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RESEARCH ARTICLE

FARM SIZE EFFICIENCY DIFFERENTIALS OF BIO-FORTIFIED CASSAVA PRODUCTION IN NIGERIA: A STOCHASTIC FRONTIER ANALYSIS APPROACH

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ABSTRACT

The study specifically investigated farm size efficiency differentials of bio-fortified cassava production in Nigeria. Data were collected through a cross-sectional survey of bio-fortified cassava producers in Nigeria. The estimated coefficients of the parameters of production variables for small scale bio-fortified cassava farm size (land, herbicide and fertilizer) played a major role in bio-fortified cassava production on a small scale in Nigeria. For the medium and large scale bio-fortified cassava farm size, production variables (land, labor and fertilizer) and (land, labor, herbicide and fertilizer) respectively played a major role in bio-fortified cassava production. The average economic efficiency of the small, medium and large scale bio-fortified cassava producers was 42%, 54% and 63% respectively. Policies intended to increase the popularization and cultivation of bio-fortified cassava in Nigeria should be targeted toward the small and medium scale cassava farmers since they carried the majority of the producer of bio-fortified cassava in Nigeria.

KEYWORDS

Efficiency, Farm size, Stochastic Frontier Analysis, Bio-fortified cassava and Nigeria.

1. INTRODUCTION

Agriculture is an important component of a national economy including the Nigeria economy, contributing to the latter approximately 21.91% of the gross domestic product (GDP) (Plecher, 2020; Singh-Peterson and Iranacolaivalu, 2018). In Nigeria, farming and other agricultural activities constitute the principal sustainable livelihood of most Nigeria people (Ibiremo et al., 2011). Among the cash crops important in Nigeria agriculture, cassava (Manihot esculenta) production plays an important role in ensuring poor people's livelihood (Otekunrin and Sawicka, 2019). The whole country has an area of approximately 824 thousand hectares planted to cassava (FAO, 2018), with cassava yield growing by 9.94 million tonnes in 2018 (FAO, 2018). Cassava is an important staple food in Nigeria (Kolapo et al., 2020). Cassava is a starchy crop which contributes to the staples of millions in sub-Saharan Africa (SSA). According to a study, about 177,948 million tonnes of cassava were produced in Africa. Nigeria is regarded as the world's largest producer of cassava with a total of about 20.4 percent of the world export in year 2017 (Otekunrin and Sawicka, 2019; Otekunrin and Sawicka, 2019).

Cassava is a major staple food crop in Nigeria. As defined by some researcher, a staple crop is the one that is been eaten regularly and which also provides larger proportions of the population's nutrients (Otekunrin and Sawicka, 2019). Cassava fulfil this purpose as it can be eaten raw or in a processed form. Cassava is an essential component of the diet of about 70 million Nigerians (FAO, 2013). Nigeria, being the largest producer of cassava in the world is producing an average annual estimate of 45 million metric tons which had been translated into a major global market share of about 19 percent (Hillocks, 2002); Phillips et al., 2004). The production of biofortified vitamin-A cassava started in 2011 with the intervention of the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA) which were funded by Harvest Plus program (Kolapo and Fakokunde, 2020; Kolapo, Olayinka and Muhammed, 2020). Five years after the intervention program, statistics revealed that over 1million of Nigerian farming households grows yellow cassava varieties that contains substantial quantities of vitamin-A even after processing (Kolapo et al., 2020).

In Nigeria diets today, yellow bio-fortified cassava represents additional source of vitamin A (Saltzman et al., 2014). The production of bio-fortified cassava in Nigeria in on the increase and the producers were expected to be efficient based on the attributes of the bio-fortified cassava varieties. Efficiency in agricultural production such as the production of bio-fortified cassava is defined as the measure of effectiveness that produces the minimum waste of resources, effort, and skill. The reason behind estimating efficiency is that if decision making units are not making

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efficient use of existing technologies, then efforts designed to improve efficiency would be more cost effective than introducing a newtechnology as a means of increasing output (Shappiro, 1983). Efficiency measurement is important because it leads to a sustainable resource savings, which have important implications for both policy formulations and management (Bravo-Ureta and Evenson, 1994). However, despite the increase in cassava production in Nigeria, it remained well behind the population growth rate, but it is the only tropical root and tuber which plays some role in world trade (Jochen, 1993; Awoyinka, 2009; Okigbo, 2007).

Therefore, based on the introduction of bio-fortified vitamin A cassava and the quest to meet the demand of the growth in the population, there is the need to examine the farm size efficiency of production of this important crop to aid policy formulation, increase productivity and derive maximum benefit from its production. Also, cassava has low input requirements and farmers in Nigeria are poorly endowed with farm resources and as such the available scarce inputs need to be efficiently utilized, hence the need to investigate the farm size efficiency of bio-fortified cassava production. Research works bordering on farm size efficiency differentials of bio-fortified cassava production in Nigeria are scant or nonexisting. Few works such as attempted such study but failed to ascertain the differentials of efficiency of bio-fortified cassava in the important agricultural zones in Nigeria (Ogunleye et al., 2019). They failed to ascertain and compare the technical, allocative and economic efficiency of the different farm size in bio-fortified cassava farming (Ogunleye et al., 2019).

There is a need for a study that will determine the efficiency determinants of factors influencing the technical, allocative and economic efficiency among these categories of bio-fortified cassava farms and compare these coefficients in the various cassava zones of Nigeria to enable uniform policy or specific policy frameworks be designed for boosting the production of bio-fortified cassava in Nigeria based on research findings. The farm size in Nigeria is however categorized into three namely, small, medium and large scale biofortified cassava farms. Specifically, the study described the socio-economic characteristics of bio-fortified cassava producers by farm size; determined the costs and returns of bio-fortified cassava production by farm size and analyzed the determining factors influencing the technical, allocative and economic efficiency of small, medium and large-scale bio-fortified cassava farms. The need for this study was borne out of the desire to increase the level of productivity in bio-fortified cassava production and also to throw more light on the problems associated with its production in Nigeria. The findings of this study help to provide information and a solution to the decreasing productivity and yield of bio-fortified cassava per hectare, leading to an improvement in bio-fortified cassava production.

