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Efficiency of Sorghum Production in Selected Local Government Areas of Kano State, Nigeria: A Stochastic Frontier Approach

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ABSTRACT

This study analyzed the technical, allocative and economic efficiencies of sorghum production in selected Local Government Areas of Kano State, Nigeria. A Multi-stage sampling technique was employed to randomly select 215 sorghum farmers. Data were collected using structured questionnaire and analyzed using descriptive statistics and stochastic production frontier function. The results indicate that the average age of sorghum farmers was 42 years with a mean farming experience of 25 years. The majority (76.75%) had some form of formal education. It was further found that membership of cooperative ($p<0.05$), extension contact ($p<0.01$), and access to credit ($p < 0.01$) were key determinants responsible for the variation in efficiency among sorghum producers in the study area. The mean technical, allocative, and economic efficiencies were 0.61, 0.62 and 0.37 respectively. It is concluded that sorghum farmers were not economically efficient and it is recommended that farmers receive training on improved agronomic practices and have increased access to credit facilities to boost productivity and efficiency.

INTRODUCTION

Sorghum (*Sorghum bicolor (L) Moench*) is a major food crop in Africa and the world's fifth most important cereal as well as the staple food in the Northern States of Nigeria that covers the Sahelien, Sudanian and Guinea savannah ecological zones (Ajeigbe, Ignatius, Folorunsho and Abubakar, 2020). In Nigeria, aorghum is grown on over 5.5 million hectares, which accounts for the production of 2.7 to 2.8 million tones annually (Statista, 2021). As a result of competing demands for sorghum by both human consumption and animal feeds, enhancing production efficiency is crucial to bridge the gap between demand and supply.

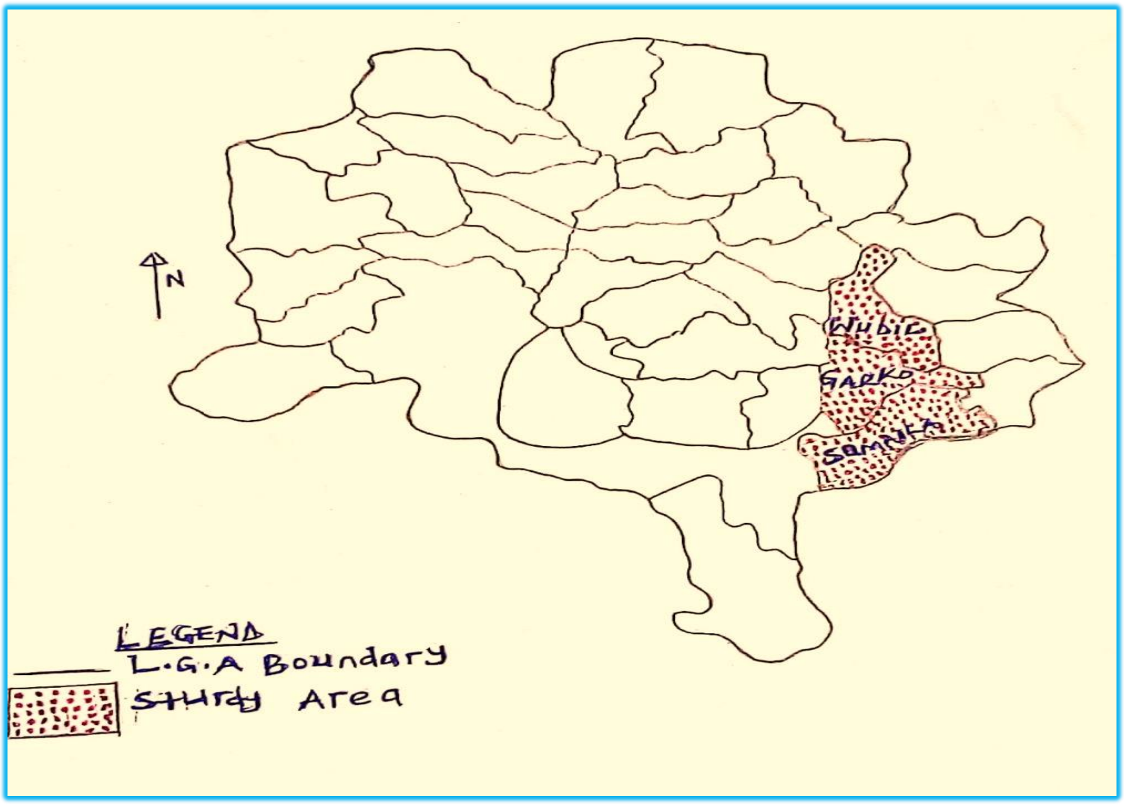
In production economics, efficiency is categorized into three types; technical, allocative and economic. Improving efficiency is a viable strategy for increasing productivity without necessarily increasing resource use or adopting new technologies, thereby reducing the crop's demand-supply deficit (Sime et al., 2022). The relationship between farm size and productivity remain a contested issue in agricultural economics. While some studies support an inverse relationship (Sheng et al., 2019). However, Muyanga & Jane (2019), maintain that there are positive relationship between productivity and farm size. Therefore, this study aims to contribute to this discourse by investigating the technical, allocative and economic efficiency of sorghum farmers in Kano State. The objective is to identify the factors responsible for inefficiencies with a view to informing targeted policies aimed at enhancing sorghum productivity in the region.

