



APPLICATION OF DATA ENVELOPMENT ANALYSIS (DEA) TO SMALL-SCALE
SORGHUM PRODUCERS IN YOBE STATE, NORTH-EAST NIGERIA

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ABSTRACT

The study investigated the efficiency of small-scale sorghum production in Karasuwa Local Government area of Yobe State, North East, Nigeria. Using primary data of 2020 rainy season, the research employed a multi-stage random sampling procedure and selected 120 respondents from four sorghum-growing villages (Bukarti, Ga sma, Jaji-Maji, and Karasuwa) of the local government. The efficiency of producers, their socioeconomics profile and constraints associated with sorghum production were estimated using Data Envelopment Analysis (DEA), and Descriptive Statistics. The results of the DEA indicated that, 15% and 62% of the total farmers in the study area were found to be efficient under constant returns to scale assumptions respectively. Similarly, 81 and 12 DMUs operated on increasing and constant Returns to Scale respectively. Besides, a total of 73.4% and 80.8% with respect to Technical and Pure Technical efficiency scores had between 0.6 and 1.00 scale scores indicating that farmers in the study area make use of optimal resources to maximize profit. Major constraints identified include; inadequate capital, high cost of inputs and lack of credit facilities. The study therefore recommends provision of adequate credit facilities to farmers, subsidies on farm inputs, high yielding varieties and other policy intervention that would improve productivity per hectare.

Keywords: Analysis, Data, Efficiency, Nigeria and Sorghum

INTRODUCTION

Sorghum (*sorghum bicolor*) is the fifth most produced grain globally, interest in producing the crop has gained ground due to its inherent drought tolerance, short growing season and relatively low cost of production and readymade markets. World sorghum production fluctuates between 57 million metric tonnes (mt) to 66 million metric tonnes from 2012 -2016 and currently stands at 57.8 million metric tonnes with annual yield of 1.4 t/ha (FAOSTAT, 2020). US is the world leading producer of sorghum producing about 9.47 mt in 2019/2020 followed by Nigeria with 6.6 mt under a cultivated area of 5, 397,024 ha (FAOSTAT, 2020).

In Nigeria, sorghum is the third cereal in terms of production after maize and millet, it is grown in almost all the northern state and used as the primary food crop in diverse forms. It is industrially used for brewing alcoholic and non-alcoholic drinks and other confectioneries. Industrial demand has noted to be growing from a base of 2% of annual production in 2009 to about 20% of the total sorghum produced in 2018 indicating the need to boost output to maintain self -sufficiency in production (Akinyinka *et al.*, 2020). The health benefits of sorghum as strong anti -proliferative and antioxidants against colon cancer cells compared to other grains and fruits made it from nutritional perspective one of the most important food crops for human consumption (Oyediran *et al.*, 2017).

In Yobe state, sorghum is evidently one of the major cultivated crops produced largely by small scale farmers which are characterized by low level of resources, low savings and investment and employed traditional farming system. The crop is mostly intercropped with millet, cowpea and

sesame with an average yield of $< 1.0 \text{ t ha}^{-1}$ (Ahmad *et al.*, 2022). In the same vein, Zalkuwi (2015) and Vihi *et al.* (2019) opined that such category of farmers operates below optimal efficiency level and get unfair market prices for their produce with little or no profit and are faced with the problem of choices for allocating scarce resources between crop and animal enterprises in order to maximize their objective. In view of this, the study seeks to estimate the production efficiency of sorghum farmers, their socioeconomic profile and challenges faced in the study area so as to draw conclusion as per whether or not producers utilized resource efficiently and maximize profit. The findings of the study will provide guidance for informed decision for sorghum producers and policy makers while also drawing attention to other better production efficiency methods.

MATERIALS AND METHODS

The study was conducted in Karasuwa Local Government Area of Yobe State, North East Nigeria. The area lies on ordinates $13^{\circ}00'N$ and $10^{\circ}47'E$ with an estimated total population of about 106,992 as per 2006 population census. The sources of data used for the study was primary data elicited through verbal interview and structured questionnaire that was administered to target respondents (farmers). The study adopted multistage sampling procedure. Four village areas (Jajimaji, Karasuwa, Bukarti and Gasma) were purposively selected based on the intensity of sorghum production. A total of 3890 sorghum farmers were identified from the four areas. Thirty (30) farmers were selected from each of the area using simple random sampling, thus giving a sample size of one hundred and twenty (120) respondents. The data collected were on the socio-economic characteristics, cost of inputs, output and constraints faced by sorghum producers.

