NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 53 Number 1, April 2022 Pg. 363-368
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng

Returns to Scale and Production Efficiency among Sweet Potato Farmers in Benue State, Nigeria

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Abstract
This study examined Sweet Potato production efficiency in Nigeria. A multi-stage sampling technique was employed in selecting 93 Sweet Potato farms. Data on farm and farmers' characteristics, input and output quantities and prices, constraints to Sweet Potato production among others were collected with a well-structured questionnaire. The data were analysed with descriptive statistics, Data Envelopment Analysis (DEA) and Tobit regression. The results of the analysis revealed that the mean Technical Efficiency (TE), Allocative Efficiency (AE), Economic Efficiency (EE) under Constant Returns to Scale (CRS) assumption were 0.685, 0.445 and 0.301 respectively. On the other hand, the TE, AE and EE under Variable Returns to Scale (VRS) assumption were 0.783, 0.604 and 0.467 respectively. The Scale Efficiency (SE) was found to be 0.877. The results indicate that access to credit increased TE of farms by 3.5%. Regular training of Sweet Potato farmers increased their AE by 10.5% and EE by 16.6%. Access to credit by farmers decreased SE of farms under CRS and VRS by 1.9% respectively. Labour shortage, poor access to improved technology and infestation by insect pests were the three most important constraints limiting Sweet Potato production in the study area. Therefore, improving the efficiency of Sweet Potato production will require policies that will see to regular training of farmers by extension agents and other stakeholders and enhancement of rural farmers' access to credit.

Keywords: TE, AE, EE, CR, SE

Introduction

Nigeria is an agrarian country, hence, its economic growth and development heavily relies on the functioning of the agricultural sector of which the crop sub-sector plays a vital role. Agricultural sector contributed 22% to the nation's GDP, while the crop sub-sector's contribution stood at 20% in 2014 (NBS, 2014). About 36.4% of the work force in the country is directly employed by the sector. The crop sub-sector involves the production of cash and food crops, notable among the food crops are cereals, legumes, root and tubers. Some of the root and tuber crops been cultivated by farmers in the country include: Cassava, yam and sweet potato. The global ranking of the sweet potato producing countries showed Nigeria to be the largest producer in Africa, and the second largest producer in the world after China in 2014 (FAO, 2015). The total production was put at 3.92 metric tonnes with about 2% increase compared to 2013, but has the potential yield estimated at 7 metric tonnes (NBS 2014). Sweet potato has numerous potential benefits and uses. It requires fewer inputs and less labour than other crops such as cereals, more productive, and adaptable to marginal growing conditions (e.g., drought and poor soil) (Oswald *et al*., 2009). Sweet potato is an important food and feed crop in sub-Sahara Africa (SSA) and ranks fourth after maize, bananas, and cassava (Agbo and Ene, 1992). It serves as cash crop and is one of the most popular food crops which serve as food security promoting root crop in sub-Sahara Africa specifically, and the world at large. The importance of the crop in national and household food security coupled with health and livelihoods of poor farming households in Nigeria cannot be over-emphasized. Despite the numerous potential uses and benefits of sweet potato in Nigeria, the production of the crop is below the nation's potential. Sweet potato has a yield potential of 20–50 tonnes per hectare wet weight in the tropics (Caliskan *et al*., 2007). Farmers in SSA however produce below 10 tonnes per hectare wet weight on the average (FAO, 2009), while farmers in Nigeria recorded one of the world's lowest average potato yields of less than 3.1 tonnes per hectare. In the United States of America and Japan, yields of 22.8 and 21.7 tonnes per hectare were recorded respectively (FAO, 2015). The low yields in Nigeria were due to quality of planting materials (vines), high labour costs, biotic and abiotic constraints. As indicated by Fawole (2007), the low productivity recorded in sweet potato

farms is traceable to inefficiency in resource use (Fawole, 2007). Previous studies on sweet potato farms in the country focused on adaptability and productivity, value addition as well as processing ((Fawole, 2007, Adeyonu *et al*., 2016). The study by Adeyonu *et al*. (2016) on efficiency of Sweet Potato farms focused on TE (Adeyonu *et al*., 2016). To the best of researchers' knowledge, Adugna's research is the only study that focused on efficiencies (TE, AE, EE and SE) of sweet potato farms (Adugna *et al*., 2018). Hence, this study examined the efficiency (TE, AE, EE and SE) of Sweet Potato production using DEA and the constraints militating against production in Nigeria.

