IJAFLS
e-ISSN: 2602-4381
International Journal of Agriculture, Forestry and Life Sciences
Original Article Open access Int J Agric For Life Sci (2024) 8(1): 5-9

# Determinants of Technical Efficiency and Economies of Scale in Sorghum (*Sorghum bicolor*) Production, Kaduna State, Nigeria: Implication for Sustainable Income

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**Citation**
Alabi, O.O., Momoh, A.A., Isah, H., Bayei, J.D., Aluwong , J.S., Atreh, P.A., Olumuyiwa, B.A, Okoh, S.O., Haruna, O.E. (2024). Determinants of Technical Efficiency and Economies of Scale in Sorghum (Sorghum bicolor) Production, Kaduna State, Nigeria: Implication for Sustainable Income. Int J Agric For Life Sci (2024) 8(1):5-9.
**Received** :29 March 2024
**Accepted** :25 May 2024
**Published Online** :29 June 2024
**Year:** :2024
**Volume** :8
**Issue** :1 (June)
**Pages** :4-9



International Journal of Agriculture, Forestry and Life Sciences; Edit Publishing, Eskişehir, Türkiye.


**Available online** https://dergipark.org.tr/ijafls

## Abstract
This study examined the determinants of technical efficiency and economies of scale in sorghum (Sorghum bicolor) production, Kaduna State. The result shows that sorghum production was profitable in the study area. The calculated gross margin and net farm income of sorghum production per hectares were 811, 211.27 Naira (853.90 USD) and 728, 947.93 Naira (767.31 USD) respectively. The significant factors influencing technical efficiency of sorghum production include farm size, hired labour, fertilizer input, and seed input. In the technical inefficiency component, the significant socio-economic factors increasing technical efficiency of sorghum production include age, household size, farming experience, educational level, access to credit facilities, farmers' internet usage, media interest and usage. The sorghum farmers' relations with public institutions are not statistically significant in influencing technical efficiency of sorghum production. The return to scale was estimated at 0.8299, this signifies the decreasing return to scale. The average technical efficiency score was 0.6047 leaving a gap of 0.3953 for improvement. The major constraints facing sorghum farmers include lack of credit (1st), high cost of inputs (2nd), and bad road infrastructures (3rd). The policy recommendations include provision of credit facilities to sorghum farmers at low interest rate devoid of cumbersome administrative procedures. The provision of fertilizers, improved seeds, and chemicals to sorghum farmers at affordable prices for increase productivity and efficiency.

Key words
Determinants, Technical Efficiency, Elasticities of Production, Economies of Scale, Sorghum Production, Sustainable Income, Nigeria.

**Introduction**
Sorghum (*Sorghum bicolor*) is the fourth most important cereal crops in the world after wheat, rice, and maize (Sani and Oladimeji, 2017). It is a staple food crop in Africa, India, and China. Sorghum (*Sorghum bicolor*) is widely cultivated in the northern guinea savannah zone of Nigeria. The production of sorghum in Nigeria for 2022 season was 6,806,370 tonnes, the area harvested was 5,700,000 hectares, and the yield in 100g/ha was 11941 (FAOSTAT, 2023). Nigeria is the leading sorghum producers in Africa at 34%, followed by Sudan at 21%, other countries like Ethiopia, Tanzania, Uganda, Rwanda, and Kenya which accounted for 7,4,2, 0.8, and 0.6% respectively of sorghum produced in Africa (Okeyo et al., 2020). Nigeria is the largest producer of sorghum in West Africa accounting for around 71% of total output in the sub-region (Ogbonna, 2011). India and United States of America are the leading sorghum producers in the world cultivating 16 million and 11 million hectares respectively. Total sorghum production in the world exceeds 50 million tonnes (Sani and Oladimeji, 2017). Sorghum is the largest staple cereal crop accounting for 50% of the total output and occupying about 45% of the total land area devoted to cereal crops production in Nigeria (FAO, 2019). It has been reported that between 70 – 85% of the poor Africans entirely depend on agriculture for livelihood (Byerlee et al., 2005; Ravallion et al., 2007). Sorghum serves as a staple food crop for many sub-Saharan African countries and it's a key ingredient for various industries such as feed, breweries (FAO, 2015). Sorghum plays an important role in providing food security in the face of climate change and as a source of livestock feeds in many developing countries (Mundia et al., 2019). Sorghum is a very valuable industrial crop for brewing non-alcoholic and alcoholic drinks as well as in the confectionary and baking industry in Nigeria (Baiyegunhi and Fraser, 2009). Sorghum grain is fermented for malting and used in preparing local brewing products. Industrially, sorghum is predominantly used by firms producing beverages, confectionaries, breakfast cereals, and a small percentage of the sorghum grain is also used as animal feed. The stalks are used to build fences or shelters and as livestock feed. Sorghum is used as raw materials for the biofuel industries (Yahaya et al., 2022; GAIN, 2020). Sorghum stover and stems are used as animal feed and wall board for house building respectively (Omonona et al., 2019). The small-scale farmers' who constitute the largest percentage of farming populations are threatened with the problems of rural poverty. The farmers cannot afford to purchase necessary farm inputs such as pesticides, fertilizers, improved seeds, which leads to low productivity. The farmers had low income, low savings and investment, and hence low productivity. Sorghum yields in Nigeria and most of sub-Saharan Africa are low (Omonona et al., 2019). Sorghum production in most sub-Saharan Africa is characterized as traditional, subsistence, and small-scale with low yields, whereas in industrialized countries such as the USA, production is mechanized, large scale and high input use (CGIAR, 2015). Technical efficiency measures the ability of a sorghum production unit to obtain the maximum possible output from a combination of production factors. Efficiency can be defined as the ability of the sorghum producers to produce the maximum quantity of sorghum with the minimum production factor. Technical efficiency is a precise and relevant instrument in the analysis of the technical performance of farms, especially those producing cereals. Technical efficiency measures the efficiency of the use of resources and factor of production. Technical efficiency is the allocation of inputs involved in the production process of a given output. The sorghum economic potential has not been fully realized in Nigeria and sub-Saharan African (SSA) countries due to a number of production and productivity constraints. The small-scale sorghum farmers who accounted for 90% of sorghum production for instance still prefer to use their farm-saved seed which is local and unimproved varieties. This local landrace has low yield potentials, long maturity, tall plant height and are non-responsive to improved agronomic management practices (Ajeigbe et al., 2018). A critical analysis of existing literatures shows the current research gap to fill which show no work done on technical efficiency and economies of scale in sorghum production in the study area.