Analytical Technique

To achieve the objectives of this study, data gathered were analyzed using Data Envelopment Analysis (DEA) and Descriptive Statistics

Models Specification:

Data Envelopment Analysis (DEA)

DEA is a linear programming model that attempts to maximize a service unit's efficiency within the performance of a group of similar service units. It is non-parametric mathematical approach to frontier estimation which used set of entities commonly called decision making units (DMUs) that receive multiple inputs and produce multiple outputs. (Coelli, 1996). In DEA the CCR and BCC models are used to determine the efficient and inefficient (Farmers) DMUs based on constant and variable return to scale efficiencies.

The CCR Efficiency Model – Was built on 'constant return to scale' (CRS) assumption suggested by Charnes *et al.* (1978). It is called technical efficiency model/global efficiency under which the production possibility set is formed without any scale effect. The CCR model for each DMU (farm) is as follows;

$$\text{Max } \theta_{CCR}(k_0) = \sum_{j=0}^0 U_j Y_j K_0 \quad \dots(1)$$

$$\text{Subject to } \sum_{j=0}^0 U_j Y_j K_0$$

$$\sum_{j=0}^n \theta_1, X_i k_0 = 1 \quad \dots(2)$$

$$\sum_{j=0}^n \theta_1, X_i k_0 + \sum_{j=0}^0 U_j Y_j k_0 - U(k_0) \geq 0 \quad U_j \geq 0, \theta_j \geq 0 \quad \dots(3)$$

$$k = 1 \dots \dots k, \quad j = 1 \dots \dots n, \quad i = 1 \dots \dots m$$

Where U_j is the weight for output j , i is the weight for input i , n is the number of output, K is the number of DMUs, Y_{jk} is the amount of output J and DMU K and X is the amount of input j of DMU K

The BCC Efficiency Model – this model assumed ‘variable return to scale’ and it is referred to pure technical efficiency where the production possibility set is the convex combination of the observed units. The CRS assumption is appropriate when all DMUs are operating at optimal scale. However imperfect completion, government regulations, constraint on finance etc may cause a DMU not to operate at optimal scale which results in measures of technical efficiency that are compounded by ‘scale efficiencies. Banker *et al.* (1984) suggested the adjustment of CRS DEA to account for variable return to scale that would permit the computation of TE without the effect of scale efficiency. The model put forward by those authors and used for each DMU in this study is as follows;

$$\text{Max } \theta_{BCC}(k_0) = \sum_{j=0}^n U_j Y_j k_0 \quad \dots(4)$$

$$\text{Subject to; } \sum_{j=0}^n \theta_1, X_i k_0 = 1 \quad \dots(5)$$

$$\sum_{j=0}^n \theta_1, X_i k_0 + \sum_{j=0}^0 U_j Y_j k_0 - U(k_0) \geq 0 \quad U_j \leq 0, \theta_j \geq 0 \quad \dots(6)$$

$$k = 1 \dots \dots k, \quad j = 1 \dots \dots n, \quad i = 1 \dots \dots m$$

Scale Efficiency

DMU may be inefficient due to unfavorable environment or the inefficient operation of the DMU itself. Comparisons of the CCR and BCC efficiency scores to find the true effect became imperative. While the CCR model assumes a radial expansion and reduction of all observed DMUs, the BCC model only accepts the convex combinations of the DMUs as the production possibility set. If a DMU is fully efficient in both the CRR and BCC scores, it is operating at the most productive scale size. A low CCR score indicates locally efficient, a DMU with full BCC and CCR scores, are considered globally efficient. Thus, the ratio of the two scores characterizes the scale efficiency of a DMU as follows:

$$SE = \frac{\theta_{CCR}}{\theta_{BCC}} \quad \dots(7)$$

Where, θ_{CCR} and θ_{BCC} are CCR and BCC scores of a DMU, SE score of 1 shows scale efficiency or CRS and $SE < 1$ indicates scale inefficiency. Scale inefficiency can be due to the existence of either increasing returns to scale (IRS) or decreasing returns to scale (DRS). The SE score does not reveal whether a DMU is operating under IRS or DRS. This is achieved by imposing non-increasing returns to scale (NIRS) condition in the DEA model. IRS and DRS can be determined by comparing the efficiency scores obtained by the BCC and NIRS models. If the two efficiency scores are equal, then DRS apply; otherwise IRS is obtained (Sadiq *et al.*, 2016).