Conceptual/theoretical framework and literature review

Efficiency is a concept in economics that is greatly used in managerial and production economics. Efficiency can be defined as the largest amount of ratios of weighted outputs to weighted inputs subject to the condition that similar ratios for every Decision Making Unit (DMU) are less than or equal to one (Cooper *et al*., 2011). It then follows that the efficiency of each DMU is relative to the ratio of output to input of the most efficient firm. Economic Efficiency in agriculture implies getting the maximum amount of output per hectare of land cultivated or per animal, with the least cost of production in terms of manpower and other inputs (Oancea, 2003). Generally, economic efficiency can be separated into two distinct types-TE and AE (Farrell, 1957). A firm (farm) that is not 100% efficient technically will find it difficult to be efficient in resource allocation (Farrell, 1957). Technical efficiency in agriculture is a term which refers to the capacity of a farm to either produce the maximum amount of output(s) from the given level of inputs, or to produce the given level of output(s) from the minimum amount of inputs for the given technology. Allocative efficiency is a measure of the extent to which the farm's marginal value product can be equated with the marginal costs. It considers inputs utilization by the enterprise (farm) in relation to their current prices in the market. The AE, just like the TE, becomes relevant if the objective of the farm is to maximize its profits or to minimize its costs. Scale efficiency on the other hand is defined as the most efficient scale of operation when the objective is to maximize mean productivity. Efficiency analysis involves two techniques which are the parametric Stochastic Frontier Analysis (SFA) and non-parametric DEA. The SFA was developed to provide coherent principles to analyze efficiency (Aigner *et al*., 1977; Meeusen, and van den Broeck, 1977; Chavas and Aliber, 1993). The imposition of a deterministic functional form (Translog, Cobb-Douglass, etc.) on a production or a cost frontier will make it parametric. The assumption here is that any difference between the calculated function and the observation is as a result of farm's inefficiency and some random errors out of the farmer's control. The DEA method was initiated by Farrell (1957) and Charnes *et al*. (1978) re-formulated it to a mathematical programming problem. In DEA, no postulations about the functional forms relating inputs and outputs are required and the farm's inefficiency is derived solely from the difference between the calculated function and the observation (frontier technology). Also, DEA method can be used for production system that has to do with multiple inputs and multiple outputs, and it can estimate all the associations between inputs and outputs (TE, AE, EE and SE) simultaneously (Yusuf and Malomo, 2007). However, employing DEA method in measuring farm's efficiency requires that choice be made between two options. The first of the options is to choose between Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). Constant Returns to Scale assumes that all DMUs are operating at the optimal scale, implying that it is possible for big and small farms to reach the same level of productivity. The CRS assumption has been criticized because it is not likely that all big and small farms will reach the same level of productivity in developing countries because the farms are heterogeneous in nature. Variable Return to Scale is superior to CRS due to its ability to estimate the efficiency scores (TE, AE and EE) with no regard to SE effects (Coelli, 1996). Banker *et al*. (1984) suggested an adoption of VRS DEA model over CRS DEA model. Also, VRS DEA is common in agricultural production; the second option is to choose between input-based DEA and output-based DEA. The focus of the input-based DEA model is to produce the same amount of output(s) by using fewer inputs, and its output-based counterpart focuses on using the same amount of inputs to produce maximum output(s). Choosing between the two models will be a function of availability of resources; hence, the choice will vary from region to region and country to country. A number of studies have employed CRS DEA and VRS DEA to measure efficiency of farms (Murthy *et al*., 2009; Begum *et al*., 2010; Watkins, *et al*., 2014). Also, Begum *et al*. (2010) and Shrestha *et al*. (2016) used input-based approach and the choice was justified based on the fact that the studies were done in developing countries (Murthy *et al*., 2009; Begum *et al*., 2010; Watkins *et al*., 2014). To the best of our knowledge, little or nothing is known about Sweet Potato production efficiency using DEA, hence, this study used input-based CRS DEA model and VRS DEA model to evaluate Sweet Potato production efficiency in Nigeria been a developing country.