2. Theoretical Framework

The review of relevant literature explains the techniques of estimating the farm efficiency of agricultural production. The following two techniques exist: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). However, among the preference methods listed above, the Stochastic Frontier Analysis (SFA) method is vastly recommended because of the following reasons; availability of data, types of data (cross-section, time series and panel), convenience of the analysis, other economic underpins and indeed advantages derived from the tools (Battese and Coelli, 1995). Stochastic Frontier Analysis (SFA) has been widely adopted and used by many researchers (Ajibefun et al., 2006; Coelli and Battese, 1996; Ogundele and Okoruwa, 2006; Ayinde et al., 2011; Taphee and Jongur, 2014; Ogunleye et al., 2019). This is because the Stochastic Frontier Analysis (SFA) makes a distinction between statistical noise and random noise around the obtained production frontier and inefficiency (Kebede, 2001; Oren and Alemdar, 2006).

The stochastic model specification not only address the noise problem associated with earlier deterministic function, but also permit the estimation of standard errors and tests of hypotheses which were not possible with the early deterministic model because of the violation of the maximum likelihood condition. However, the main criticism of stochastic frontier is that there is no a-priori justification for the selection of any particular distributional form U*i*. In agricultural economics literature, the use of Stochastic Frontier Analysis (SFA) is recommended because of the inherent nature of uncertainty/variability associated with agricultural production due to weather, fires, pests, diseases, etc (Coelli and Battese, 1996; Coelli et al., 1998). The present study adopts the stochastic frontier approach already developed by earlier studies (Ani et al., 2013; Taphee and Jongur, 2014; Ogunleye et al., 2019).

3. Methodology

3.1 Area of Study

This study was carried out in Nigeria. Nigeria is located in West Africa on the Gulf of Guinea and has a total area of 923,768 km^2 making it the world's 32nd largest county. It shares a 4,047 km border with Benin(77km), Niger(1497km), chad (87km), Cameroon (1690km) and has a coastline of a least 853km. Nigeria lies between latitude 4^o and 14^o North and longitude 2^o and 15^o East. The far South is defined by its tropical rain forest climate where annual rainfall is 60 to 80 inches (1524mm to 2032mm) per year. The coastal plain are found in both the South-West and the South-East, this forest zones most southerly portion is defined as salt water swamp also known as the mangrove swamp. The tropical climate in the area favors the growth of some varieties of annual crops such as groundnut, yam, cassava, maize, rice, cowpea, plantain and banana and the tree crops include cocoa, kola nut and palm produce. There are two distinct seasons in Nigeria, namely the rainy season which last from March to October and the dry season which comes up with harmattan and last from November to February. Nigeria is the most populous country in Africa and account for about 18% of the continent total population. Nigeria was one of the first country in Africa where bio-fortified cassava was introduced in 2011, hence the choice of the study area.

3.2 Sampling procedures and sample size

Multistage sampling procedures were employed for the study. The first stage involved purposive selection of three States because the introduction of bio-fortified cassava in 2011 started in these States. This included Oyo, Benue and Akwa-ibom State. The second stage involved purposive selection of two Local Government Areas (LGAs) because of the concentration of bio-fortified cassava producers in the areas. The third stage involved purposive selection of three communities from each of the selected LGAs. At the third stage, ten bio-fortified cassava farmers were purposively selected from each community to make a total of 360 (Three hundred and sixty) respondents. Primary data were used for the study. The primary data were sourced from cross-sectional survey of bio-fortified cassava farmers in the study area with the aid of well-structured questionnaire to cover information about the socioeconomic characteristics of respondent and inputs and outputs of bio-fortified cassava production. Data were collected in June 2019- September, 2019.

3.3 Analytical techniques

The data were analyzed using descriptive statistics, Farm budgeting analysis and Stochastic Frontier Analysis (SFA) and ANOVA.

3.4 Descriptive statistics

Descriptive statistics was used to summarized the socio-economic characteristics of the bio-fortified cassava farmers.

3.5 Budgetary technique

The budgetary technique was used to estimate the costs and returns to the production of bio-fortified cassava. the various types of inputs used and their costs implication were analyzed using enterprise budget analysis. The costs were divided into variable costs and fixed costs.

The enterprise budget equations are;

Gross Margin (GM),

$$GM= \sum p_i q_i \sum r_i x_i \quad (1)$$

Where

p_i =average price of bio-fortified cassava sold (₦)
q_i =average quantity of bio-fortified cassava sold per production cycle
r_i =average price of variable inputs(₦)
x_i =average quantity of variable inputs used (kg)

Subsequently, the net returns were obtained from gross margin.

Net returns=GM−TFC (2)

NI=GM -TFC (3)

ROI = NFI/T (4)

BCR = TR/TC (5)

TVC = Summation of all the variable cost which includes; Land preparation, Planting materials, Chemical used, Labour used (planting, weeding, fertilizer and pesticide application and harvesting), Transportation etc. Fixed costs include depreciation on fixed assets (e.g. building, wheel barrow, tractor, plougher, cutlass, hoes etc.); this was charged using straight-line method.

Where:
GM = Gross margin; NFI = Net farm income; TC = Total cost incurred; ROI = Return on investment; BCR = Benefit cost ratio; TVC= Total variable cost incurred; TFC= Total fixed cost incurred; TR= Total revenue generated from production.