**Objectives of the Study**
The broad objective is to examine the determinants of technical efficiency and

economies of scale of sorghum (*Sorghum bicolor*) production, Kaduna State, Nigeria. The specific objectives are to:

(i) determine the socio-economic, institutional, and farm specific characteristics of sorghum farmers;
(ii) analyze the costs, returns and profitability of sorghum production;
(iii) evaluate the factors influencing the technical efficiency of sorghum production;
(iv) estimate the elasticities of production, and economies of scale in sorghum production;
(v) determine the technical efficiency scores of sorghum farmers; and
(vi) identify the constraints faced by sorghum farmers in the study area.

**Methodology**

This research study was conducted in Kaduna States. The sample size and sample frame of sorghum farmers in the area was 160 and 267 respectively. Primary sources of data were obtained. A well-designed and a well-structured questionnaire was administered to the respondent using well-trained extension officers. The structured questionnaire was subjected to validity and reliability tests. This research work used the formula advanced by Yamane (1967) in the estimation of the sample size. The formula is stated thus:

$$n = \frac{N}{1+N(e^2)} = 160 \ldots\ldots\ldots\ldots (1)$$

Where, $n$ = Calculated Sample Size, $N$ = Sample Frame (Number), $e$ =Maximum Acceptable Margin of Error as Determined by the Researcher (5%) Data were analyzed using the following statistic and econometric tools:

**Farm Budgetary Technique**

Gross margin model (GM) and net farm income analysis (NFI) of sorghum production was estimated using the following models:

$$GM = TR - TVC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$NFI = \sum_{i=1}^{n} P_i Q_i - \left[\sum_{j=1}^{m} P_j X_j + \sum_{k=1}^{k} GK\right] \ldots. (3)$$

Where, $P_i$ = Price of Sorghum ($\frac{N}{Kg}$), $Q_i =$ Quantity of Sorghum (Kg), $P_j =$ Price of Factor Inputs ($\frac{N}{Unit}$), $X_j =$ Quantity of Factor Inputs (Units), $TR$ =Total Revenue obtained from the Sales of Sorghum (N), $TVC =$ Total Variable Cost (N), $GK =$ Cost of all Fixed Inputs (Naira), $NFI =$ Net Farm Income (Naira)

The farm budgetary technique was used to analyze the costs, returns and profitability of sorghum production as stated in specific objective 2 (ii).

**Financial Analysis**

This study follows the work advanced by of Alabi et al. (2020), who defined gross margin ratio (GMR) as:

$$Gross\ Margin\ Ratio = \frac{Gross\ Margin}{Total\ Revenue} \ldots\ldots. (4)$$

This study follows the work advanced by Olukosi and Erhabor (2015), who defined operating ratio (OR) as:

$$Operating\ Ratio = \frac{TVC}{GI} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, $TVC$ = Total Variable Cost (Naira), $GI$ = Gross Income (Naira),

The rate of return per Naira invested (RORI) in sorghum production is stated as follows:

$$RORI = \frac{NFI}{TC} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, $NFI$ = Net Farm Income from Sorghum Production (Naira), $TC$ = Total Cost (Naira)

The financial analysis was used to analyzed the profitability of sorghum production as stated in specific objective 2 (ii).

**Stochastic Production Efficiency Frontier Model**

This research study follows the model advanced by Alabi *et al*. (2022[a]), who defined the stochastic production efficiency frontier model as:

$$Y_i = f(X_i, \beta_i) e^{v_i - u_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$l_n Y = \beta_0 + \beta_1 l_n X_1 + \beta_2 l_n X_2 + \beta_3 l_n X_3 + \beta_4 l_n X_4 + \beta_5 l_n X_5 + +V_i - U_i \ .(8)$$

where, $Y_i =$ Output of Sorghum (Kg), $X_i =$ Vectors of Factor Inputs, $\beta_i =$ Vectors of Parameters, $V_i$ = Random Variations in Sorghum Output, $U_i$= Error Term due to Technical Inefficiency, $X_1$ = Farm Size (Ha), $X_2$ = Hired Labour Input in Mandays, $X_3$ = Fertilizer Input (Kg), $X_4$ = Chemical Input (Litre), $X_5$ = Seed Input (Kg), $X_6$ = Family Labour (Mandays)

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \cdots . \alpha_9 Z_9 \ldots\ldots\ldots. (9)$$

where, $Z_1$ = Age (Years), $Z_2$ = Household Size (Number, $Z_3$ = Gender (1, Male; 0, Otherwise), $Z_4$ = Farming Experience (Years), $Z_5$ = Educational Level (Years), $Z_6$ = Access to Credit Facilities (Naira) $Z_7$ = Farmers Internet Usage (1, Aware; 0, Not Aware), $Z_8$ = Media Internet Usage (1, Usage; 0, Not Use), $Z_9$ = Relations with Public Institutions (1, Receive Support; 0, Do Not Receive Support) $\alpha_0$ = Constant Term, $\alpha_1 - \alpha_9$ = Parameters to be Estimated, $U_i$= Error Term due to Technical Inefficiency. This will be used to achieve specific objectives 3 (iii) and 5 (v).