METHODOLOGY

Study Area

The study was conducted in Kano State, Nigeria. The State covers an area of about 20,280 square kilometers with a projected populations of 13,969,085 (Male: 7,124,234 and Female: 6,844,852) as at 2021 at 3.2% growth rate (NPC, 2021). Geographically it lies between latitude 10˚ 30´N and 13˚02´N, and longitude 8˚ 45´E and 12˚ 05´E. The State experience an average annual rainfall of 617 mm, with temperature ranging between 14.2˚C in January to about 40.3˚C in April being the warmest month. Kano borders

Jigawa to the north and east, Bauchi to the southeast, Kaduna to the southwest, and Katsina to the northwest. Due to the predominance of sorghum production, Wudil, Garko and Sumaila LGAs were selected. Most of the people in this area are farmers, traders and artisans. Other crops cultivated in the area include millet, maize, wheat, rice, groundnut and vegetables. Animals reared are cattle, goats, sheep and poultry.



Source: Adapted from the Administrative Map of Kano State

Figure 1: Map of Kano State showing Study Area (Wudil, Garko and Sumaila L.G.A.)

Sample size and sampling technique

A multi-stage sampling technique was employed. In the first stage, Wudil, Garko and Sumaila LGAs were purposively selected based on their high sorghum production. In the second stage, two wards from each of the selected LGAs were also purposively selected based on predominance of sorghum production in the wards. A sample frame of 1,438 farmers was obtained from Kano State Agricultural and Rural Development Authority (KNARDA, 2019). Using a 15% sampling intensity, a total sample size of 215 was randomly selected as shown in Table 1.

Table 1: Sample size and Sampling Technique

LGAs	Wards	Sample Frame	Sample Size (15%)
Wudil	Indabo	264	40
	Kausani	253	38
Garko	Garko	242	36
	Sarina	228	34
Sumaila	Sumaila	241	36
	Garfa	210	31
	Total	1438	215

Source: Kano State Agricultural and Rural Development Authority (KNARDA), 2019

Method of Data Collection

Primary data were used for this study. The primary data were generated through structured questionnaire. The data gathered include the socio-economic characteristics of sorghum farmers, yields obtained, farm size, cropping patterns, inputs (seeds, fertilizer, agro-chemicals, labour), and cost and price information for inputs and outputs for the 2019 production year.

Analytical techniques

The data collected were analyzed using descriptive Statistics and Stochastic frontier analysis (SFA).

Descriptive statistics: The descriptive statistics such as frequency, mean and percentages were used to summarize the socioeconomic characteristics of the sorghum farmers in the study area.

Stochastic production frontier function: This was used to estimate the level of technical, allocative and economic efficiencies of sorghum production. Following the methodology of Coelli (1996) and Battese and Coelli ((1995), the stochastic production frontier model is specified as:

$Y_i = f(X_i, \beta) + (V_i - U_i)$ …………………………………………………………………………………… (1)

Where:

Y_i = Output of the i-th farmer

X_i = K x 1 vector of input quantities of the i-th farmer

β = Vector of unknown parameter estimated

Vi = Random error term assumed to be $N(0,\delta v^2)$ and independent of the U_i. It is assumed to account for measurement error and other factors not under the control of the farmer.

U_i = Non-negative random error term associated with technical inefficiency.