RESULTS AND DISCUSSION

Socio economic characteristics of respondents

Table 1 revealed that 28.3% of the respondents in the study area were within the ages of 41-50 years, 25% between the age of 31-40 years and 22.5% within the age of 51-60 years. This shows that farmers in the study area were within their active productive ages. The result implied that, farmers could handle manual work and other labour challenges efficiently. The mean age of the farmers was 49 years, minimum of 25 years and maximum of 75 years.

Household size revealed that 50.0% of the farmers have family size of between 1-10 members, 42.5% of the respondents had household size of 11-20 while only 7.5% had 21-30

members. Average of 10 members per household was recorded in the study area. The implication is that large family members supply cheap labour and invariably reduce the operating cost of the farm. However, large family size implied more dependents and the need for other sources of livelihood (Umar *et al.*, 2015; Muhammad *et al.*, 2022).

Table 1. Socio economic characteristics of the respondents

Variable (n=120)	Frequency	Percentage
Age		
21 – 30	7	5.8
31 – 40	30	25
41 – 50	34	28.3
51 – 60	27	22.5
> 60	22	18.4
Min	25	
Max	75	
Mean	49	
Std Deviation	12.06	
Household size		
1-10	60	
11-20	51	
21-30	9.0	
Min	0.0	50.0
Max	28.0	42.5
Mean	10.0	7.5
Std dev	6.03	
Level of Education		
Qur'anic		
Primary	28	
Secondary	22	
Tertiary	34	
Never been to school	24	
Membership of Association	12	23.3
Yes		18.3
No	27	28.3
	93	20.0
		10.122.5
		77.5

Farmer's efficiency scores

Table 2 revealed the efficiency distributions based on technical and pure technical efficiencies of the farmers in the study area. Fifteen per cent that is 18 DMUs and 62 percent (75 DMUs) from total farmers were found to be efficient under constant and variable returns to scale assumptions respectively. A total of 73.4% and 80.8% with respect to technical and pure technical efficiency scores recorded efficiency scores between 0.6 and 1.00 scales indicating that farmers in the study area make use of optimal resources to maximize profit. However, the wide variation in the technical efficiency implies that all the farmers were not fully aware of the right production techniques or did not apply them properly, while wide variation in pure technical efficiency indicates that the farmers were irrational in resource allocation at their disposal. So also, for technical efficiency, farmers with efficiency score of less than one is inefficient in technology usage.

Table 2. DMUs distribution of efficiency score based on CCR and BCC DEA models.

Efficiency Level	TE (CRS)	%	PTE (VRS)	%	SE	%
0.3	3	(2.5)	1	(0.83)	0	(0)
0.4	13	(10.8)	2	(1.7)	0	(0)
0.5	16	(13.3)	20	(16.7)	2	(1.7)
0.6	14	(11.7)	7	(5.8)	8	(6.7)
0.7	23	(19.2)	10	(8.3)	19	(15.8)
0.8	20	(16.7)	3	(2.5)	30	(25.0)
0.9	13	(10.8)	2	(1.7)	30	(25.0)
1.0	18	(15.0)	75	(62.5)	31	(25.8)
Total	120	(100)	120	(100)	120	(100)
Minimum	3		1		0	
Maximum	23		75		31	
mean	15		15		15	
Std Dev	6		25		14	
Std Error	21.1		8.8		4.6	

Source: Authors computation using DEAP 2.1. from 2020 field survey. Figures in parenthesis are percentages

Return to Scale Properties

Table 3 revealed Return to Scale properties of farms, whether the DMUs operates at Optimal, Sub- optimal or Super- optimal that is, CRS, IRS or DRS. This information direct how resources were allocated by farmers in achieving higher yield. As seen earlier, the BCC model includes both IRS and DRS, while the imposed Non-Increasing Returns to scale (NIRS) gives DRS. The same value for technical efficiency TE and NiRS indicates that a farm has DRS while different value shows that the DMU operates at IRS. The results from the study area indicated that, 12 farms operate under Constant Returns to Scale, 81 farms had IRS and 27 farms achieved DRS respectively. It can be inferred from the results therefore, a proportionate increased in all inputs translate to more proportionate increase in Sorghum output in the study area and that technological changes are imperative for significant changes in yield and doubling farmer's income.