**Elasticity of Production Model and Return to Scale**

Elasticity of production is a measure of a farm success in producing maximum output from a given set of inputs. The elasticity of production ($E_P$) and return to scale ($RTS$) was estimated using the formulae: -

$$E_{P_{X_i}} = \frac{\partial Y}{\partial X_i} \cdot \frac{\overline{X}}{\overline{Y}}, i = 1, 2 \ldots k \quad (10)$$

$$\sum_{i=1}^{K} E_{P_{X_i}} = RTS \quad (11)$$

Where; $\overline{X} =$ Mean of Inputs (Units), $\overline{Y} =$ Mean of Output (Units), $E_{P_{X_i}} =$ Elasticity of Production of Input $x_i$ , $\sum_{i=1}^{K} E_{P_{X_i}} =$ Return to Scale i.e Sum of Elasticity of Production

Sanusi *et al*. (2022) and Alabi and Safugha (2022[b]) suggested that return to scale of the farm operations can either be increasing, decreasing, or constant return to scale base on the value of the estimated coefficients**.** This was used to achieve part of specific objective 4 (iv).

**Principal Component Analysis**

Constraints faced by sorghum farmers was subjected to principal component analysis or factor analysis. The principal component analysis is stated thus:

$$\alpha_K = (\alpha_{1k}, \alpha_{2k}, \alpha_{3k}, \ldots \alpha_{pk}) \quad (12)$$

$$\alpha_k^T X = \sum_{j=1}^{p} \alpha_{kj} X_j \quad (13)$$

The variance of each of the principal components are:

$$Var[\alpha_k^T X] = \lambda_k \quad (14)$$

$$S = \frac{1}{n-1} \sum_{i=1}^{n} (X_i - \overline{X_i}\ (X_i - \overline{X}_i)^{\mathrm{T}} \quad (15)$$

Where, $X_i$= Vector of p Random Variables, $\alpha_k =$ Vector p Components, $\lambda_K =$ Eigen Value, T = Transpose, S = Covariance Matrix, This was use to achieve part of specific objective 6 (vi).

**Results and Discussion**

**Socio-Economic, Farm Specific and Institutional Characteristics of Sorghum Farmers**

Table 1 presented the socio-economic, institutional, and farm specific characteristics of sorghum farmers. The socio-economic characteristics include gender, age, marital status, years in schooling, household size, farming experience, farm size, member of cooperatives, extension contact, and access to credit facilities. In terms of gender, about 75% (120) of sorghum farmers were male, while 25% (40) of sorghum farmers were female. This result is in line with findings of Aduba et al. (2013) and Baiyegunhi and Fraser (2009) who reported that women majorly take part in processing. Also, the male dominance may be due to demand of time and effort required to work in the enterprise. The mean age of sorghum farmers was 43 years with a standard deviation of 8.813. About 71.88% of sorghum farmers were less than 50 years of age, while 18.12% of sorghum farmers were 51 years and above. This implies that the sorghum farmers were young, active, energetic in their productive age. This result is in line with findings of Tugga et al. (2023) who reported in their studies that sorghum farmers are within their active age and can make positive contribution to agricultural production. About 86.87% of sorghum farmers were married, 2.50% were single, 4.38% were divorced, while 6.25% were widowed. This result is in line with findings of Aduba et al. (2013) who reported that 92.90% of sorghum farmers were married. These married farmers engaged in sorghum production in order to cater for the wants and needs of their family. Averagely, sorghum farmers had 6 years (SD = 3.6840) of schooling. Most sorghum farmers (54.39%) attended primary school (1 – 6 years), and 39.37% attended secondary education (7 – 12 years), in comparison, the least proportion (6.25%) was recorded for tertiary education (13 years and above). According to Yahaya et al. (2022) who reported that education is vital for productivity, the improvement of agricultural management and the creation of farmers' rural prosperity. Farmers with formal education can easily make farm decisions and adopt innovations about agricultural production methods. Sorghum farmers with formal education have better understanding and knowledge of farm production technologies. About 45% of sorghum farmers had less than 5 persons as members of the household. Also, 35.63% of sorghum farmers had between 6 to 10 persons as members of the household. Averagely, sorghum farmers had 7 persons as household size. The importance of household size as reported by Amaza (2000), and Oladimeji and Abdulsalam (2013) were based on the availability of labour for farm production. In addition, the total area cultivated, the marketable surplus and the amount of farm produce retained for domestic consumption were all determined by the size of the farm household. The results presented on Table 1 also shows that about 40% of sorghum farmers had less than 10 years of farm experience in sorghum production. In addition, 51% of sorghum farmers had between 11 to 20 years' experience in sorghum production. The mean farm experience in sorghum production was 14 years (SD = 9.3329). According to Sani and Oladimeji (2017) who reported that farming experience of a sorghum farmers determines his ability to adhere to agronomic practices, make effective farm decisions, and also combine inputs or resource allocations. In addition, farming experiences also influence farm production efficiencies because accumulation of skills assists a sorghum farmer to perform better on his farms. Furthermore, about 77.50% of sorghum farmers had farm size that is less than 2 hectares. Also, 26% of sorghum farmers had farm size that ranged between 2.1 to 4 hectares. The average cultivated farm size was 1.59 hectares (SD = 1.59875), this implies that sorghum farmers were small-scale or peasant farmers. The institutional variables under considerations were members of cooperatives organizations, extension contact, and access to credit facilities. About 68.13% of sorghum farmers were members of cooperative associations, while 31.87% of sorghum farmers were not members of cooperative associations respectively. In addition, 58.75% of sorghum farmers had contact with extension officers, while 41.25% of sorghum farmers had no contact with extension officers. The contact with extension officers should enhance the ability of sorghum farmers to utilize the farm resources efficiently through the adoption of improved methods used in sorghum production. About 55.63% of sorghum farmers have access to credit facilities, while 44.37% of sorghum farmers do not have access to credit facilities. According to Ekong (2003) who reported that credit facilities is a strong factor that is needed to develop any farm enterprise, the availability of credit could determine the extent of production capacity.