The explicit form of the Cobb-Douglas production function is presented as follows:

$1nY = \beta_0 + \beta_1 1nX_1 + \beta_2 1nX_2 + \beta_3 1nX_3 + \beta_4 1nX_4 + \beta_5 1nX_5 + \beta_6 1nX_6 + v - u$ ……… (2)

Where;

Y = Sorghum output (kg)

β_0 = Constant term

X_1 = Farm size (ha)

X_2 = Quantity of seed used (kg)

X_3 =Quantity of fertilizer used (kg)

X_4 = Quantity of herbicide used (ltr)

X_5 = Labor used (man-day)

X_6 = Quantity of sorghum consumed (kg)

β_1 - β_6 = Estimated parameter

The technical inefficiency effect model Ui as specified by Coelli (1996), is defined by;

$Ui = \delta_0 + \sum \delta_i Z_i$ ………………………………………………………………………………. (3)

Which is explicitly expressed as:

$Ui = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i}$ ……………………………….. (4)

Where:

U_i = Technical inefficiency

Z_1 = Age of the farmer (in years)

Z_2 = Formal education (in years)

Z_3 = Total household size (Number of people in household)

Z_4 = Sorghum production experience (in years)

Z_5 = Membership of farmers association (Dummy variable; where; 1= member of farmers' association, 0 = otherwise)

Z_6 = Extension contact (Dummy variable, where; 1=had contact with extension, 0 = otherwise)

Z_7 = Access to credit (Dummy variable, where 1 = had access to credit, 0 = otherwise)

δ_0 = constant

δ_1 - δ_7 = Estimated parameter

Allocative efficiency specification

The stochastic frontier cost function was used to estimate allocative efficiency (AE), following Schmidt and Lovell (1979) and Battese and Coelli (1995). If we wish to specify a stochastic frontier cost function, we simply alter the error term specification from $(V_i - U_i)$ to $(V_i + U_i)$, this substitution will transform the production function defined by (1) into cost function (Coelli, 1996);

$C = Q + (V_i + U_i)$ i = 1.... n, (implicit) ……………………………………………………….. (5)

Where;

C is the (logarithm of the) cost of production of the i-th firm,

Q is a k x 1 vector of (transformation of the) input prices of the i-th firm,

β is a vector of unknown parameters estimated

V_i are random variables which are assumed to be $N(0,\delta v^2)$ and independent of the U_i

U_i are nonnegative random variables which are assumed to account for the cost of inefficiency in production, which are often assumed to be $[N(0,\delta u^2)]$

The explicit form is expressed as follows:

$1nC = \beta_0 + \beta_1 1nP_1 + \beta_2 1nP_2 + \beta_3 1nP_3 + \beta_4 1nP_4 + \beta_5 1nP_5 + \beta_6 1nP_6 + v + u$ …………... (6)

Where,
C = Total cost of sorghum production (Naira)
P_1 = Cost of renting land (₦/ha)
P_2 = Cost of labor used (₦/man-day)
P_3 = Cost of seed used (₦/kg)
P_4 = Cost of fertilizer used (₦/kg)
P_5 = Cost of herbicide used (₦/ltr)
P_6 = other costs (₦/ha)
β_1 - β_6 = Parameters to be estimated of the cost function

Economic efficiency specification

Farrell (1957) as cited in Ogunniyi (2015), defined the economic efficiency as the product of technical and the allocative efficiencies.
Economic Efficiency (EE) = Technical Efficiency (TE) X Allocative Efficiency (AE) …… (7)

RESULTS AND DISCUSSION

Socio-economic Characteristics of Sorghum Farmers

This results in Table 2 present the socio-economic characteristics of sorghum farmers in the study area. These include age, gender, and marital status, educational level, farming experience and farm size.

Table 2: Socioeconomic Characteristics of the Sorghum Farmers

Variables	Frequency	Percentage	mean
Age (Years)			42
Gender			
Male	193	89.77	
Female	22	10.23	
Marital Status			
Married	188	87.44	
Single	20	9.3	
Divorced	7	3.26	
Farm Size(Ha)			1.7
Farming Experience (years)			25

Source: Field survey, 2019

The results in Table 2 revealed that the mean age of sorghum farmers in Kano State was 42 years, implying that sorghum farmers were in their active and productive age. This indicates the availability of able-bodied labor force to carry out the strenuous farming activities and it is expected to increase their production efficiency. This finding aligns with Muhammed *et al.*, (2022), who reported that the productive age of sorghum farmers was between 21-45 years in the study of sorghum production in Nigeria. The results also showed that majority (89.77%) of sorghum farmers were male. The might be as result of gender inequality in Nigeria where male has access to production resources more than women have and as a result, encourages more men to go in to farming than women. This finding agrees with Aduaba *et al.*, (2013) and Jimjel, (2013) who reported that sorghum farming was dominated by 90% and 85% male in the study of economic analysis of sorghum production among sorghum farmers in kwara state, Nigeria and socio-economic factors that affect sorghum production in Adamawa state, Nigeria respectively. The results further revealed that majority (87.44%) of sorghum farmers were married. This implies that majority of the respondent were married in the study area.This is due to the fact that the study area is agrarian societies where marriage is seen as a way of increasing the household size to assist in carrying out farming activities which can go along way in boosting farm income thereby alleviating poverty. This finding is in consonance with Yusuf (2017), who reported that majority of sorghum farmers were married in Gombe State, Nigeria. The results also indicate an average farm size and farming experience of 1.7 hectares and 25 years. This indicates that majority of sorghum farmers were small farm holders who engage in subsistence agriculture. According to NBS, (2006), small scale farmers are farmers who cultivate between 0.1 hectare and 5.99 hectares and produce on subsistence level. Besides, the sorghum farmers had wealth of experiences over time to manage and adjust to challenges associated with sorghum production in the study area.

