiency of farmers engaged in maize-based cropping systems in a specified area. Assessing efficiency is essential because it represents the initial step in a process that could lead to substantial resource savings and is a key driver of productivity growth. Against this background, this study aims to fill this gap by analyzing the determinants of maize production efficiency in different farms in South Western Nigeria. Utilizing a stochastic frontier analysis, the research seeks to provide insights into the factors influencing maize production efficiency, to inform policy and practice to enhance productivity and support sustainable development in the region.

Therefore, the research is expected to offer valuable insights to overcome problems associated with maize-based production. Findings from this study are expected to guide farmers in achieving both allocative and technical efficiency, maximizing profits, and transitioning agriculture from subsistence to commercial production. This is in line with the vision to make Nigeria a self-sufficient nation in line with the Sustainable Development Goals (SDGs) by 2030. In addition, the study aims to present insights that improve the efficiency of maize-based farmers by recommending improved cultivation methods to optimize input usage. Finally, the study will provide policymakers with information and recommendations to inform decision-making processes aimed at increasing maize-based production in the study area.

2. MATERIALS AND METHODS

Study Area

The research was conducted in South West Nigeria, covering six states: Lagos, Oyo, Ogun, Ekiti, Ondo and Osun. Located between 2.311° and 6.001° East longitude and 6.0211° and 8.0370° North latitude, the region is characterized by a highland zone with an elevation of around 250 meters above sea level. Southwestern Nigeria experiences a tropical climate with distinct wet (April to October) and dry (November to March) seasons (Omonijo et al., 2023). The area covers 77,818 square kilometers and has a population of approximately 32.5 million, mostly of the Yoruba ethnic group.

Edo and Delta states bound the region to the east, Kwara and Kogi states to the north, Benin Republic to the west, and the Gulf of Guinea to the south. It exhibits diverse vegetation including freshwater swamps, mangrove forests, lowland forests, and savannah areas. The region also has favourable socio-economic indicators such as the lowest infant mortality rate in the country and a high level of educational attainment. The region's GDP has grown significantly, contributing to its position as the largest economy on the African continent in 2023.

Data Source and Collection

Data were primarily collected through structured questionnaires administered to respondents. The questionnaires captured information on input and output quantities, unit prices, income, farm size, and the welfare impact of maize production. In addition, socio-economic data such as age, gender, household size, access to credit, and educational attainment were collected to provide a comprehensive understanding of the respondents' profiles.

Sample size and sampling procedure

The study used a multistage sampling procedure to collect data from maize-based farmers. Initially, two states (Ondo and Ekiti) were targeted. Two Local Government Areas (LGAs) with the highest proportion of maize farmers were selected in each state. Subsequently, two communities were randomly selected from each LGA, for a total of 24 communities. Finally, a purposive ballot sampling method was used to select ten respondents from each maize-based cropping system in each community, resulting in a sample size of 240 respondents.

Data analysis

Data analysis involves the application of statistical methods, including descriptive statistics and stochastic frontier analysis. Stochastic frontier: There are two primary methodologies for evaluating technical efficiency: The classical method and the frontier approach. Criticism and controversy over the limitations of the classical method have prompted economists to develop advanced econometric, statistical, and linear programming techniques specifically tailored to the analysis of technical efficiency problems. All these approaches share a common feature – the concept of a boundary. That is, efficient firms are those operating at the production frontier, while inefficient firms are those operating below it. The choice to use the parametric frontier approach is motivated by inherent differences in small-scale production in developing countries.

The stochastic frontier approach is particularly preferred because it recognizes the myriad factors affecting small-scale production. He attributes part of the variation to random errors, including measurement errors and statistical noise, as well as farm-specific inefficiencies (Olutumise et al., 2023; Ijigbade et al., 2023; Olubunmi-Ajayi et al., 2023). Consequently, the stochastic frontier method decomposes the error term into a two-sided random error, capturing both the inefficiency component and the impact of factors beyond the farmer's control. This approach was used to estimate and compare the level of technical, economic, and allocative efficiency among large, medium, and small maize farmers. This is specified as follows:

$$InQYi = b0 + b1LnFX1 + b2LnHX2 + b3LnLX3 + b4LnFX4 + b5LnSX5 + Vi - Ui \quad \ldots\ldots(1)$$

Here:

QYi = Quantity of maize-based product produced in kg (after conversion into grain equivalent)

FX1 = Fertilizer (kg)

HX2 = Herbicides (Litres)

LX3 = Labour (man days)

FX4 = Farm size (ha).
SX5 = seeds (kg)
Vi = The two-sided normally distributed random error that cannot be influenced by the farmers e.g. weather disaster
Ui = One-sided technical inefficiency component with a half-normal distribution.
The inefficiency model was defined to estimate the influence of some farmer's socioeconomic variables on the technical efficiency of the farmers.
The model will be specified by;
Ui= ä0 + ä1Z1 + ä2Z2 + ä3Z3 + ä4Z4 +…………..ä10Z10 …………………………………… (2)
Where:
Z1 = Farming experience (in years)
Z 2 = Farmer's Age (in years)
Z 3= Sex (male = 1, female = 0)
Z4 = Marital status (married =1, otherwise =0)
Z 5 = Educational level (years of formal education)
Z 6 = Loan/Credit Access (Yes = 1; No = 0)
Z 7 = Farm Size (Ha.)
Z 8= Household size (number)
Z 9 == Membership of farmers' cooperative (yes = 1; No = 0)
Z 10 = Land ownership (Inherited =1, Lease = 0)
To illustrate their potential impact on the farmers' technical inefficiencies, this was incorporated into the model. äs are scalar parameters to be estimated.