**Table 1:** Socio-Economic, Farm Specific and Institutional Characteristics of Sorghum Farmers

| Variables | Frequency | Percentage |
|---|---|---|
| **Gender** | | |
| Male | 120 | 75.00 |
| Female | 40 | 25.00 |
| **Age (Years)** | | |
| ≤ 20 | 02 | 01.25 |
| 21 – 30 | 10 | 06.25 |
| 31 – 40 | 37 | 23.13 |
| 41 – 50 | 82 | 51.25 |
| 51 and above | 29 | 18.12 |
| **Mean Value** | 43.30 (SD = 8.813) | |
| **Marital Status** | | |
| Married | 139 | 86.87 |
| Single | 04 | 02.50 |
| Divorced | 07 | 04.38 |
| Widowed | 10 | 06.25 |
| **Years in Schooling** | | |
| 1 – 6 | 87 | 54.38 |
| 7 – 12 | 63 | 39.37 |
| 13 and above | 10 | 06.25 |
| **Mean Value** | 6.6125(SD = 3.6840) | |
| **Household Size (Number)** | | |
| 1 – 5 | 72 | 45.00 |
| 6 – 10 | 57 | 36.63 |
| 11 – 15 | 21 | 13.12 |
| 16 and above | 10 | 06.25 |
| **Mean Value** | 7.03125(SD = 4.4685) | |
| **Farming Experience (Years)** | | |
| 1 – 10 | 64 | 40.00 |
| 11 – 20 | 51 | 31.87 |
| 21 – 30 | 35 | 21.88 |
| 31 and above | 10 | 06.25 |
| **Mean Value** | 14.937 (SD = 9.3329) | |
| **Farm Size (Hectares)** | | |
| ≤ 2 | 124 | 77.50 |
| 2.1 – 4 | 26 | 16.25 |
| 4.1 – 6 | 09 | 05.62 |
| 6.1 and above | 01 | 00.63 |
| **Mean Value** | 1.59875 (SD=1.21864) | |
| **Member of Cooperatives (Dummy)** | | |
| Yes | 109 | 68.13 |
| No | 51 | 31.87 |
| **Extension Contact (Dummy)** | | |
| Yes | 94 | 58.75 |
| No | 66 | 41.25 |
| **Access to Credit Facilities (Dummy)** | | |
| Yes | 89 | 55.63 |
| No | 71 | 44.37 |
| **Total** | **160** | **100.00** |

*Source: Field Survey (2023) SD = Standard Deviation*

**The Costs, Returns and Profitability of Sorghum Production per Hectare**

Table 2 presented the costs, returns, and profitability of sorghum production per hectare in the study area. The various costs incurred in sorghum production and the revenue obtained was based on the prevailing market prices as at the time of the field survey. The total costs (TC) involved in sorghum production consists of total variable cost (TVC) and total fixed costs (TFC). The TVC accounted for 84.11% of the total cost (TC) of production, while the TFC accounted for 15.89% of the TC. The TVC include seed input (07.09%), fertilizer input (18.31%), agrochemical input (07.49%), labour input (47.82%), transportation (0.99%), loading and offloading (0.57%), fees and commission (0.47%), and bags or sacks (1.38%). The TFC include depreciation on farm implement (7.64%), land rent (4.77%), taxes (0.73%), and interest paid on capital (2.75%). The total revenue (TR) obtained was 1, 246, 781.43 Naira. The estimated gross margin (GM) and net farm income (NFI) was 811, 211.27 Naira (853.90 USD) and 728, 947.93 Naira (767.31 USD) respectively. This shows that sorghum production was profitable in the study area. The GMR of sorghum production was 0.65, this implies that for every one naira invested in sorghum production about 65 kobo covered taxes, profits, depreciation, and expenses. The operating ratio (OR) of sorghum production was estimated at 0.54, this signifies that 54% of sales revenue from sorghum produce was used to the cover cost of sorghum sold and other operating expenses. The OR is used to measure the profitability and operating efficiency of sorghum production, a low OR is acceptable and it is a signal for positive development. The rate of return on investment (RORI) was calculated at 1.41, this means that for every one Naira invested in sorghum production, a profit of 41 kobo was made. This result is in line with findings of Tugga et al. (2023) who evaluated profitability of sorghum among small-scale farmers in selected local government areas of Gombe State, Nigeria. The results obtained the gross margin of 167, 188.6 Naira per hectare, and return to naira invested of 2.12.