3.6 Stochastic Frontier Model

Stochastic frontier model was used to analyzed the factors affecting the efficiency of bio-fortified cassava production by farm size. The stochastic frontier production model for the study is expressed in equation1 as:

$$Yi = \beta_o + \sum_{k=1}^{4} \beta_k X_{ki} + \frac{1}{2}\sum_{k=1}^{4}\sum_{j=1}^{4} \beta_k X_{ki} X_{ji} + V_i - U_i \quad (6)$$

where,

Yistands for the observed individual *i*th producer's output (kg);

X_1 represents the hectares of land used by the *i*th producer;

X_2 indicates labor input consisting of family and hired labor (man-days per hour);

X_3 shows the quantity of herbicides used (gram), and;

X_4 represents quantity of fertilizer used on *i*th producer's farm (in Naira);

β_o= vector of unknown parameters estimated

Vi= are random variables associated with random factors; and

Ui= which are non-negative random variables which are assumed to account for technical inefficiency in production.

Accordingly, technical efficiency (TE) of an individual producer is defined in terms of the ratio of the observed (Yi^*)output to the corresponding frontier output (Yi), conditioned on the level of inputs used by the producer. Technical inefficiency is therefore defined as the amount by which the level of production for the producer is less than the frontier output. This is shown in the equation below:

$$TE_i = \frac{Yi^*}{Yi} = \frac{f(Xi\beta)\exp\,(Vi-Ui)}{f(Xi\beta)\exp\,(Vi)} = \exp\,(-Ui) \quad (7)$$

The stochastic cost function which is the basis for estimating the allocative efficiency (AE) of the producer's farm is specified as follows:

$$Ci = \alpha_o + \sum_{k=1}^{4} \alpha_k P_{ki} + \frac{1}{2}\sum_{k=1}^{n}\sum_{i=0}^{n} \alpha_{kj} P_{ki}P_{ji} + V_i - U_i \quad (8)$$

where,

C_i stands for the total cost of producing the bio-fortified cassava output of *i*th farm on per kg basis (₦);

P_1 indicates cost of land (₦);

P_2 indicates cost of total quantity of family and hired labour (man-days) required to perform various production activities on the *i*th producer's farm (₦);

P_3 shows cost of quantity of herbicide used (gram), on *i*th producer's farm (₦);

P_4 represents the total cost of fertilizer used on *i*th producer's farm (₦) and

$\alpha_s$are vector of unknown parameters to be estimated
The sources of technical inefficiency effects in equations (7) is modeled in terms of the farm's and producer's characteristics and specified as:

$$U_i = \delta_o \sum_{i=0}^{10} \delta_n Z_i \quad (9)$$

where,

U_i= technical and allocative inefficiency effects of the equations (7) and (8) respectively;

Z_1 =Age of the producer in years;

Z_2 =Gender of the producer (1=male, 0= otherwise)

Z_3 = Educational level (years);

Z_4 = Years of production experience (years)

Z_5 = Farm Size (ha);

Z_6 = Membership of association (1=yes, 0=otherwise)

Z_7 = Access to credit (Yes=1, 0= otherwise)

Z_8 = Access to planting materials (Yes=1, 0=otherwise)

Z_9 = Access to extension agent (Yes=1; 0=otherwise)

Z_{10}= Training (1=Yes, 0=otherwise)

3.7 Economic Efficiency (EE)

This is the multiplication of technical and allocative efficiency,

EE= TE× AE

3.8 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was used to test for significant difference in the profitability of bio-fortified cassava production among these categories of bio-fortified cassava farmers. To stabilize the variance, data collected was transformed using square root transformation while percentage data was transformed with angular transformation (arcsine), Significant means was separated using Duncan's Multiple Range Test, DMRT at P<0.05.

4. Results and Discussion

4.1 Socio-economic characteristics of the biofortified cassava farmers in Nigeria

The result of the socio-economic characteristics of bio-fortified cassava farmers by farm size were presented in Table 1. The result of the study shows that the mean ages of the small, medium and large scale biofortified cassava farmers were 47(±13.77), 46(±12.27) and 48(±14.21) respectively. This is no significant difference in the ages of the three categories of farmers. This result implies that bio-fortified cassava farmers were in their active and productive age (Oparinde et al., 2017). Majority (68.37% and 89.25%) of the medium and large scale bio-fortified cassava farmers were male while about 46.38% of the small scale bio-fortified cassava farmers were male. This shows that production of bio-fortified cassava on medium and large scale were mainly popular among men while production on small scale were mostly common among the women. This might be due to the fact that men are more prone to adopting new technology than women and might also be due to the drudgery nature of farm practices involved in the production of bio-fortified cassava, hence, men will be more involved than women. Majority (79%, 83.21% and 85.31%) of the small, medium and large scale bio-fortified cassava respectively were married.

This implies that producers of bio-fortified cassava farmers were responsible and also the use of family labour might be possible for the production of bio-fortified cassava. The mean years of formal education of small, medium and large scale biofortified cassava farmers were 14.39 (±6.83), 14.34 (±5.25) and 16.13 (±7.29) respectively. This revealed that respondents were literate and thus, can read and write. About 43.37% of the small scale bio-fortified cassava farmers had access to credit while 58.17% of the medium scale bio-fortified cassava farmers had access to credit with majority (79.38%) of the large scale bio-fortified cassava farmers having access to credit. This implies that large scale bio-fortified cassava farmers had more access to credit and this might have facilitated them producing bio-fortified cassava on a large scale. The mean years of experience of small, medium and large scale bio-fortified cassava farmers were 14.62(±6.92), 13.38(±6.18) and 15.19(±8.34) respectively. This shows that the respondents had been into cassava production for a long time even before the introduction of new improved bio-fortified cassava in 2011. Majority (86.23%, 87.42% and 94.47%) of the small, medium and large scale bio-fortified cassava farmers respectively belong to one association or the other. This revealed that they might experience group dynamics and benefits such as credit facilities, farm inputs and etc.