3. RESULTS AND DISCUSSION

Scale Economy of Respondents

Farm size classification is in three stages, namely small, medium, and large, the table shows that the average farm size for maize farms was 1.25 ha, 1.10 ha for maize-cassava farms, and 0.6 ha for maize pits. Farms and 1.42 ha for maize-rice farms (Table 1). This farm size could be uneconomical for farmers trying to make a profit. It also highlights the fact that the farmers in the study area were small farmers. A consequence of the small size of their farms is that outputs would be relatively low. Smallholder farming also presents challenges such as limited resources, vulnerability to risk, poor market access, and political and institutional challenges, among others.

The average farm size obtained in this study agrees with the results reported by Olarinde, (2011) and Fadare and Akerele, (2014) where most of the maize farmers cultivated between 0.5 and 2.0 hectares of land. This classification agrees with the findings of Leah et al., (2016) who say that units with less than five hectares per farm household are defined as small farming units, medium farms have a farm size of 5-15 hectares, and large farms have 15-50 hectares.

Table 1 Distribution of Respondents' farmland based on size

Farm size (Ha)	Scale	Sole Maize		Maize-Cassava		Maize-Yam		Maize-Rice	
		Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
0-4.9	Small	52	77.6	51	47.2	30	81.1	15	53.6
5-14.9	Medium	9	13.4	48	44.4	7	18.9	5	17.9
≥15	Large	6	8.95	9	8.3	0	0	8	28.5
Total		67	100	108	100	37	100	28	100
Mean		1.25		1.10		0.6		1.42	

Estimation of the Stochastic Frontier Production Function

Table 2 shows the results of maximum likelihood estimation (MLE) for the stochastic frontier production function applied to a single maize farmer in the research area. The sigma-squared (σ2) value was 0.593 for small farms, 0.010 for medium farms, and 2.160 for large farms. Both small and large farms were statistically significant at the 1% level, indicating a satisfactory fit and appropriateness of the assumed distribution form for the composite error term in the model. The variance ratio (gamma (γ)) was 0.999 for small farms, 0.001 for medium farms, and 0.623 for large farms. This ratio measures the proportion of the production variance of tongue corn farmers to the total variance. Therefore, 99.9% of the variation in maize production for small farms, 0.1% for medium farms, and 62.3% for large farms was attributed to differences in their technical efficiency.

The low value of $\sigma 2$ for medium-sized farms indicates a relatively stable and consistent level of maize production, probably due to a combination of efficient management practices, optimal use of inputs, and reduced exposure to risk factors. In small farms, the results showed that the coefficients of the amount of herbicides used, labour, amount of seed, and farm size had a positive and significant effect on maize production. Specifically, these coefficients were significant at the 1% level, indicating that a percentage increase in the amount of herbicides used would lead to a 15.7% increase in corn production. Similarly, a percentage increase in farm size would increase corn production by 48.7%. Additionally, a percentage increase in labour would result in an 18.6% increase in corn production, and a percentage increase in the seed would result in a 27.9% increase in corn production, all else being equal.

As expected, higher amounts of seed, herbicide, and labour contribute to increased corn production, while increasing farm size also increases corn production. The coefficient of fertilizer was negatively significant at the 5% level and this showed that a percentage increase in the amount of fertilizer used would reduce their area performance by 1.1%. This result was in disagreement with the findings of Fatuase, (2017) who were positive about the output. Based on this result, corn growers in this category could increase their corn production and possibly profitability by increasing the amount of corn seed per unit area, increasing farm size, herbicides, and labour, and reducing fertilizer. This finding for maize seed is consistent with the result reported by where the coefficient of corn seed was found to be positive and significant at a 5% level.

The result shows that farmers experience increasing marginal returns to scale. It means that a unit increase in any of these inputs will result in more than one increase in farmers' outputs. In medium farms, the coefficients of herbicides, fertilizers, labour, and seed had a positive and significant relationship at the 1% level with maize production in the study area. A percentage increase in the amount of herbicides used will lead to a 135.7% increase in corn production, a percentage increase in labour used will lead to a 41.1% increase in corn production, and a percentage increase in the seed will lead to a 92.8% increase in corn production. A percentage increase in fertilizer use will also increase corn production by 7.9%. Farm size had a positive but not significant relationship with maize production. In large farms, farm size coefficients had a positive and significant relationship with farmer production by 1%. This means that a unit increase in farm size will lead to an 85.7% increase in production.