**Table 2:** The Costs, Returns and Profitability Analysis of Sorghum Production per Hectare

| Variables | Units | Value (N) | Percentage (%) |
|---|---|---|---|
| **Variable Cost** | | | |
| Seed Input | Kg | 36,698.82 | 07.09 |
| Fertilizer Input | Kg | 94, 810.67 | 18.31 |
| Agrochemicals | Litre | 38, 762.21 | 07.49 |
| Labour Input | Mandays | 247, 621.72 | 47.82 |
| Transportation | Naira | 5,149.47 | 00.99 |
| Loading and Offloading | Naira | 2,957.62 | 00.57 |
| Fees and Commission | Naira | 2,421.41 | 00.47 |
| Bags/Sacks/Sewing | Naira | 7,148.24 | 01.38 |
| **Total Variable Cost (TVC)** | Naira | **435,570.16** | **84.11** |
| **Fixed Cost** | | | |
| Depreciation on Farm | Naira | 39, 531.14 | 07.64 |
| Implement | Naira | 24, 721.27 | 04.77 |
| Land Rent | Naira | 3,769.21 | 00.73 |
| Taxes | Naira | 14, 241.72 | 02.75 |
| Interest Paid on Capital | | **82, 263.34** | **15.89** |
| **Total Fixed Cost (TFC)** | | **517,833.50** | **100.00** |
| **Total Cost (TC)** | 2,800.12Kg | --------- | |
| Quantity Sold | Naira/Kg | 445.26 | |
| Price | Naira | 1,246,781.43 | |
| Total Revenue (TR) | Naira | 811, 211.27 | |
| Gross Margin (GM) | Naira | 728,947.93 | |
| Net Farm Income | Number | 0.65 | |
| Gross Margin Ratio (GMR) | Number | 0.54 | |
| Operating Ratio (OR) | Number | 1.41 | |
| Rate of Return on Investment | | | |

*Source: Field Survey (2023)* *950 Naira = 1USD*

**Technical Efficiency Scores of Sorghum Producers in the Study Area**

Table 3 shows the summary statistics of technical efficiency scores of sorghum producers. The majority (71.89%) of sorghum producers were between 21 to 80 % efficiency levels. The mean technical efficiency was 60.47 % leaving a gap of 39.53 % for improvement. This means that the sorghum farmers are able to obtain 60.47% of potential output from a given mixture of production inputs. Thus, opportunity still exists for increasing sorghum productivity and income through increased efficiency using available resources and by adopting new technologies and techniques used by the best performing sorghum farmers. In addition, the least technical efficiency score was 6.80 %, while the best performing sorghum farms had the maximum technical efficiency of 98.90%. If the average sorghum farmers were to achieve the level of technical efficiency like most of its efficient counterparts, then the average sorghum producers could make 38.86 % cost savings calculated as $\left[\left[1-\frac{60.47}{98.90}\right]\times 100\right]$. The calculated value for the most technically inefficient sorghum farmers reveals a cost savings of 93.12 % calculated as $\left[\left[1-\frac{6.80}{98.90}\right]\times 100\right]$. This is consonance with findings of Sani and Oladimeji (2017) who obtained an average technical efficiency score of 0.83 for sorghum farmers in Gombe State, Nigeria. Also, the result of Alemu and Haji (2016) obtained an average technical efficiency score of 0.74 for sorghum farmers in Eastern Ethiopia.

**Table 3:** Distribution of Technical Efficiency Scores among Sorghum Farmers

| Technical Efficiency Score | Frequency | Percentage |
|---|---|---|
| 0.00– 0.20 | 09 | 05.63 |
| 0.21 – 0.40 | 15 | 09.38 |
| 0.41 – 0.60 | 59 | 36.88 |
| 0.61 – 0.80 | 41 | 25.63 |
| 0.81 – 1.00 | 36 | 22.50 |
| Mean | 0.6047 | |
| Standard Deviation | 0.2226 | |
| Minimum | 0.0680 | |
| Maximum | 0.9890 | |

*Source: Field Survey (2023)*

**Factors Influencing Technical Efficiency of Sorghum Production**

The results of the maximum likelihood estimate of the Stochastic frontier production model for sorghum farmers was presented in Table 4. In the technical efficiency component, the variables included in the model were farm size, hired labour, fertilizer input, chemical input, seed input, and family labour. The estimated coefficients of all the parameters of the production functions were positive. The significant variables influencing technical efficiency of sorghum production include: farm size ($P < 0.05$), hired labour ($P < 0.05$), fertilizer input ($P < 0.05$), and seed input ($P < 0.01$). The coefficient of farm size (0.1375) was positive and significant at 5% probability level. A 1% increase in farm size will lead to 13.75% increase in output of sorghum farmers. The fertilizer is a major land augmenting input because it improves the quality of land by raising the yields per hectare. A 1% increase in fertilizer input will lead to 12.57% increase in output of sorghum farmers. This result is in agreement with the findings of Oladiebo and Fajuyigbe (2007).

The return to scale is the summation of all elasticities of production. The regression coefficients are the respective elasticities of production. The return to scale is the summation of elasticities (EP) of production from the regression coefficients of the Cobb Douglas production function. The elasticities of production for farm size as an example was estimated at 0.1375. The return to scale (RTS) was calculated at 0.8299, this signifies decreasing to scale. This means that an increase in one factor keeping other factors constant will lead to less than proportionate increase in output of sorghum farmers. This return to scale value describes that smallholder sorghum farmers are exactly operating in rational production stage and that area has a value of $0 \leq RTS \leq 1$ to reach constant return to scale CRS or RTS=1. This result is in line with the findings of Alabi and Anekwe (2023). The value of gamma ($\gamma$) was estimated to be 0.5442 and it was statistically significant at 1% probability level. This is in line with the theory that true gamma ($\gamma$) should be greater than zero. This implies that 54.42% of random variations in the yield of the sorghum farmers was due to the farmers' inefficiency in their respective farms and not as a result of random variability. These factors are under the control of sorghum farmers, hence reducing the influence of the effect of gamma ($\gamma$) will greatly increase the yield and enhance the technical efficiency of the sorghum farmers.