Table 1: Socio-economic characteristics of bio-fortified cassava farmers by farm size

Variables	Small scale	Medium Scale	Large Scale	Pooled
Age (years)	47 (±13.77)	46 (±12.27)	48 (±14.21)	47 (±14.35)
Male (%)	46.38	68.37	89.25	67.36
Married (%)	79.00	83.21	85.31	81.57
Formal education (years)	14.39 (±6.83)	14.34 (±5.25)	16.13 (±7.29)	14.92 (±6.48)
Access to credit (%)	43.37	58.17	79.38	61.71
Years of experience (years)	14.62 (±6.92)	13.38 (±6.18)	15.19 (±8.34)	14.22 (±6.43)
Membership of association (%)	86.23	87.42	94.47	88.41

Figures in parentheses are standard deviation

4.2 Farm specific characteristics by farm size

Presented in Table 2 is the farm specific characteristics of the bio-fortified cassava farmers by farm size. From Table 2, majority (83.57%) of the small-scale bio-fortified cassava farmers had a farm size of between 1-2ha while 16.43% of them had a farm size of between 2.1-3ha. The implies that farm size of between 1-2ha were more common among scale bio-fortified cassava farmers in Nigeria. Among the medium scale bio-fortified cassava farmers, about 57.41% of them had a farm size of between 4.1-5ha while 42.59% of the medium scale bio-fortified cassava farmers had a farm size of between 3.1-4ha. Considering the large-scale bio-fortified cassava farmers, about 26.67% of them had a farm size of between 4.1-5ha while majority (73.33%) had a farm size of ≥5.1ha. The mean farm size for the small, medium and large-scale bio-fortified cassava farmers were 1.2(±0.37), 2.3(±1.98) and 4.2(±2.59) respectively. This result implies that production of bio-fortified cassava in Nigeria is still largely on small scale as majority (57.5%) of the respondents were small scale bio-fortified cassava farmers (Table 2).

As regarding the mode of land acquisition of bio-fortified cassava farmers by farm size in Table 2, about 43% of the small scale bio-fortified cassava farmers inherited their farm land, 5.8% purchased their farm land, 16.9% rented their farm land while 34.3% of the small scale bio-fortified cassava farmers acquired their farm land through communal/gift. Considering the medium scale bio-fortified cassava farmers, about 39.82% inherited their farmland, 8.33% purchased their farm farmland, 31.48% rented their farmland while 20.37% of the medium scale bio-fortified cassava farmers acquired their farmland through communal/gift. About 8.89% of the large scale bio-fortified cassava farmers acquired their farm land through inheritance, 40% got their farmland through purchase, 37.78% of them were through rent while 13.33% of the large scale bio-fortified cassava farmers got their farmland through communal/gift. This result implies that acquisition of farmland through inheritance for the production of bio-fortified cassava were more common among the small scale bio-fortified cassava farmers in the study area while acquisition of farm land through purchase and rent were more common among medium and large scale bio-fortified cassava farmers in Nigeria.

The varieties of bio-fortified cassava grown by the farmers by farm size were also presented in Table 2. Among the small scale bio-fortified cassava farmers, about 29.5% grown TMS 01/1371, 16.9% grown TMS 01/1412, 22.2% grown, TMS 01/1368, 9.2% grown TMS 01/0593, 11.6% grown TMS 01/0539 while 10.6% of the small scale bio-fortified cassava farmers grown TMS 01/0220 varieties in Nigeria. Among the medium scale bio-fortified cassava farmers, about 7.4% grown TMS 01/1371, 4.6% grown TMS 01/1368, 14.8% grown TMS 01/0593, 30.6% grown TMS 01/0539 while 42.6% of the medium scale bio-fortified cassava farmers grown TMS 01/0220 varieties in Nigeria. Among the large-scale bio-fortified cassava farmers, about 13.3% of grown TMS 01/1412, 17.8% grown TMS 01/0593, 40% grown TMS 01/0539 while 28.9% of the large scale bio-fortified cassava grown TMS 01/0220 varieties. This result implies that cultivation of bio-fortified cassava varieties released in 2011 (TMS 01/1371, TMS 01/1412 and TMS 01/1368) were more popular among small scale bio-fortified cassava farmers in Nigeria while the cultivation of bio-fortified cassava varieties released in 2016 (TMS 01/0593, TMS 01/0539 and TMS 01/0220 were more popular among the medium and large scale bio-fortified cassava farmers. This might be attributed to access to information and planting materials by the medium and large-scale bio-fortified cassava farmers in Nigeria.