The result shared a similar opinion with the studies of (Ehinmowo et al., 2017; Bankole et al., 2018). Fertilizers, herbicides, and labour had a positive interaction with the amount of corn produced but were not statistically significant. Fertilizer use does not have a significant effect on corn production, although it has a positive elasticity coefficient, and is directly related to corn production. Maize farmers likely used more inputs than their farm size would require for optimal production. Ogunniyi et al., (2015) believe that findings of this kind could indicate that many farmers were buying and using more fertilizers than the optimal level, given relative input/output prices, thereby negatively affecting efficiency. Therefore, changes in the amount of fertilizer applied by corn growers in the surveyed area will not bring about a significant change in corn production.

The insignificant effect of fertilizer on maize production in this study contradicts the result published by Mutambara et al., (2013) who studied the production and productivity of maize exposed to modern and traditional weed control methods in the Federal Capital Territory, Nigeria, and found that fertilizer application had a significant positive effect on maize production. However, seed coefficients were negatively related to corn abundance. However, this may be a result of farmers not adhering to the recommended amount of seed, resulting in wasteful use of inputs and associated low productivity and economies of scale. This finding for maize seed does not agree with the result reported by where the coefficient of corn seed was found to be positive and significant at 5%.

Similarly, Séogo et al., (2021) in a survey of the technical efficiency of maize production and its determinants across agro-ecological zones in northern Nigeria found that maize seed coefficient was a significant determinant of maize production. For the three cropping methods, farmers are at stage I of the production scale, which means that there are increasing marginal returns to scale. At this stage, marginal productivity is higher than average productivity. It can therefore be inferred that a one percent change in inputs leads to more than a one percent change in outputs. Farmers can thus expand the scale of production to maximize outputs. In the collected data, the results showed that four factors (fertilizer, labour, farm size, and seed amount) had a positive and significant effect on maize production.

The coefficients for these factors were significant at the 1% level, indicating a strong relationship between these variables and maize production. Specifically, the findings revealed that a percentage increase in the amount of fertilizer used would lead to a 5.3% increase in corn production. Similarly, a percentage increase in farm size would increase corn production by 7.9%. Additionally, a percentage increase in labour and the amount of seed used would increase corn production by 2.5% and 9.1%, respectively. To delve deeper into these findings, it is worth noting that statistical significance was observed at different levels for these factors. The use of higher seed rates was found to have a remarkably strong effect with a significant effect at the 1% level.

This means that a 1% increase in the amount of seed used by farmers led to an impressive 9.1% increase in maize production, underscoring the importance of seed selection and growing practices. In addition, the amount of fertilizer used, labour input, and farm size was found to have a significant effect, albeit at a slightly higher 10% significance level. This shows that a 1% increase in fertilizer use led to a remarkable 5.3% increase in maize production. A similar increase in farm size resulted in a substantial increase in maize production by 7.9%, which is consistent with the findings of (Key, 2019; Ren et al., 2021; Sheng and Chancellor, 2019). Additionally, a 1% increase in the labour force contributed to a 2.5% increase in corn production. This is consistent with the study by (Chen et al., 2011).

Table 2 Maximum Likelihood Estimates of Stochastic Production Function for Sole Maize Farmers

Variables Parameter		Scale of Production											
		Small Scale			Medium Scale			Large Scale			Pooled		
		Coefficients	Std. error	t value	coefficients	Std. error	t value	Coefficients	Std. error	t value	coefficients	Std. error	t value
Constant	β0	6.793***	0.712	9.531	-0.001***	2.110	-6.184	7.180	7.558	0.949	5.806***	0.173	33.60
Fertilizer	β1	-0.011**	0.005	-2.315	-0.079***	0.008	-9.120	0.076	0.270	0.283	0.053*	0.030	1.75
Herbicides	β2	0.157***	0.023	6.750	1.357***	0.087	15.600	1.550	1.147	1.352	0.041	0.049	0.84
Labour	β3	0.186***	0.031	5.904	0.411***	0.040	10.226	0.327	0.829	0.395	0.025*	0.015	1.72
Farm size	β4	0.487***	0.118	4.101	0.184	0.217	0.848	0.857***	1.163	7.371	0.089*	0.052	1.7
Seeds	β5	0.279***	0.089	3.107	0.928***	0.149	6.198	0.609	0.695	0.875	0.091***	0.015	6.2
Sigma-squared	σ2	0.593***	0.096	6.144	0.010	0.010	0.925	2.160***	1.124	1.921	0.884***	0.200	4.42
Gamma	Γ	0.999***	0.000	117663.6	0.001	1.007	0.001	0.623***	0.028	16.097	0.585***	0.173	3.39
LR Test		-30.368			7.935			-12.6299			14.506***		

Note: *, **, and *** mean significance at 10%, 5%, and 1% respectively.