The value of sigma square ($\sigma^2$) was 0.3882 and this was highly significant at 1% level of probability. This signifies a good fit and correctness of the specified distributional assumptions of the composite error terms. This result is in line with Sani and Oladimeji (2017) who examined determinants of technical efficiency among sorghum farmers under agricultural transformation agenda in Gombe State, Nigeria. The results show that the significant factors influencing sorghum production in Gombe State, Nigeria are seed, fertilizer, and labour. The sigma square and gamma values were estimated at 0.6188 and 0.8144 respectively. In addition, Alemu and Haji (2016) who evaluated economic efficiency of sorghum production for smallholder farmers in Eastern Ethiopia reported that the significant factors influencing technical efficiency of sorghum production include age, experience, sex, and farm size.

**Socio-Economic Factors Influencing Technical Inefficiency of Sorghum Production**

Table 4 also shows the maximum likelihood estimates of socio-economic factors influencing technical inefficiency of sorghum production. The socio-economic variables included in the technical inefficiency model include: age, household size, gender, farming experience, educational level, and access to credit. All the socio-economic factors included in the technical inefficiency component had negative coefficients. All the signs of the socio-economic factors included in the technical inefficiency component were in line with a priori expectations. The significant socio-economic factors negatively influencing technical inefficiency includes: - age ($P < 0.10$), household size ($P < 0.10$), farming experience ($P < 0.01$), educational level ($P < 0.01$), and access to credit ($P < 0.05$). The coefficient of educational level is -0.3717, this implies a 1% increase in farm experience among sorghum farmers will lead to a 37.17% decrease in technical inefficiency of sorghum production. This result is in line with earlier findings of Sani and Oladimeji (2017). According to Kalirajan and Shard (2004) who reported that education of farmers sharpens his managerial input and leads to better decision making in farming. Education also widens the scope of farmers' horizon towards the adoption of innovations or new farm technologies, thereby moving the farmers away from traditional practices. The coefficient of farm experience in sorghum production was negative (-0.1640). This means a 1% increase in farming experience among sorghum farmers will lead to 16.40% decrease in technical inefficiency of sorghum production. Farmers' experience could be linked with skills accumulation which could increase productivity and enhance resource allocations hence reduce technical inefficiency among sorghum farmers. This is in line with Sani and Oladimeji (2017) who evaluated technical efficiency of sorghum production in Gombe State, Nigeria using stochastic frontier production model, reported that in the technical inefficiency component the significant socio-economic factors include education, farming experience, membership of cooperatives, and farm size. Farmers internet usage (-0.12076) and media interest and usage (-0.03509) had negative coefficients and are statistically significant in influencing technical efficiency of sorghum farmers at 5% probability level each. This outcome conforms with a priori expectations. A 1% increase in internet usage among sorghum farmers holding all other regressors constant will give rise to 12.07% increase technical efficiency of sorghum production. Also, 1% increase in media interest and usage among sorghum farmers holding all other predictors constant will give rise to 3.05% increase in technical efficiency of sorghum production. In addition, the relations of sorghum farmers with public institutions were not statistically significant in influencing technical efficiency of sorghum production.

**Table 4:** Results of the Maximum Likelihood Estimates of the Stochastic Frontier Production Model for Sorghum Farmers

| **Variables** | **Coefficients** | **Z-Score** |
|---|---|---|
| Farm Size | 0.1375** | 2.04 |
| Hired Labour | 0.1504** | 2.67 |
| Fertilizer Input | 0.1257** | 2.20 |
| Chemical Input | 0.0341 | 0.36 |
| Seed Input | 0.3416*** | 5.24 |
| Family Labour | 0.0406 | 0.67 |
| Constant | 2.3714*** | 4.93 |
| **RTS** | **0.8299** | |
| Age | -0.2302*** | - 3.47 |
| Household Size | - 0.1234* | - 1.90 |
| Gender | - 0.0427 | - 0.35 |
| Farming Experience | - 0.1640*** | - 3.41 |
| Educational Level | - 0.3717*** | - 8.50 |
| Access to Credit | - 0.1547** | - 2.34 |
| Farmers Internet Usage | -0.12076** | -2.46 |
| Media Interest and Usage | -0.03509** | -2.27 |
| Relations with Public Institutions | -0.01271 | 1.04 |
| **Diagnostic Statistics** | | |
| Log-Likelihood | -121.6581 | |
| Sigma Square (Total Variance) ($\sigma^2$) | 0.3882*** | |
| Gamma (Variance Ratio) ($\gamma$) | 0.5442*** | |

*Source: Field Survey (2023) ***-Significant at 1% Probability Level, **-Significant at 5% Probability Level*-Significant at 10% Probability Level*

**Constraints Faced by Sorghum Producers**

The constraints faced by sorghum farmers were subjected to principal component analysis (Table 5). Six (6) constraints with Eigen-value greater than one (1) were retained by the principal component model. Lack of credit facilities was ranked 1st with an Eigen-value of 4.7183, and this explained 38.14% of all constrained retained by the model. High cost of input was ranked 2nd with an Eigen-value of 3.7922, and this explained 17.62% of all constraints retained by the principal component model. Bad road infrastructure was ranked 3rd with an Eigen-value of 2.7514, and this explained 5.14% of all constraints retained by the model. All constraints retained by the principal component model jointly explained 72.95% of all constraints included in the analysis. The Kaiser-Meyer-Olkin measures of sampling adequacy (KMO) of 0.6915 and Bartlett test of sphericity of 2941.42.01 and were statistically significant at 1 % probability level which demonstrated that the variables were feasible for principal component analysis. This result is in line with the findings of Alabi and Anekwe (2023), Onuk et al. (2020), and Aduba et al. (2013). The work of Aduba et al. (2013) on economic analysis of sorghum production among sorghum farmers in Kwara State, Nigeria enumerated the constraints facing sorghum farmers to include high cost of labour, high cost of transportation, inadequate fund, inadequate access to extension services, inadequate access to improved seeds, lack of market for products, lack of motorable roads, lack of recommended agrochemicals, poor pricing of sorghum products, and problems of pests and diseases.