Materials and Methods

The Survey design was adopted for the study. The study was carried out in Benue State. Cluster and simple random sampling techniques were used to select the respondents for the study. Benue State was clustered into three senatorial districts thus; North East senatorial district (Zone A), North West Senatorial District (Zone B), and Benue South Senatorial district Zone (C). One Local Government Area (LGA) was randomly selected from each of the clustered senatorial districts: Kastina-Ala selected from Zone A; Buruku selected from zone B; and Otukpo selected from Zone C. Furthermore, two (2) council wards were randomly selected from each LGA with Mbacher and Mbajir Council Wards selected from Kastina-Ala, Binev and Shorov Council Wards

selected from Buruku, Adoka-icho and Adoka-haje Council Wards selected from Otukpo, then sixteen sweet potato farmers were purposively selected and that gave us a total sample size of 96 respondents. Following the derivation of the efficiencies using the Data Envelopment Analytical (DEA) model, Tobit regression model was employed to determine the factors influencing sweet potato farms' efficiencies. Information on production constraints encountered on Sweet Potato farms were collected using a five-point Likert-type scale. Ten questions on production constraints generated were from literature and researchers' personal field experience. Each of the farmers interviewed was asked to rate the level of importance of each constraints to his/her Sweet Potato production on a five-point Likert-type scale (1 = not at all important; 5 = extremely important).

Results and Discussion

Socioeconomic characteristics of the respondents

The summary of variables analysed using descriptive statistics in this study is presented in Table 1. The results showed that the mean Sweet Potato output in the study was 3.93 tonnes/hectare, while the average farm land cultivated as 1.69 hectares. The farm land cultivated compares well with the national average size of 2.0 hectares. The use of improved vine variety was not popular in the study area as only about 32% of the farmers made use of it. Majority of the farmers owned the land cultivated, about 26% of the farmers were females; more than half did not have access to credit and also belonged to farmers' cooperative society. The mean age and experience in farming of the farmers were about 49 years and 22 years respectively, which implied that they were quite experienced and belonged to active labour force. The result on age distribution of respondents confirms International Labour Organization's (ILO's) report that economically productive person in a population is within the age of 49 years (ILO, 2006). Farmers' average years of schooling stood at about 10 years and a minority of them (29%) had been exposed to entrepreneurial training in the last 5 years.

Efficiency measurement

The frequency distribution and mean of the efficiency estimates from the DEA analysis are shown in Table 2. The estimated efficiency scores ranged between 0.127 and 1.000 for TE, AE, EE and SE. The high variability in the scores necessitated the clustering of the scores into five categories which are: <0.60, 0.60–0.69, 0.70–0.79, 0.80–0.89 and >0.89 to show their position in relation to the maximum efficiency of 1. The results indicate that there are substantial inefficiencies in sweet potato production in the study area under CRS and VRS assumptions, which implied that most of the technologies farmers are using are inefficient. Hence, there is need for many of the farmers to adopt improved technologies to reduce inefficiencies. The mean TE, AE and EE values were lower under the CRS than under the VRS assumption, which are in consonance with the submissions of Murthy *et al*. (2009), Begum *et al*. (2010), and Watkins *et al*. (2014).