Determinants of Allocative Efficiency of Sole Maize Farmers

Ordinary least square was used to examine factors affecting the allocative efficiency of maize-based farmers in a given area. The value of R2 was 0.162, 0.69.2, and 0.7902 for small scale, medium scale, and large scale, respectively, indicating that almost 16.2%, 69.2%, and 79.02% of the variation in the dependent variable was due to the explanatory variables for small, medium and large scale. Similarly, the F-values of 2.214, 39.197, and 40.005 for small, medium, and large scales are strongly significant at a 1% probability level, indicating that all the independent variables together influence the behavior in the dependent variable. In small farms, it can be noted from Table 3 that four variables were statistically significant while seven variables were positively related to allocative efficiency. The results revealed that variables such as respondent age, gender, farming experience, and access to credit were significant in addressing the level of allocative efficiency of farmers.

The age coefficient was statistically significant at the 5% level with allocation efficiency. This coefficient suggests that each unit increase in age leads to a very small increase in allocative efficiency. Older farmers may have a wealth of experience gained from years of practical work in agriculture. This accumulated experience could lead to better resource allocation decisions because older farmers could have encountered a wider range of situations and learned from past successes and failures. In addition, older farmers can gain a deeper understanding of local conditions, climate patterns, and soil characteristics, allowing them to make more informed decisions when allocating resources such as seeds, fertilizers, and labor. Gender was also significant at the 10% level with allocation efficiency. This can be interpreted to mean that a male head of household increases allocative efficiency by 0.6% over a female counterpart, ceteris paribus.

The observed gender disparity in allocative efficiency raises questions about the underlying factors influencing decision-making in agricultural households. Social norms, access to education and information, control over resources, and household division of labor can all contribute to differences in farm management practices between male and female heads of households. Interventions to address gender disparities in agriculture can include efforts to improve women's access to education, ancillary services, land tenure rights, and financial resources. Empowering women farmers to fully participate in decision-making processes can contribute to a fairer and more efficient allocation of resources on the farm. In addition, the coefficient of agricultural experience was positive and significant at the 1% level in affecting allocative efficiency. This suggests that as the number of farming years increases, allocative efficiency increases by about 0.4%, holding other factors constant.

A likely reason for the positive relationship between farm experience and allocative efficiency suggests that learning by doing plays a critical role in improving farm management practices over time. As farmers gain experience, they become more adept at identifying opportunities to optimize resource use and minimize waste. In addition, experienced farmers can better understand market dynamics, consumer preferences, and technological innovations, allowing them to make more strategic decisions regarding crop selection, input use, and marketing strategies. Singh et al., (2016) support this perspective and suggest that the length of time a farmer has been engaged in farming can provide insight into the practical knowledge they have gained in overcoming inherent challenges in agricultural production. Alem et al., (2018) similarly noted that farmers depend heavily on their farming experience to increase efficiency and productivity.

Olubunmi-Ajayi et al., (2023), however, differ in their findings. They reported a negative significant relationship between farming experience and allocative efficiency. The coefficient of access to credit was again positive and significant at the 5% level. This suggests that the relationship between access to credit and allocative efficiency is unlikely to be due to random chance. Statistically, this means that there is strong evidence to support the idea that the relationship is real and not just a coincidence. This is expected because access to credit facilities is expected to help farmers optimally acquire modern technology and appropriate inputs for the farm business. The findings of Adeyemo et al., (2010) disagree with the results of this study where age and farming experience contributed to farmers' inefficiency while cooperative membership and education level increased efficiency in their studies conducted on cassava farming in Odeda Local Government of Ogun State, Nigeria.

In medium-sized farms, the results revealed that variables such as age, gender, household size, land acquisition, and source of labor were significant in addressing the level of farmer's allocative efficiency. The gender coefficient was significant at 10%, meaning that male heads of households increase allocative efficiency by 1.16% over the female counterpart, ceteris paribus. This may be due to the increase in farm size. The age coefficient was statistically significant at the 5% level and positively related to allocative efficiency. This means that an annual increase in the age of common tongue corn farmers will increase their allocative efficiency by 0.038%. Also, the coefficient of household size was significant at 5%, indicating that as the number of persons in the household increases, the allocative efficiency increases by about 3.82%, with other factors remaining constant.

A likely explanation for the positive correlation between household size and allocative efficiency could be the support provided by family members on the farm, which subsequently reduces labour costs in the long run. The coefficient of land purchase was significant at 1%, with the acquisition of land through inheritance increasing allocative efficiency by 4.95%. In large farms, the variables gender, education level, and farming experience were positively related and significant to allocative efficiency, while the farm size variable was significant but negatively related to allocative efficiency. The coefficients of gender and farming experience were both significant at 5% with values of 0.008 and 0.005. This suggests that male heads of household increase allocative efficiency by 0.8% than their female counterparts. He also stated that increasing a few farming experiences will increase the allocation efficiency by 0.5%.