**Table 5:** Results of the Principal Components Analysis of the Constraints Faced by Sorghum Farmers

| Constraints | Eigen-Value | Difference | Proportion | Cumulative | Ranks |
|---|---|---|---|---|---|
| Lack of Credit Facilities | 4.7183 | 0.9261 | 0.3814 | 0.3814 | 1st |
| Lack of Improved Seeds | 3.7922 | 1.0408 | 0.1762 | 0.5576 | 2nd |
| Bad Road Infrastructures | 2.7514 | 0.3361 | 0.0514 | 0.6090 | 3rd |
| Inadequate Extension Services | 2.4153 | 0.2775 | 0.0412 | 0.6502 | 4th |
| High Cost of Labour | 2.1378 | 0.1117 | 0.0401 | 0.6903 | 5th |
| High Cost of Fertilizer | 2.0261 | 1.1900 | 0.0392 | 0.7295 | 6th |
| **Bartlett Test of Sphericity** | | | | | |
| Chi Square | 2941.42 | | | | |
| Rho | 1.0000 | | | | |
| KMO | 0.6915 | | | | |

*Source: Field Survey (2023)*

**Conclusion and Recommendations**

This research study has established that sorghum production was profitable in the study area. This is in line with reports of Tugga et al. (2023) who reported that sorghum production is profitable among small scale farmers in Gombe State, Nigeria. The sorghum farmers were energetic, active, productive in their youthful age. They are peasant, or small-scale farmers and majority (77.50%) of the producers cultivated less than 2 hectares of sorghum farms. The gross margin and net farm income of sorghum production were estimated at 811,211.27 Naira (853.90 USD) and 728,947.93 Naira (767.31 USD) per hectares respectively. The gross margin and operating ratios were calculated at 0.65 and 0.54 respectively. The significant factors influencing output of sorghum farmers include farm size, hired labor, fertilizer input, and seed input. The significant socio-economic factors reducing technical inefficiency of sorghum production include age, household size, farming experience, educational level, access to credit facilities, farmers' internet usage, media interest and usage. The sorghum farmers' relations with public institutions is not statistically significant in influencing technical efficiency of sorghum production. The average technical efficiency score of sorghum farmers was 60%, leaving a gap of 40% for improvement. The major constraints faced by sorghum farmers include: lack of credit facilities (1st), high cost of inputs (2nd), and bad road infrastructures (3rd). Based on the findings of this research work, the following recommendations were made:

(i) Credit facilities should be made available for sorghum farmers at low interest rate with no collaterals and devoid of cumbersome administrative procedures.
(ii) Farm inputs such as fertilizers, chemicals and improved seeds should be given to sorghum farmers at affordable prices and at appropriate time to increase productivity and efficiency.
(iii) Feeder roads should be constructed and more roads should be rehabilitated to facilitate easy access and movement of agricultural produce to nearby market.
(iv) Extension officers should be employed to disseminate innovations and new research findings to farmers.

New farm technologies and techniques together with labour saving equipments' should be introduced to sorghum farmers to increase productivity and efficiency.

**Statement of Conflict of Interest**

The author(s) declare no conflict of interest for this study.

**Author's Contributions**

The contribution of the authors is equal

**References**


Aduba, J.J., Mohammed, B.T., Jilasaya, I., Ozumba, I.C (2013). An Economic Analysis of Sorghum Production among Sorghum Farmers in Kwara State, Nigeria. Global Journal of Current Research, 1(4), 116 – 123

Ajeigbe, H.A., Akinseye, F.M., Jonah, J., Kunihya, A (2018). Sorghum Yield and Water Use under Phosphorous Fertilization Applications in the Sudan Savanna of Nigeria. Global Advanced Research Journal of Agricultural Sciences, 7 (8), 245 – 257

Alabi, O.O., Oladele, A.O, Oladele, N.O (2020). Economic Market Decisions among Marginal Maize Farmers in Abuja, Nigeria: Applications of Double Hurdle Model and Factor Analysis. Russian Journal of Agricultural and Socio-Economic Sciences, 8(104): 114–125. DOI: https://doi.org/ 10.18551/rjoas.2020-08.14

Alabi, O.O., Oladele, A.O., Maharazu, I (2022a). Economies of Scale and Technical Efficiency of Smallholder Pepper (Capsicum species) Production in Abuja, Nigeria. Journal of Agricultural Sciences (Belgrade),67(1):63–82. DOI:https://doi.org/10.2298/JAS2201063A

Alabi, O.O., Anekwe C.E (2023). Economics of Climate Smart Agricultural Practices (CSAPs) Used by Smallholder Sorghum Producers in Nigeria. Australian Journal of Science and Technology, 7(1); 65 – 71.

Alabi, O.O., Safugha, G.F. (2022b). Efficiency of Resource-Use and Marginal Value Productivity Analysis Among Maize Farmers, Abuja, Nigeria. International Journal of Agriculture, Forestry and Life Sciences, 6(2):28-33.

Alemu, G, Haji, J (2016). Economic Efficiency of Sorghum Production for Smallholder Farmers in Eastern Ethiopia: The Case of Habro District. Journal of Economics and Sustainable Development,7 (15), 44 – 51.