Table 2: Farm specific characteristics by farm sizes

Variables	Small scale Freq (%)	Medium Scale Freq (%)	Large Scale Freq (%)	Total Freq (%)
Farm size (ha)				
1.0-2.0	173(83.57)	--	--	173(48.06)
2.1-3.0	34(16.43)	--	--	34 (9.44)
3.1-4.0	--	46(42.59)	--	46(12.78)
4.1-5.0	--	62(57.41)	12(26.67)	74(20.56)
≥5.1	--	--	33(73.33)	33(9.17)
Total	**207 (100.0)**	**108 (100.00)**	**45 (100.00)**	**360 (100.00)**
Mean	1.2(±0.37)	2.3(±1.98)	4.2(±2.59)	
Mode of land acquisition				
Inherited	89(43.0)	43(39.82)	4(8.89)	136(37.78)
Purchase	12(5.8)	9(8.33)	18(40.0)	39(10.83)
Rent	35(16.9)	34(31.48)	17(37.78)	86(23.89)
Communal/Gift	71(34.3)	22(20.37)	6(13.33)	99(27.5)
Total	**207 (100.0)**	**108 (100.0)**	**45 (100.0)**	**360 (100.00)**
Varieties grown				
TMS 01/1371	61(29.5)	8(7.4)	--	69(19.2)
TMS 01/1412	35(16.9)	--	6(13.3)	41(11.4)
TMS 01/1368	46(22.2)	5(4.6)	--	51(14.2)
TMS 01/0593	19(9.2)	16(14.8)	8(17.8)	43(11.9)
TMS 01/0539	24(11.6)	33(30.6)	18(40.0)	75(20.8)
TMS 01/0220	22(10.6)	46(42.6)	13(28.9)	81(22.5)
Total	**207 (100.0)**	**108 (100.0)**	**45 (100.0)**	**360 (100.0)**

Table 3: Average costs and returns to bio-fortified cassava production per season by farm size

Variables	Small Scale Amount (₦) % of total costs	Medium Scale Amount (₦) % of total costs	Large Scale Amount (₦) % of total costs
A. Total revenue Variable cost	284159.27	823572.62	1585463.68
Land preparation	42786.32 48.93	89854.43 24.42	128432.64 17.76
Planting material	8620 9.85	18743	64743 8.95
Fertilizer	1650	28451	39264
Herbicides	3400	19652	31753
Labor cost	14370 16.43	49435 13.44	87934 12.16
B. Total Variable Costs (TVC)	70826.32 81.00	206135.43 56.04	352126.64 48.68
Fixed cost Rent on land	14850 16.97	96413 26.21	185632 25.66
Depreciation on sprayer	843	9324	28461
Depreciation on wheelbarrow	929	8329	33837
Depreciation on tractor	--	18485 5.03	64962 8.98
Depreciation on other equipment	--	29148 7.92	58325 8.06
C. Total fixed costs (TFC)	**16622 19.00**	**161699 43.96**	**371217 51.32**
D. Total costs (B+C)	**87448.32**	**367834.43**	**723343.64**
E. Gross margin (A-B)	**213332.95**	**617437.19**	**1233337.04**
F. Net Farm Income (A-D)	**196710.95**	**455738.19**	**862120.04**
Return on Investment (ROI)	1.06	1.24	1.19
Benefit cost ration	2.06	2.24	2.19

4.3 Costs and returns to bio-fortified cassava production by farm size in Nigeria

In other to ascertain the profitability of bio-fortified cassava production, the average gross margin, net returns, rate of returns and benefit cost ratio of the bio-fortified cassava farmers were calculated by farm size. The input used, costs, output data generated from the bio-fortified cassava farmers were used to compute the gross margin and net returns to bio-fortified cassava production. The average costs and returns for the bio-fortified cassava production by farm size were presented in Table 3. The result revealed the revenue generated for one production season by small scale bio-fortified cassava farmers was ₦284159.27. From Table 8 Small scale farmers, the cost of land preparation (₦42786.32) on individual cost accounted for a large proportion (48.93%) of the total costs with the total variable costs (₦70826.32) accounting for the largest proportion (81%) of the total costs. Rent on land (₦14850) accounted for a significant proportion 16.97% of the fixed cost with the total fixed costs accounting for just 19%. The negligible small proportion of the fixed costs shows the crude method of agricultural small-scale practices in Nigeria.

The average net return (net farm income) from the production of bio-fortified cassava in Table 3 (small scale) was ₦196710.95. This implies that the production of bio-fortified cassava in Nigeria is a profitable enterprise even on a small scale. The return on investment of small scale bio-fortified cassava farmers indicated that for every one naira invested in bio-fortified cassava production, the farmer gains ₦1.06. The implication is that bio-fortified cassava production on a small scale in Nigeria is profitable. The result agrees in the Profitability of investment and farm level efficiency among groups of Vitamin A cassava farmers in Oyo State, Nigeria who found out that bio-fortified cassava production is a profitable business enterprise (Ogunleye et al., 2019). The benefit cost ratio of 2.06 among the small-scale cassava farmers shows that for every ₦2.00 return to bio-fortified cassava production, 6k is been spent on the cost of producing the bio-fortified cassava. Also, the costs and returns for medium scale bio-fortified cassava farmers were calculated and presented in Table 3. The average revenue generated by the medium scale bio-fortified cassava farmers in one production cycle in Nigeria were ₦823572.62.

The cost of land preparation ₦89854.43 takes the largest proportion of the variable cost while the total variable cost ₦206135.43 takes the largest share of the total costs. The costs of rent on land ₦96413takes the largest proportion of the fixed cost while the total fixed costs (₦161699) accounted for 43.96% of the total costs of producing bio-fortified cassava on a medium scale. The average total cost of producing bio-fortified cassava on a medium scale was ₦367834.43. The net farm income realized by the medium scale bio-fortified cassava farmers was ₦455738.19 which shows that production of bio-fortified cassava on a medium scale is a profitable enterprise in Nigeria. The return on investment of medium scale bio-fortified cassava farmers indicated that for every one naira invested in bio-fortified cassava production, the farmer gains ₦1.24. The implication is that bio-fortified cassava production on a medium scale in Nigeria is profitable. The result agrees with in the Profitability of investment and farm level efficiency among groups of Vitamin A cassava farmers in Oyo State, Nigeria who found out that bio-fortified cassava production is a profitable business enterprise (Ogunleye et al., 2019).