Table 3. Farms distribution based on Return to Scale

Scale category	Return to Scale	Number of Farms
Optimal	Constant return to scale (CRS)	12
Sub Optimal	Increasing return to scale (IRS)	81
Super Optimal	Decreasing return to scale (DRS)	27

Source: Authors computation using DEAP 2.1. from 2020 field survey.

Ranking Analysis for DMUs

Some efficient farms otherwise DMUs exhibit better operational practices over the others, therefore discrimination have to be made among them to select the best, this is done through Ranking. It is the number of times an efficient farm appears in a reference set (RFS) over the others and is considered as superior unit. From Table 4 DMU 67, 51, 9, 91 and 93 appeared more in the RFS, numbering 77, 62, 45, 40, and 24 times respectively making them to be ranked 1, 2, 3, 4, and 5 as the most efficient operating units. The implication is that, identifying efficient operating practices would help to improve efficiency not only among the inefficient farms but also among the efficient ones. The comparison therefore would benefit the lower ranked DMUs to copy and manage their resources for better output.

Table 4. Ranking according to RFS

DMU (farms)	FRS	Ranking
DMU67	77	1 st
DMU51	62	2 nd
DMU9	45	3 rd
DMU91	40	4 th
DMU93	24	5 th
DMU26	12	6 th
DMU15	9	7 th
DMU73	8	8 th
DMU50	7	9 th
DMU37	6	10 th
DMU68	5	11 th
DMU39	4	12 th
DMU8	3	13 th
DMU117	3	13 th

Source: Authors computation using DEAP 2.1 from 2020 field survey.

Challenges faced by sorghum producers

Table 5 showed that, 44.9% of the farmers had insufficient capital which limits cultivation of more hectares of land, use of recommended inputs, agricultural mechanization, storage and processing thus, implying low level of outputs. Insufficient capital or low access to credit facilities has always been the bane of agricultural production in Nigeria. About 33.8% of the farmers opined that high costs of inputs especially labour input was their major challenge in sorghum production. Man-day labour with respect to land preparation, weeding, harvesting and transportation were too high and formed the major components of operating cost. In a similar study, Vihi *et al.* (2019) found out that, major constraint faced by sorghum producers in Riyom local government area were high cost of fertilizer and inadequate capital. 14.9% of the respondents in the study area ascribed

problems to insecurity issues, the Boko Haram insurgency and Banditry constitutes a growing concern and apprehension in the mind of many farmers in the study area. the implication was that many farmers had abandon their farms while others gave very little attention as staying in farms during some period may exposed one to the danger of attack. Table (1) further revealed that, small per cent of the respondents (6.3%) indicated that, Covid 19 and its restrictions were part of the problems encountered during the period of the study particularly farmers living around the urban centers like Karasuwa and Jaji Maji where lockdown was enforced.

Table 5. Constraints faced by sorghum producers

Constraints	Frequency	Percentage
Insufficient capital	114	44.9
High cost of inputs	86	33.8
Inadequate extension agent	38	14.9
Covid 19 and its restrictions	16	6.3
Total	254**	100

Source: Author's findings from field survey 2020 ** Multiple response

CONCLUSION AND RECOMMENDATIONS

The study concluded that, farmers in the study area were generally efficient in sorghum production as indicated by the results from DEA. A total of 73.4% and 80.8% with respect to technical and pure technical efficiency scores recorded efficiency values between 0.6 and 1.00 scales indicating that farmers in the study area make use of optimal resources to maximize profit. Similarly, the result inferred that, a proportionate increased in all inputs translate to more proportionate increase in Sorghum output in the study area as 81 DMUs, 12 DMUS and 26 DMUs operated at IRS, CRS and DRS respectively. Major constraints bedeviling sorghum farmers during the study period include inadequate capital, high cost of inputs and lack of extension agents. The study therefore recommends provision of adequate credit facilities to farmers, subsidies on farm inputs, high yielding sorghum varieties and other policy interventions that will enhance productivity and maximize output per hectare.

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