Factors influencing Sweet Potato production efficiency

The results of the factors influencing Sweet Potato production efficiency is presented in Table 3. As shown in the Table, the diagnostic statistics showed that the independent variables used in the model have good explanatory power. Age of farmers contribute significantly and positively to TE in Sweet Potato production at ($P < 0.10$). The positive influence of age on level of TE indicates that as farmers grow older and gain more experience in Sweet Potato, they tend to be knowledgeable about utilization of inputs more efficiently. The result is in conformity with Tiku *et al*. (2015), but in sharp disagreement with Otunaiya *et al*. (2015). The sex of the farmer had negative significant influence on farms' AE and EE at ($P < 0.1$), implying that female farmers were more allocatively and economically efficient than male farmers. This may be due to the fact that females were more prudent with resources than their male counterparts. This result is in consonant with the submission of Shrestha *et al* (2016), but deviates from that of Tiku *et al*. (2015). The result of the analysis also showed that education and farms' TE are positively related ($P < 0.10$), this may be because educated farmers had acquired better skills which were utilized in accessing information and proper planning of their farms better than their less educated ones. Begum *et al*. (2010) and Oluwatayo *et al*. (2016) obtained similar result. Entrepreneurial training received by farmers' had direct significant association with Sweet Potato farm's AE and EE ($P < 0.05$ and $P < 0.10$) with coefficients of 0.11 and 0.17 respectively. Training programs expose farmers to modern farming techniques and marketing activities. Credit access significantly increased TE with coefficient of 0.04 ($P < 0.05$) and decreased SE with coefficient of 0.02 ($P < 0.01$). In the case of TE, it could be that the farmers had access to credit which enabled them to get needed inputs for optimum yield. The result is in line with the findings of Shrestha *et al*. (2016). The inverse association between credit access and SE may not be unconnected with the fact that large scale farmers did not depend on credit to finance their farming operations. The result is consistent with that of Shrestha *et al*. (2016). Indirect significant relationship exist between market distance and TE ($P < 0.10$), implying that increasing the market distance will lower TE of Sweet Potato farms. Farmers rely on market for the purchase of various farm inputs and also sales of their outputs. The results of standardized coefficients of the independent variables are shown in Table 2 Factors capable of improving EE of Sweet Potato production are ranked in the order of importance using their beta values. The value was higher for sex, vine type, training, credit access, education, value addition status, market distance, farming experience and age. The vine type, value addition status and farming experience though not significant in Tobit regression, are capable of improving efficiency of Sweet Potato farms in the study area.

Constraints in Sweet Potato production

Constraints in Sweet Potato production is presented in Table 4. As presented in the table, the most important constraint in Sweet Potato production is labour shortage, which could be responsible for some of the inefficiencies obtained in Sweet Potato production in the country; still characterized by hoe and cutlass that rely heavily on human labour. However, a sizable number of abled persons in most parts of the country including Benue State have abandoned farming for transport business with motorcycle which provides them with a relatively stable daily wage. This has resulted into shortage of farm labour in the study area. Poor access to improved technology is the second most important production constraint on farms as reported by the farmers. Most of the farmers relied on crude implements such as cutlass and hoe for the associated farming activities and the use of improved vine for planting was not popular among them. The third most important constraint is poor yield. This may also be connected to the use of crude implements and local type of vines among other factors. Similar result was obtained by Okonya *et al*. (2014). Insect pests ranked fourth, low access to credit was the fifth important constraint in Sweet Potato production. This may be due to the fact that farmers found it difficult to meet the conditions set out by most of the formal credit sources and some informal sources before they could access loan. The result is similar to that of Fuglie (2007). Diseases are the next important constraint involved in Sweet Potato production and this may affect the yield of the crop, and hence, level of efficiency. Other important production constraints were bad roads, low price of output, lack of processing facilities and high transport cost.

Conclusion

The results of the analysis of efficiency of sweet potato farms revealed that the farms were not efficient in the use of resources. Farmers' and institutional characteristics influenced the TE, AE, EE and SE of the farms differently. While farmers' level of education had direct relationship with farms' TE only, entrepreneurial training received had direct influence on both AE and EE. Access to credit influenced farms' TE positively, but had a negative effect on farms' SE. Also, TE of Sweet Potato farms was negatively influenced by distance to the nearest market. Labour shortage, poor access to improved technology and infestation by insect pests were the three most important constraints limiting Sweet Potato production in the study area. The study therefore concludes that improving the efficiency of Sweet Potato production will require policies that will see to regular training of farmers by extension agents and other stakeholders and enhancement of rural farmers' access to credit.