The coefficient of education was significant at 1%, implying that an annual increase in education level increases allocative efficiency by 1.4%. The findings suggest that factors such as gender, education level, farming experience, and farm size play an important role in determining allocative efficiency in large farms. Households headed by men, individuals with higher levels of education, and those with more experience in agriculture tend to show higher levels of allocative efficiency. Conversely, larger farm sizes are associated with lower allocative efficiency. These findings could have implications for farm management strategies, resource allocation decisions, and policies aimed at improving agricultural productivity and efficiency. According to the combined findings, the R-squared value and F-value were determined as 0.239 and 21.613, respectively, which are considered statistically significant at the 10% level.

The R2 value of 23.9% indicates that the selected independent variables accounted for about 24% of the variation observed in allocative efficiency. Furthermore, an F-value of 21.6, significant at the 5% probability level, indicates that at least one of the independent variables affected the behavior of the dependent variable. In addition, other coefficients such as age (0.009), educational attainment (-0.057), farm size (0.104), farming experience (0.015), and access to credit (0.022) were found to have significant effects on the allocative efficiency of maize. Farmers operating a common tongue maize cropping system. These coefficients were statistically significant at various significance levels, including 5%, 1%, 5%, 10%, and 10%, respectively. The findings suggest that the independent variables have different effects on the allocative efficiency of maize farmers operating in different cropping systems.

The coefficients indicate that age, educational attainment, farm size, farming experience, and access to credit have significant effects on allocative efficiency. However, the direction of the effect is different for each variable. This coefficient suggests that each unit increase in age leads to a very small increase in allocative efficiency. This coefficient suggests that higher levels of education lead to lower allocative efficiency. This coefficient also suggests that larger farm size leads to a significant increase in allocative efficiency. This coefficient suggests that more years of farming experience leads to a small increase in allocative efficiency, and this coefficient suggests that access to credit leads to a small increase in allocative efficiency. This research is consistent with previous studies conducted on this topic.

For example, Anang and Shafiwu, (2022) found similar results regarding the negative effect of educational attainment on allocative efficiency in maize cultivation in contrast to the findings of (Olutumise and Oparinde, 2022). In addition, Adeyeye et al., (2024) and Akinbola et al., (2024) also identified a significant relationship between farm size and allocative efficiency, supporting our findings. Moreover, Appiah-Twumasi et al., (2022) and Anang and Shafiwu, (2022) documented the effect of access to credit on the allocative efficiency of maize farmers, which is consistent with our results. Conversely, Azhar et al., (2023) investigated the relationship between agricultural productivity and educational attainment in Punjab, Pakistan, and the results indicated a positive and significant effect of educational attainment on agricultural productivity.

More years of education led to increased allocative efficiency, thereby improving agricultural outcomes. Similarly, Doss, (2018) analyzed data from multiple countries and found that education significantly contributes to agricultural productivity and efficiency. The findings highlighted the importance of educational attainment such as literacy and numeracy skills in reducing inefficiencies in resource allocation and agricultural decision-making processes as also reported by several studies such as (Olubunmi-Ajayi et al., 2023; Oparinde et al., 2023; Olutumise et al., 2024).

Efficiencies Distribution of Sole Maize Farmers

Table 4 outlines the levels of technical, economic, and allocative efficiency among maize-only farmers. Efficiencies are expressed as percentages. Technical efficiency assesses the effectiveness with which farmers use inputs to generate outputs, while economic efficiency gauges how resources are optimized for profit maximization. Allocative efficiency reflects the farmers' capacity to distribute resources to minimize costs and optimize outputs. According to the table, the average technical efficiency rates for small, medium, and large-scale maize farms were 58.7%, 75.4%, and 99.8%, respectively, indicating the percentage of maximum potential output achieved due to production efficiency. The data show that small-scale farms have lower technical efficiency (58.7%) compared to medium (75.4%) and large-scale (99.8%) farms.

Table 3 Determinants of Allocative Efficiency of Sole Maize Farmers

Variables Parameters		**Scale of Production**							
		Small Scale		**Medium Scale**		**Large Scale**		**Pooled**	
		Coefficients	**P-Value**	**Coefficients**	**P - Value**	**Coefficients**	**P – Value**	**Coefficients**	**P – Value**
Constant	Z0	0.132	0.722	-0.844	0.222	178.234	0.352	-0.031	-
Age	Z1	0.001**	1.883	0.038**	2.042	0.001	0.010	0.009**	0.045
Gender	Z2	0.006*	1.954	0.116*	1.956	0.008**	2.045	-0.102	0.282
Marital Status	Z3	0.046	0.571	-1.138	0.123	0.028	0.059	0.002	0.982
Household size	Z4	0.020	0.381	0.382**	2.100	0.013	0.201	0.001	0.964
Educational level	Z5	0.059	0.762	0.030	0.000	0.014***	3.111	-0.057***	-0.006
Farming Experience	Z6	0.004***	2.466	-0.198	0.010	0.005**	2.002	0.015*	0.094
Farm size	Z7	0.002	0.989	0.426	0.045	-0.007***	3.412	0.104**	0.0501
Land acquisition	Z8	0.033	1.695	0.384***	3.059	-0.059	0.201	0.025	0.715
Source of Labour	Z9	-0.017	0.820	0.495**	2.201	-0.032	.0412	0.008	0.571
Access to credit	Z10	0.168**	2.230	0.227	0.041	-178.889	0.753	0.022*	0.088
R2	-	0.162	-	0.692	-	79.02	-	0.239	-
F-Value	-	2.214**	-	39.197***	-	40.005***	-	21.613*	-

Note: *, **, and *** mean significance at 10%, 5%, and 1% respectively.