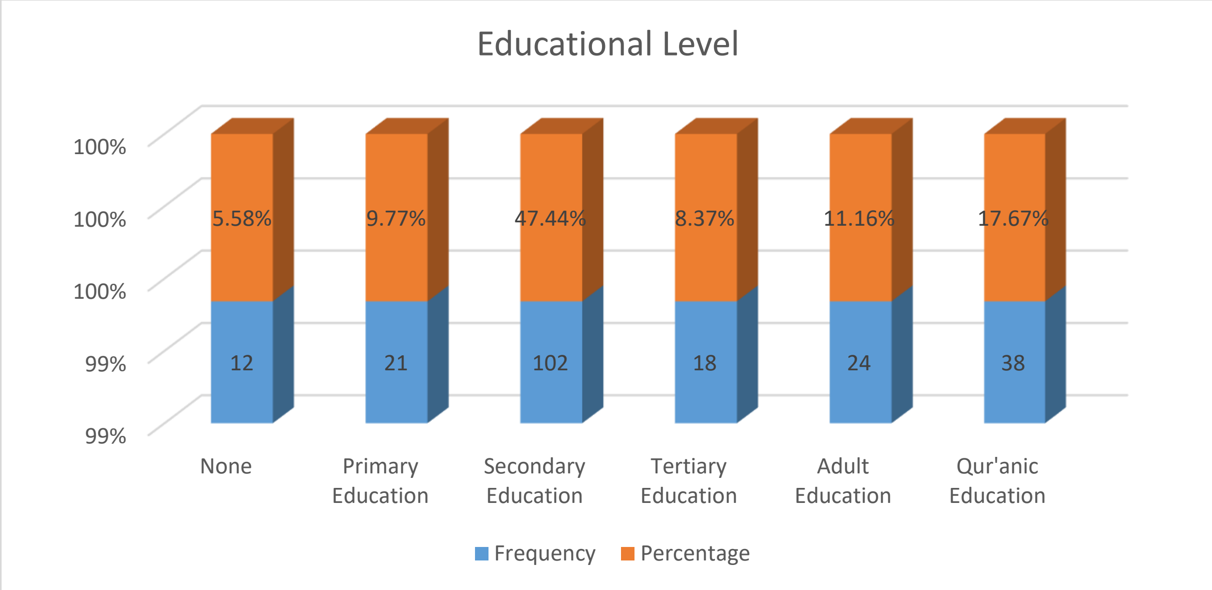


Figure 2: Educational level of the sorghum farmers in Kano State

The results in Figure 2 revealed that most (47.44%) of sorghum farmers had secondary education while 5.58% had no formal education. This relatively high level of education is favourable for the adoption of improved farming technologies

Maximum likelihood estimates of the stochastic frontier production function for sorghum farmers

The results of stochastic frontier production function for the maximum likelihood estimate are presented in Table 3 below:

Table 3: Maximum likelihood estimates of the stochastic frontier production function for sorghum farmers

Variables	Coefficient	Standard error	t-ratio
Constant	9.3975	0.9573	9.816***
Farm size	1.5552	0.1390	11.1884***
Cost of seeds	-0.0965	0.0416	-2.318**
Fertilizer	0.0662	0.0901	0.735NS
Herbicides	0.0467	0.0702	0.665NS
Labour	0.0422	0.0820	0.515NS
Quantity consumed	-0.1975	0.0822	-2.403***
Inefficiency model			
Age	0.0009	0.0053	0.174NS
Years of school	-0.0061	0.0136	-0.455NS
Household size	0.03286	0.0304	1.0NS
Farming experience	-0.0027	0.0047	-0.57NS
Membership of coop	0.1600	0.0742	2.21**
Extension contact	0.2255	0.0709	3.1***
Access to credit	0.5409	0.1307	4.138***
Variance parameters			
Gamma (γ)	0.9960	0.2461	8.111***
Sigma squared (δ^2)	1.2217	0.0028	436.0***
RTS	1.4163		

Source: Field survey, 2019 * 1% probability, ** 5% probability and*10% probability**

The diagnostic statistics in Table 3 shows that the variance parameters for the stochastic frontier production function were statistically significant at 1%probability level. The estimated value of variance ratio represented by gamma (γ) was 0.9960. This implies that about 99 percent variations in the production among the sorghum farmers is due to inefficiencies while the value of sigma squared (δ^2)1.2217 indicates good fit and correctness of the distributional form assumed for the composite error term in the model.