The benefit cost ratio of 2.24 among the medium scale bio-fortified cassava farmers shows that for every ₦2.00 return to bio-fortified cassava production, 24k is been spent on the cost of producing the bio-fortified cassava. The average revenue generated by the large-scale bio-fortified cassava farmers in one production cycle in Nigeria were ₦1585463.68. The cost of land preparation ₦128432.64 also takes the largest proportion (17.76%) of the variable cost while the total variable cost ₦352126.64 takes the largest share (48.68%) of the total costs. The costs of rent on land ₦185632 takes the largest proportion (25.66%) of the fixed cost while the total fixed costs (₦371217) accounted for 51.32% of the total costs of producing bio-fortified cassava on a large scale. The average total cost of producing bio-fortified cassava on a large scale was ₦723343.64. The net farm income realized by the large-scale bio-fortified cassava farmers was ₦862120.04 which shows that production of bio-fortified cassava on a large scale is a profitable enterprise. The return on investment of large-scale bio-fortified cassava farmers indicated that for everyone naira invested in bio-fortified cassava production, the farmer gains ₦1.19. The implication is that bio-fortified cassava production on a large scale is profitable (Ogunleye et al., 2019). The benefit cost ratio of 2.19 among the large-scale bio-fortified cassava farmers shows that for every ₦2.00 return to bio-fortified cassava production, 19k is been spent on the cost of producing the bio-fortified cassava. However, it can be implied that production of bio-fortified cassava on all the categories of farm size including small, medium and large scale were profitable, farmers in the category of medium and large scale however, realize more income in a production cycle than the small scale bio-fortified cassava farmers.

4.4 Efficiency of Bio-fortified Cassava Production by Farm Size

4.4.1 Technical efficiency of Bio-fortified Cassava Production by Farm Size

The stochastic frontier model specified was estimated by the maximum likelihood (ML) method using frontier 4.1 software developed (Coelli, 1995). The ML estimates and inefficiency determinants of the specified frontier were presented in Table 4 by farm size. The result of study revealed that the generalized likelihood function was -16.23, -36.37 and -11.47 for small, medium and large bio-fortified cassava farm size respectively. The likelihood function in Table 4 implies that inefficiency exist in the data set. The likelihood ratio value represents the value that maximizes the joint densities in the estimated model. Thus, the functional form used in this estimation is an adequate representation of the data. The value of gamma (γ) is estimated and it was highly significant at ($p<0.01$), ($p<0.01$) and ($p<0.01$) level of probability for small, medium and large bio-fortified cassava farm size respectively. This is consistent with the theory that γ-value should be greater than zero. This implies that 99% of random variation in the output of the bio-fortified cassava farmers was due to the producers' inefficiency in their respective production farms and not as a result of random variability.

Since these factors are under the control of the producers, reducing the influence of the effect of γ will greatly enhance the technical efficiency of the producers and increase their output. The value of sigma square (σ^2) was significantly different from zero at $p<0.01$, $p<0.05$ and $p<0.01$ level of probability for small, medium and large bio-fortified cassava farm size respectively. This indicates a good fit and correctness of the specified distributional assumptions of the composite error terms while the γ indicates the systematic influences that are unexplained by the production function and the dominant sources of random error. This means that the inefficiency effects make significant contribution to the technical inefficiencies of bio-fortified cassava producers. However, the estimated coefficients of the parameters of production variables for small scale bio-fortified cassava farm size (land, herbicide and fertilizer) were positive and significant at 1% level of probability each and hence play a major role in bio-fortified cassava production on a small scale.

For the medium scale bio-fortified cassava farm size, production variables such as land, labor and fertilizer were positive and significant at 1%, 1% and 5% probability level respectively and also play a major role in bio-fortified cassava production on a medium scale. For the large-scale bio-fortified cassava farm size, all the production variables (land, labor, herbicide and fertilizer) were positive and significant at 1% probability level each. This implies that all the production variables play a major role in bio-fortified cassava production on a large scale. The average technical efficiency for the small, medium and large scale bio-fortified cassava farmers was 0.52, 0.64 and 0.73 respectively implying that, on average, the respondents are able to obtain 52%, 64% and 73% of potential output from a given mixture of production inputs for the small, medium and large scale bio-fortified cassava farmers.

Thus, in a short run, there is minimal scope (48%, 36% and 27%) for small, medium and large-scale farmers respectively of increasing the efficiency, by adopting the best management practices and techniques for the production of bio-fortified cassava. For small scale bio-fortified farm size, the estimated coefficient for land was 0.042 which is positive and statistically significant at 1% level of probability. The estimated (0.042) coefficient of land implies that increasing land size by 1% will lead to increased bio-fortified cassava output by 4.2% among the small-scale bio-fortified cassava farmers. Furthermore, the coefficients of the quantity of herbicide used by the small-scale bio-fortified cassava farmers was 0.282 which is positive and statistically significant at 1% level of probability. This implies that a 1% increase in herbicide used will increase bio-fortified cassava output by 28.2% among the small-scale bio-fortified cassava farmers. Also, the coefficient of fertilizer used by the small-scale bio-fortified cassava farmers was 0.042 which was positive and significant at 1% probability level. This implies that small scale bio-fortified cassava farmers can increased their output by 0.42% if they increase fertilizer used by 1%.

Regarding medium scale bio-fortified cassava farmers, the estimated coefficient (0.305) of land was positive and statistically significant at 1% level of probability. This implies that 1% increase in land size will leads to 30.5% increase in output among the medium scale bio-fortified cassava farmers. In addition, the coefficients (0.931) of labor was positive and significant at 1% probability level among the medium scale bio-fortified cassava farmers. This implies that increasing labor used by 1% will increase bio-fortified cassava output by 93.1% among the medium scale bio-fortified cassava farmers. Furthermore, the coefficients (0.006) of fertilizer used was positive and significant at 5% probability level. This implies that medium scale bio-fortified cassava farmers could increase their output by 6% if they increase fertilizer used by 5%. For the large scale bio-fortified cassava farmers, the coefficient (0.068) of land was positive and significant at 1% probability level. This implies that the outputs of large scale bio-fortified cassava farmers could increase by 6.8% if they increase their land size by 1%.