Most small-scale farms (36.54%) had technical efficiency between 31% and 60%, with extremes ranging from 8.7% to 99.9%. For medium-scale farms, a similar distribution was observed, with 33.33% of farms falling into each of the three efficiency ranges (31%-60%, 61%-90%, and above 90%), displaying minimum and maximum technical efficiency values of 0.521 and 0.988, respectively. All large-scale farms demonstrated technical and allocative efficiency above 90%, with efficiencies ranging from 0.521 to 2.215. In terms of allocative efficiency, no sole maize farmers reached 100%, indicating all were below the maximum possible cost efficiency level. Small, medium, and large farms had mean allocative efficiencies of 59.3%, 86.6%, and 88.2% respectively, showing the percentage of potential cost efficiency they could potentially achieve.

This suggests room for improvement in their resource allocation decisions based on input prices. Among medium-scale farms, 44.44% had an allocative efficiency above 90%, while this figure was 100% for large-scale farms. Economic efficiency, a combined measure of technical and allocative efficiency, showed that small farms had nearly perfect efficiency at 99.8%, while medium and large farms recorded 89.8% and 73.5%, respectively, suggesting lower performance relative to their technical and allocative efficiencies. The study also reflects that 34.33% of farmers had a technical efficiency score below 30%, underscoring a significant inefficiency in input use or resource allocation.

Approximately 47.76% of farmers achieved a technical efficiency between 31% and 60%, indicating a moderate level of efficiency. The remaining farmers displayed higher efficiencies, with only a small fraction reaching the uppermost efficiency bracket (90%-100%). These findings highlight a broad variability in efficiency among farmers, with some achieving near-perfect efficiency and others operating far below potential, underscoring the diverse capabilities and challenges within the farming community. The study concludes with a broader analysis of mean values and variations in efficiency scores, showing significant discrepancies and potential for improvement across the board.

Table 4 Technical (TE), Economic (EE), and Allocative (AE) Efficiencies of Sole Maize Farmers

Efficiency Range	Small scale			Medium Scale			Large Scale			Pooled		
	TE	EE	AE	TE	EE	AE	TE	EE	AE	TE	EE	AE
	%	%	%	%	%	%	%	%	%	%	%	%
< 0.3	17.30	0	17.30	0	0	0	0	16.67	0	34.33	11.94	34.33
0.31-0.6	36.54	0	36.54	33.33	0	22.22	0	16.67	0	47.76	25.37	32.84
0.61-0.9	34.61	0	34.61	33.33	44.44	33.33	0	0	0	14.93	35.82	26.86
> 0.9	11.53	100	11.53	33.33	55.55	44.44	100	66.66	100	2.99	26.87	5.97
Total	100	100	100	100	100	100	100	100	100	100	100	100
Mean	0.5870	0.9984	0.5934	0.7542	0.8984	0.8660	0.999	0.9221	0.973	0.400	0.670	0.461
SD	0.2502	0.1460	0.2506	0.2047	0.1039	0.3172	0.8503	0.4177	0.1086	0.217	0.263	0.276
Minimum	0.0876	0.9983	0.0877	0.5216	0.6986	0.5316	0.99842	0.00554	0.9092	0.060	0.096	0.009
Maximum	0.9997	0.9984	1.0000	0.9883	0.9856	1.0000	0.99843	0.99946	1.0000	0.971	0.939	0.979

4. CONCLUSION AND RECOMMENDATIONS

The study aimed to evaluate the efficiency and productivity of sole maize farmers across different scales of production—small, medium, and large—in a specific agricultural region. The findings highlight significant differences in technical, allocative, and economic efficiencies among these scales, providing insights for policy and practice to enhance maize production. The research confirms that the majority of maize farmers operate on small-scale farms with an average size ranging from 0.6 to 1.42 hectares, which aligns with the classifications reported by previous studies. This small scale presents challenges such as limited resources, vulnerability to risks, and poor market access, which can potentially hinder farmers' ability to break even or achieve high levels of productivity. Maximum likelihood estimates (MLE) for the stochastic frontier production function again show that small farms show a higher degree of variability in efficiency compared to medium and large farms.

For smallholder farms, the use of inputs such as herbicides, labour, and seed significantly increases maize production, while fertilizer has a negative impact. Medium farms show positive and significant effects of herbicides, labour, seed, and fertilizer on maize production, while large farms benefit significantly from increased farm size. The data collected indicate that fertilizers, labour, farm size, and seed rate are critical determinants of maize production at all scales. For small farms, age, gender, farming experience and access to credit are among the significant factors affecting allocative efficiency. Older farmers and farmers with more farming experience tend to have higher allocative efficiency, and male-headed households show slightly higher efficiency than female-headed households. Access to credit positively influences allocative efficiency. In medium-sized farms, age, gender, household size, land acquisition and source of labor are significant factors.