The coefficient for Farm size (1.5552) was positive and statistically significant at 1%, showing that sorghum output increases with land area. This finding contradicts the inverse farm size-productivity relationship (Sheng et al, 2019) but may be explained by the overall small and fragmented nature of landholdings in the area. Where marginal increase in size can lead to significant output gains.

The coefficient for cost of seed (-0.0965) was negative and statically significant at 1% probability level, this implies that a unit increase in cost of sorghum seed may likely leads to decrease in the cost of production. This is against the *a priori* expectation because increase in cost of sorghum seed is expected to increase the cost of production. The reason for this result could be attributed to the fact that majority of the sorghum farmers mostly used sorghum seed from the store and are likely to sell more when the price increase and thereby reducing the quantity of sorghum seed. The result disagrees with the findings of Tijjani and Bakari (2014) who found that adoption of improved seeds increase the cost of production although may likely increase the technical efficiency. The quantity of sorghum consumed (often retained for seed or food) had a negative and significant coefficient, implying that higher retention rates reduce marketable surplus and potentially reinvest able capital.

Inefficiency variables

The positive signs of the coefficient for the inefficient variables indicate that an increase in these variable increases inefficiency (i.e., decreases efficiency). This is the common interpretation for such model.

The results showed that cooperative membership, extension contact, and access to credit were all positive and significant. This indicate that a lack of these resources significantly increases inefficiency. Therefore, enhancing access to cooperatives, extension services and credit is crucial for reducing inefficiency. This finding move in concord with studies by Ahmed and Mesfin (2017) on cooperative, Bangkim & Zakia (2021) on extension and Aduba et al., (2013) on credit.

Technical Allocative and Economic Efficiencies of Sorghum Farmers in the Study Area

The distribution of technical, allocative and economic efficiencies scores are presented on Table 4.

Table 4: Technical, Allocative and Economic Efficiency of Sorghum Farmers in Kano State

Efficiency class	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
	Technical efficiency		Allocative Efficiency		Economic efficiency	
0.01-0.30	168	78.1	36	16.7	156	72.7
0.31-0.60	19	8.8	8	3.7	26	12.1
0.61-0.90	8	3.7	9	4.2	1	0.5
0.91-1.20	20	9.3	162	75.6	32	14.9
Total	215					
Mean	0.61		0.62		0.37	
Minimum	0.01		0.41		0.01	
Maximum	1.00		0.98		0.98	

Source: Field survey, 2019

The results in Table 4 showed that the mean technical efficiency (TE) was 0.61, implying that farmers could increase output by 39% using same level of inputs by adopting the practices of most efficient peers. This finding is consistent with Abba (2012), who reported mean technical efficiency of 0.72 in Adamawa State, Nigeria.

The results also revealed that the mean allocative efficiency (AE) of the sorghum farmers was 0.62 which indicate that sorghum farmers in the study area could reduce cost by 38% by optimally combining inputs given their prices. Majority (75.6%) of the farmers had allocative efficiency of 0.98 and above. This implies that the farmers are fairly efficient in allocating the limited resources for production

However, the mean economic efficiency (EE) was low at 0.37. This implies that sorghum farmers in the study area are not using resources in cost-minimizing and output maximizing manner. Therfore, for a farmer to achieve economic efficiency of his most efficient counterpart, he could realize about 63% cost savings. This finding move in tandem with Gosa *et al,* (2016), reported mean EE of 32% in the study of economic efficiency of sorghum production for smallholder farmers in Habro District, Ethiopia.

CONCLUSION AND RECOMMENDATION

Based on the findings of this study it can be inferred that sorghum farmers were relatively technically and allocative efficient, however, economically inefficient. The inefficiency is driven by lack of access to key resources, cooperative support, agricultural extension services and formal credit. It is recommended that Government and NGOs should intensify effort to provide regular and effective extension services to educate farmers on good agronomic practices, efficient use of inputs and cost management and all existing credit facilities and schemes should be put in place by the Government to assist farmers should be strengthened so that farmers can have access to soft loan and such loans should be interest free with no stringent condition so that farmers can expand their scale of sorghum production.

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