Furthermore, the coefficient (0.024) of labor was positive and significant at 1% level of probability among the large scale bio-fortified cassava farmers. This implies that the large scale bio-fortified cassava farmers can increase their output by 2.4% if they increase labour use by 1%. Also, the coefficient of herbicide (1.330) was positive and significant at 1% probability level among the large scale bio-fortified cassava farmers. This implies that the bio-fortified cassava outputs can be increased by 13.3% if they increase herbicide used by 1%. In addition, the coefficient (0.369) of fertilizer used was positive and significant at 1% level of probability among the large scale bio-fortified cassava farmers. This implies that large scale bio-fortified cassava farmers can increased their outputs by 36.9% if they increase their fertilizer used by 1%. The estimated result of the inefficiency model was presented in Table 4. Generally, a negative sign on a coefficient means that the variable increases technical inefficiency, while a positive sign will decrease technical inefficiency. The result present in Table 4 shows that among the small-scale bio-fortified cassava farmers, the technical inefficiency variables such as age, education and access to credit was significant.

Among the medium-scale bio-fortified cassava farmers, the technical inefficiency variables such as gender, membership in association and access to credit were significant. Among the large-scale bio-fortified cassava farmers, the technical inefficiency variables such as, age and education were significant. Age in bio-fortified cassava production was positive and significant at 5% and 1% respectively for the small and large scale bio-fortified cassava farmers in Nigeria. This shows that increase in age in bio-fortified cassava production would reduce technical inefficiency. Producers' age could be associated with skill accumulation over years which could enhance productivity and resource allocations thereby reducing technical inefficiency. Education in bio-fortified cassava production was positive and significant at 1% each for small and large-scale bio-fortified cassava producers. This shows that increase in the years of education in bio-fortified cassava production would decrease technical inefficiency. As the producers attained more education in their enterprise, they tend to be more productive and efficiently allocate their resources thereby increasing their technical efficiency.

Access to credit was positive and significant at 5% and 1% for small and medium scale bio-fortified cassava farmers. This implies that access to credit will reduce technical inefficiency among the small and medium scale biofortified cassava producers. Gender was negative and significant at 5% for medium scale bio-fortified cassava producers. This shows that the gender of the small-scale producers could increase technical inefficiency. Male producers might be more technical efficient than their male counterparts because they are more involved in training and skill acquisition which may help them in reducing their technical inefficiency. Membership in association was positive and significant at 1% level of probability for the medium scale bio-fortified cassava farmers. The positive coefficients for membership in association implies that membership in association reduces technical inefficiency in bio-fortified cassava production among the medium scale producers. Membership in association could afford the producers the opportunity of sharing information on effective management practices by interacting with other producers. A group researcher noted that the increase in efficiency effects through producers belonging to association is as a result of association being a source of quality inputs, information and organized marketing of products (Abass et al., 2019). This implied that medium scale bio-fortified cassava producers can market their produce through association in other to have access to higher income.

Table 4: Maximum Likelihood Estimates of Stochastic Frontier Model (Technical Efficiency) of Bio-fortified cassava Production by Farm Size

Variables	Parameters	Small Scale			Medium Scale			Large Scale		
		Coeff.	Std. Err	t-ratio	Coeff.	Std. Err	t-ratio	Coeff.	Std. Err	t-ratio
Constant	β_0	0.110***	0.007	15.74	6.659***	0.439	15.16	0.011***	0.001	11.01
Land	β_1	0.042***	0.007	5.63	0.305***	0.026	11.73	0.068***	0.010	6.80
Labor	β_2	-0.045	0.029	-1.52	0.931***	0.322	2.89	0.024***	0.008	3.01
Herbicide	β_3	0.282***	0.058	4.48	0.005	0.335	0.01	1.330***	0.193	6.89
Fertilizer	β_4	0.042***	0.007	5.63	0.006**	0.003	2.01	0.369***	0.060	6.15
Inefficiency model										
Constant	Z_0	0.013	0.021	0.63	2.097*	1.276	1.69	1.593***	0.303	5.25
Age	Z_1	0.610**	0.273	2.24	4.353	4.518	0.96	0.492***	0.090	5.46
Gender	Z_2	0.020	0.020	1.01	-2.695**	1.165	-2.31	1.061	4.488	0.23
Educational level	Z_3	0.282***	0.058	4.48	0.023	0.234	0.09	0.639***	0.103	6.20
Years of experience	Z_4	0.197	0.139	1.42	1.219	1.711	0.71	4.353	4.518	0.96
Farm Size	Z_5	4.286	4.281	1.34	0.031	0.057	0.54	0.531	0.745	0.71
Membership of association	Z_6	0.044	0.054	0.82	2.798***	0.648	4.31	0.086	0.080	1.07
Access to credit	Z_7	0.318**	0.141	2.25	0.803***	0.152	5.28	0.022	0.078	0.28
Access to planting material	Z_8	7.686	7.054	1.08	0.027	0.052	0.51	0.004	0.157	0.02
Access to extension agent	Z_9	0.040	0.066	0.61	0.731	0.143	5.11	0.031	0.057	0.54
Training	Z_{10}	0.001	0.005	0.28	0.004	0.157	0.02	0.027	0.052	0.51
Sigma-square	σ^2	0.045***	0.017	2.65	0.057**	0.024	2.37	0.639***	0.103	6.20
Gamma	γ	0.947***	0.103	9.19	0.931***	0.322	2.89	1.594***	0.290	5.49
Log likelihood function	L/f	-16.23			-36.37			-11.47		
LR test		12.31			41.38			32.15		
Mean efficiency		0.52			64			73		