Larger household sizes and inherited land contribute positively to efficiency, with male-headed households again showing higher efficiency. Higher age and household size correlate with higher allocative efficiency. For large farms, significant factors include gender, education level, farming experience, and farm size. Higher levels of education and more farming experience lead to increased efficiency, while male-headed households are more efficient. However, larger farm sizes are associated with lower efficiency. The distribution of efficiency also shows that the highest technical efficiency is achieved by large farms (99.8%), followed by medium (75.4%) and small farms (58.7%). Allocative efficiency is highest in large farms (88.2%), indicating better resource allocation compared to medium (86.6%) and small farms (59.3%). Economic efficiency, the product of technical and allocative efficiency, is highest in small farms (99.8%), reflecting their ability to maximize output relative to input use.

The results therefore highlight the need for targeted interventions to improve efficiency across all scales of maize production. Smallholder farmers would benefit from better access to resources, training on optimal use of inputs, and better market access. Medium and large farmers could increase productivity through better management practices and efficient allocation of resources. Policies should focus on supporting farmers to scale up operations to medium and large scale to achieve economies of scale and improve the overall efficiency of maize production. Overall, increasing maize productivity requires a multifaceted approach that addresses the unique challenges faced by farmers at different scales. By improving technical, allocative, and economic efficiency, farmers can achieve higher outputs and profitability, contributing to food security and economic development.

Acknowledgment

We thank the participants who all contributed samples to the study. We also thank Prof. TT Amos for proofreading the work.

Author contributions

Conceptualization, OTS, and OPO; methodology, OTS, and AJ; formal analysis, OPO, and OTS; writing—review and editing, AOB, OTS and OPO; survey design, A, OTS, and TSO; project administration, OTS, and OPO; writing—original draft preparation, OTS and OPO; validation, AOB; investigation and supervision, AOB and AJ; resources, AOB, AJ, and OTS. All authors have read and agreed to the published version of the manuscript.

Ethical approval

The study was approved by the Ethics Committee of the School of Agricultural and Agricultural Technology, Federal University of Technology, Akure. (Ethical approval code: FUTA/SAAT/ARE/24/R012).

Informed consent

Written & Oral informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this manuscript.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES

1. Adeyemo R, Oke JTO, Akinola AA. Economic Efficiency of Small-Scale Farmers in Ogun State, Nigeria. Tropicultura 2010; 28(2):84-88.
2. Adeyeye MO, Ojo OO, Olubunmi-Ajayi TS, Oladosu OA. Optimizing Resource-Use Efficiency of Yam Producers in Ondo State, Nigeria: A Path to Enhanced Food Production. Int J Adv Econ 2024; 6(4):124-138.
3. Ado SG, Usman IS, Abdullahi US. Recent development in maize research at the Institute for agricultural research, Samaru, Nigeria. Afr Crop Sci Conf Proc 2007; 8:1871-1874.
4. Akinbola AE, Olubunmi-Ajayi TS, Ijigbade JO, Akinrotimi AF. Market concentration and efficiency's determinants of tomato production in Oyo State, Nigeria. Int J Appl Res Soc Sci 2024; 6(7):1333-1345.
5. Alem H, Lien G, Hardaker JB. Economic performance and efficiency determinants of crop-producing farms in Norway. Int J Product Perform Manag 2018; 67(9):1418-1434.
6. Amos TT. An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. J Soc Sci 2007; 15(2):127-133. doi: 10.1080/09718923.2007.11892573
7. Anang BT, Shafiwu AB. Profit efficiency of smallholder maize farmers in sagnarigu municipal of northern Ghana. Rev Agric Appl Econ 2022; 25(1):104-112.
8. Appiah-Twumasi M, Donkoh SA, Ansah IGK. Innovations in smallholder agricultural financing and economic efficiency of maize production in Ghana's northern region. Heliyon 2022; 8 (12):e12087. doi: 10.1016/j.heliyon.2022.e12087
9. Azhar SZ, Ur-Rahim F, Naqvi RA, Awan S. The Role of Farmers' Education in Bolstering Cereal Yields: A Case Study

of Cereals in Punjab. J Contemp Macroeconomic Issues 2023; 4 (2):106-114.