Table 1: Socioeconomic variables

Variables	Mean	Std. dev.	Min	Max
Output/Ha (Tonnes)	3.934	1.363	2	12
Farm size (Ha)	1.689	1.139	0.4	8
Labour/Ha (Man-days)	2.439	1.500	1	12.5
Vines/Ha (Kg)	93.555	21.713	62	221
Fertilizer/Ha (Kg)	78.896	97.361	0	285.7
Pesticides/Ha (Liters)	1.621	0.395	1	3
Types of vines	0.355	0.545	0	3
Farm ownership	0.828	0.379	0	1
Sex	0.731	0.446	0	1
Age (Years)	48.570	10.661	28	71
Education (Years)	9.810	5.319	0	16
Experience in farming (Years)	22.183	9.852	5	52
Access to credit	0.484	0.502	0	1
Distance to nearest market (Km)	3.985	2.047	1	8
Membership of cooperative society	0.570	0.500	0	1
Participation in Entrepreneurial Training	0.710	0.456	0	1

Table 2: Efficiency estimate from DEA (CRS and VRS) models

Efficiency score		n = 96		
TE	AE	EE	SE	
<0.60	34 (14.0)	86.0 (64.5)	94.6 (75.3)	5.4
0.60–0.69	22 (17.2)	8.6 (14.0)	1.1 (17.2)	10.7
0.70–0.79	15 (24.7)	3.2 (16.1)	1.1 (2.2)	15.1
0.80–0.89	10 (18.3)	1.1 (1.1)	2.2 (1.1)	14.0
>0.89	15 (25.8)	1.1 (4.3)	1.1 (4.3)	54.8
Mean	0.685 (0.783)	0.445 (0.604)	0.310 (0.467)	0.877
Standard error	1.558	1.868	1.748	1.456

Table 3: Tobit regression analysis of factors influencing efficiency in sweet potato production

Variables	TE	AE	EE	SE
Constant	0.909 (0.107)***	0.436 (0.150)***	0.429 (0.270)***	1.010(0.100)***
Age	0.003 (0.002)*	−0.003 (0.003)	−0.003(0.005)	0.003(0.002)
Sex	−0.542 (0.037)	−0.0836 (0.050)*	−0.162(0.085)*	−0.009(0.035)
Education	0.005 (0.003)*	0.003 (0.004)	0.002(0.008)	0.001(0.003)
Training	−0.014 (0.034)	0.105 (0.050)**	0.166(0.097)*	−0.035(0.032)
Vine type	0.027 (0.039)	0.032 (0.054)	0.048(0.098)	−0.012(0.037)
Credit Access	0.035 (0.016)**	0.059 (0.045)	0.077(0.085)	−0.019(0.006)***
Value addition status	0.005 (0.033)	0.032 (0.023)	0.010(0.043)	−0.011(0.015)
Market distance	−0.014 (0.007)*	0.002 (0.010)	0.026(0.019)	0.005(0.007)
Farming experience	0.003 (0.002)	0.005 (0.003)	0.001(0.006)	0.001(0.002)
Sigma	0.139(0.010)	0.176(0.019)	0.244(0.043)	0.130(0.010)
Log likelihood	49.630	10.533	24.160	51.451
LR	15.07	22.72	18.83	17.30

Table 4: Constraints militating against sweet potato production in the study area

Constraints	Mean value	Rank
Insect pests	3.52	4th
Diseases	2.66	6th
Labour shortage	4.43	1st
Poor access to improved technology	4.20	2nd
Lack of processing facilities	2.98	9th
Low price	2.32	8th
Poor yield	3.87	3rd
High transport cost	2.01	10th
Bad roads	2.54	7th
Low access to credit	2.19	5th

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