Amaza, P.S (2000). Resource – Use Efficiency in Food Production in Gombe State, Nigeria. An Unpublished Ph.D Dissertation Submitted to the Department of Agricultural Economics, University of Ibadan, Nigeria.

Baiyegunhi, L.J.S, Fraser, G.C.G (2009). Profitability in Sorghum Production in Three Villages of Kaduna State, Nigeria. Journal of Applied Sciences Research, 5 (10): 1685 – 1691

Byerlee, D., Diao, X, Jackson, C (2005). Agriculture, Rural Development, and Pro-Poor Growth: Country Experience in the Post-Reform Era Contribution of Agricultural Households to National Poverty Reduction in Africa. Agriculture, 21:1–15. CGIAR (2015). Sorghum.https://www.cgiar.org/our-strategy/crops-factsheet/sorghum/

Ekong, E.E (2003). Rural Sociology: An Introduction and Analysis of Rural Nigeria, Dove Educational Publication Uyo, Nigeria.

FAOSTAT (2023). Food and Agriculture Organization, Statistical Yearbook, World Food and Agriculture, Database 2022 cropping season.

FAO (2019). FAO Statistical Database (Online). Food and Agriculture Organization of the United Nations, Rome. http://.www.fao.org/faostat/en/data/QC Accessed 10 June, 2021

FAO (2015). Food and Agriculture Organization of the United Nations. Analysis of Incentives and Disincentives for Sorghum in Nigeria. Technical Note. http://www.fao.org/3/a-at583e.pdf Retrieved 25 May,2015.

GAIN (2020). Grain and Feed Update-Nigeria. Report by Global Agricultural Research Network (GAIN), Foreign Agriculture Service, United State Department for Agriculture.

Kalirajan, F Shard, P (2004). On Measuring the Contribution of Human Capital to Agricultural Production. Indian Economic Review, 24, 247 – 261

Mundia, C.W., Secchi, S., Akamani, K., Wang, G (2019). A Regional Comparison of Factors Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. Sustainability, 11, 2135.

Miassi, Y.E., Akdemir,S., Dossa, F.K, Omotayo, A.O (2023). Technical Efficiency and Constraints Related to Rice Production in West Africa: The Case of Benin Republic. Cogent Food and Agriculture, 9:1, 2191881, DOI: https://doi.org/10.1080/23311932.2023.2191881

Ogbonna, A.C (2011). Current Development in Malting and Brewing Trials with Sorghum in Nigeria: A Review. Journal of the Institute of Brewing, 117 (3): 394 – 400

Okeyo, S.O., Ndirangu, S.N., Isaboke, H.N., Njeru,L.K (2020). Determinants of Sorghum Productivity among Smallscale Farmers in Siaya County, Kenya. African Journal of Agricultural Research, 16 (5): 722 – 731. DOI: https://doi.org/10.5897/AJAR2020.14850

Oladimeji, Y.U, Adulsalam, Z (2013). Analysis of Technical Efficiency and its Determinants among Smallscale Rice Farmers in Patigi LGA of Kwara State, Nigeria. IQSR Journal of Agriculture and Veterinary Science, 3 (3), 34 – 39

Oladiebo, J.O, Fajuyigbe, A.A (2007). Technical Efficiency of Women Upland Rice Farmers in Osun State, Nigeria. Journal of Human Ecology, 22 (2), 93 – 100.

Olukosi, J.O, Erhabor, P.O (2015). Introduction to Farm Management Economics:Principles and Applications. Agitab Publishers Limited, Zaria, Kaduna, Nigeria pp77 – 83

Omonona, B.T., Liverpool-Tasie, L.S.O., Sanou, A, Wale, O.O. (2019). Is Fertilizer Use Inconsistent with Profitability? Evidence from Sorghum Production in Nigeria. Nigerian. Journal of Agricultural Economics, (NJAE), 9 (1), 1 – 13.

Onuk, E.G., Girei, A.A, Audu, S.I (2020). Production Function Analysis and Profitability of Sorghum-Groundnut Intercropping in Doma Local Government Area of Nasarawa State, Nigeria. Russian Journal of Agricultural and Socio-Economic Sciences, 6 (102), 170 – 177.

Ravallion,M., Chen, S, Sangraula,P (2007). New Evidence on the Urbanization of Global Poverty. World Bank Policy Research Working Paper 4199 (Vol 33).

Sani, A.A., Oladimeji, Y.U (2017). Determinants of Technical Efficiency among Sorghum Farmers under Agricultural Transformation Agenda in Gombe State, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 13 (3): 122 – 127

Sanusi, S. O., Alabi, O. O., Ebukiba, E. S. (2022). Analysis on Resource Use Efficiency of Smallholder's Rice Production Farmers in Federal Capital Territory of Nigeria: Probit Model Approach. AgroTech-Food Science, Technology and Environment, Vol.1 No. 1, 1-9

Tugga, S.E., Hassan, A.A., Ojeleye,O.A (2023). Profitability Analysis of Sorghum Smallscale Farmers in Selected Local Government Areas of Gombe State, Nigeria.Journal of Agripreneurship and Sustainable Development (JASD), 6 (1),47 – 55

Yamane, T. (1967). Statistics: An Introductory Analysis, 2nd Edition., New York: Harper and Row. Pp. 33-50

Yahaya, M.A., Shimelis, H., Nebie, B., Ojiewo, C.O Danso-Abbeam, G (2022). Sorghum Production in Nigeria: Opportunity, Constraints, and Recommenations. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science, 72: 1, 660 – 672 https://doi.org/10.1080/09064710.2022.2047771