10. Babatunde RO, Omotosho OA, Sholotan OS. Socio-economic Characteristics and Food Security Status of Farming Households in Kwara State, North-Central, Nigeria. Pak J Nutr 2007; 6(1):49–59.
11. Bankole AS, Ojo SO, Olutumise AI, Garba ID, Abdulqadir MI. Efficiency Evaluation of Small Holders Palm Oil Production in Edo State, Nigeria. Asian J Agric Ext Econ Sociol 2018; 24(4):1-9.
12. Bravo-Ureta BE, Evanson RE. Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay. Agric Econ 1994; 10(1):27–37.
13. Chen C, Pan J, Lam SK. A review of precision fertilizer research. Environ Earth Sci 2011; 71(9):4073-4080. doi: 10.1007 /s12665-013-2792-2
14. Doss CR. Men's crops? Women's crops? The gender patterns of cropping in Ghana. World Dev 2018; 30(11):1987-2000.
15. Ehinmowo OO, Simon-Oke OO, Fatuase AI, Ojo SO. Determinants of Technical efficiency and Income Inequality of Food Vending as a Family Business in Southwest Nigeria. Glob Bus Rev 2017; 18(6):1412-1423.
16. Fadare AO, Akerele D. Factors Influencing Adoption Decisions of Maize Farmers in Nigeria. Int J Food Agricultural Econ 2014; 2(3):45-54.
17. Fatuase AI. Climate Change Adaptation: A Panacea for Food Security in Ondo State, Nigeria. Theor Appl Climatol 2017; 12 9(3-4):939-947.
18. Ijigbade JO, Olutumise AI, Toluwase SOW, Awoseyila F, Aturamu OA. Assessing the efficiency and profitability potentials of honey input supply: The case of South West Nigeria. Trop Agric 2023; 100(4):351-364.
19. Key N. Farm size and productivity growth in the United States Corn Belt. Food Policy 2019; 84:186-195.
20. Leah HS, James SG, Navin R, Mario H, Paul CW. Subnational distribution of average farm size and Smallholder contributions to global food production. Environ Res Lett 201 6; 11(12):124010. doi: 10.1088/1748-9326/11/12/124010
21. Mutambara J, Ayoola GB, Ejembi EP, Avav T, Masvongo J, Moyo S. Production and Productivity of Maize Subjected to Modern and Traditional Methods of Weed Control Options in the Federal Capital Territory, Nigeria. J Agric Ext Rural Dev 2013; 5(5):107-114.
22. Ogunjimi O, Ogunjimi OK, Durojaye A. Technical efficiency and constraints among medium scale maize production in Oyo State, Nigeria. J Biol Agric Healthcare 2014; 4(24):1-13.
23. Ogunniyi L, Oluwafemi ZO, Adepoju AA. Mini-Livestock Farming as a Strategy for Food Security in Oyo State of Nigeria. J Agric Sustain 2015; 7(2):171-186.
24. Olarinde LO. Analysis of Technical Efficiency Differentials Among Maize Farmers in Nigeria. African Economic Research Consortium, Nairobi. AERC Research Paper 232. 2011.
25. Olubunmi-Ajayi TS, Amos TT, Borokini EA, Aturamu OA. Profitability and Technical Efficiency of Maize-Based Cropping System Farmers in Ondo State, Nigeria. Int J Agric Sci Res Technol Ext Educ Syst (IJASRT in EESs) 2023; 13(1):11-22.
26. Olutumise AI, Bankole AS, Olutumise BO, Aturamu OA. Gender differential in allocative efficiency of oil palm processors in Southwest, Nigeria. Kasetsart J Soc Sci 2023; 44 (2):327-336.
27. Olutumise AI, Ekundayo BP, Omonijo AG, Akinrinola OO, Aturamu OA, Ehinmowo OO, Oguntuase DT. Unlocking sustainable agriculture: climate adaptation, opportunity costs, and net revenue for Nigeria cassava farmers. Discov Sustain 2024; 5(1):67. doi: 10.1007/s43621-024-00249-8
28. Olutumise AI, Oparinde LO. Climate Information and Health Variables as Determinants of Technical Efficiency: Insight from Food Crop Farmers. Int J Agric Sci Res Technol Ext Educ Syst (IJASRT in EESs) 2022; 12(3):127-137.
29. Omonijo AG, Olutumise AI, Olabimpe OT. Agro-climatic zonation based on rainfall distribution over. J Meteorology Clim Sci 2023; 22(1):195-224.
30. Oparinde LO, Olutumise AI, Adegoroye A. Does agroforestry technology adoption affect income inequality among arable crop farmers in Southwest, Nigeria? A gender perspective. Sarhad J Agric 2023; 39(4):848-860.
31. Ren C, Jin S, Wu Y, Zhang B, Kanter D, Wu B, Xi X, Zhang X, Chen D, Xu J, Gu B. Fertilizer overuse in Chinese smallholders due to lack of fixed inputs. J Environ Manage 2021; 293:11291 3. doi: 10.1016/j.jenvman.2021.112913
32. Séogo W, Sawadogo WJP, Zahonogo P. Technical efficiency of maize farmers across two agro ecological zones of Burkina Faso. African J Economic and Sustainable Development 2021; 8(4):275-290.
33. Sheng Y, Chancellor W. Exploring the relationship between farm size and productivity: Evidence from the Australian grains industry. Food Policy 2019; 84:196-204.
34. Singh C, Dorward P, Osbahr H. Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. Land Use Policy 2016; 59:329-343.