***,**,* significant at 1%, 5% and 10% level

Table 5: Maximum Likelihood Estimates of Frontier Cost function (Allocative efficiency) for Bio-fortified Cassava Production by Farm Size

Variables	Parameters	Small Scale			Medium Scale			Large Scale		
		Coeff.	Std. Err	t-ratio	Coeff.	Std. Err	t-ratio	Coeff.	Std. Err	t-ratio
Constant	β_0	0.305***	0.026	11.73	0.031	0.057	0.54	0.531	0.745	0.71
Land	β_1	0.070	5.397	0.01	0.318**	0.141	2.25	1.593***	0.303	5.25
Labor	β_2	0.012***	0.003	4.00	0.639***	0.103	6.20	2.695**	1.165	2.31
Herbicide	β_3	0.931***	0.322	2.89	1.594***	0.290	5.49	0.282***	0.058	4.48
Fertilizer	β_4	0.879***	0.138	6.37	0.057**	0.024	2.37	0.042***	0.007	5.63
Sigma-square	σ^2	1.220**	0.566	2.16	0.027	0.052	0.51	0.057**	0.024	2.37
Gamma	γ	0.998	2.041	0.48	0.040	0.066	0.61	0.004	0.157	0.02
Log likelihood function	L/f	35.462			49.442			53.128		
LR test		21.538			28.478			32.924		
Mean efficiency		0.56			0.66			0.75		

***,**,* significant at 1%, 5% and 10% level*

4.4.2 Estimated Stochastic Frontier Production Cost Function (Allocative Efficiency) by farm size

The Maximum Likelihood (ML) estimates of the stochastic frontier production cost parameters (allocative efficiency) for bio-fortified cassava production by farm size were presented in Table 5. For the small scale production cost function, the sigma (σ^2= 1.22) and the gamma (γ=0.99) are quite high and highly significant at 1% level of probability. The high and significant value of the sigma square (σ^2) indicate the goodness of fit and correctness of the specified assumption of the composite error terms distribution (Abass et al., 2019). The gamma (γ = 0.99) shows that 99% of the variability in the output of small scale bio-fortified cassava producers that are unexplained by the function is due to allocative inefficiency. For the medium scale production cost function, the sigma (σ^2= 0.027) and the gamma (γ=0.40) are considerably high although not significant. The gamma (γ = 0.40) shows that 44%% of the variability in the output of medium scale bio-fortified cassava producers that are unexplained by the function is due to allocative inefficiency.

For the large scale production cost function, the sigma (σ^2= 0.057) and the gamma (γ=0.004) are also considerably high and significant at 5% level of probability. The gamma (γ = 0.004) shows that 4% of the variability in the output of large scale bio-fortified cassava producers that are unexplained by the function is due to allocative inefficiency. In Table 5. The estimated coefficients of the parameters of the cost function (labor, herbicide and fertilizer) for small scale bio-fortified cassava farmers were positive and statistically significant at 1% level of probability each respectively. The estimated coefficients of the parameters of the cost function (land, labor, herbicide and fertilizer) for medium scale bio-fortified cassava farmers were positive and statistically significant at 5%, 1%, 1% and 5% level of probability respectively.

Furthermore, the estimated coefficients of the parameters of the cost function (land, labor, herbicide and fertilizer) for large scale bio-fortified cassava farmers were positive and statistically significant at 1%, 5%, 1% and 1% level of probability respectively. This implies that majority of the input variables were important in bio-fortified cassava production irrespective of the farm size. The implication of these finding is that if there is an increase in any of the variable input the total cost of production will increase. This shows that the cost of production is influenced by the cost of variable input incurred in the production cycle.

4.4.3 Elasticity and Return to Scale

Table 6 presents the production elasticities of the inputs used in bio-fortified cassava production by farm size. In the Stochastic frontier model, the coefficients are direct elasticities of the variables. The elasticities for the small scale farm size were 0.042, 0.045, 0.282 and 0.042 for land, labor, herbicide and fertilizer respectively. The return to scale calculated for the small scale farm size bio-fortified cassava farmers were 0.411. This implies a decreasing return scale for the small scale bio-fortified cassava farmers. The result suggest that resources were under utilized by the small scale bio-fortified cassava farmers. The elasticities for the medium scale farm size were 0.305, 0.931, 0.005 and 0.006 for land, labor, herbicide and fertilizer respectively. The return to scale calculated for the medium scale farm size bio-fortified cassava farmers were 1.247 which implies an increasing return to scale for the medium scale bio-fortified cassava farmers. The results suggest that medium scale bio-fortified cassava farmers could enlarge their production scale by about 1.2% on average, in order to adequately expand productivity, given their disposable resources.

The elasticities for the large scale farm size were 0.068, 0.024, 1.330 and 0.369 for land, labor, herbicide and fertilizer respectively. The return to scale calculated for the large scale farm size bio-fortified cassava farmers were 1.791 which implies an increasing return to scale for the large scale bio-fortified cassava farmers. The results suggest that medium scale bio-fortified cassava farmers could enlarge their production scale by about 1.79% on average, in order to adequately expand productivity, given their disposable resources. This result suggests that the medium and large scale bio-fortified cassava farmers were still in stage one of the production process. Large scale farmers were however closer to the rational stage (stage two) of the production process than other categories of farms.

Table 6: Elasticities of production of input variable in bio-fortified cassava production by farm size

Variable	Elasticities		
	Small scale	Medium scale	Large scale
Land	0.042	0.305	0.068
Labor	0.045	0.931	0.024
Herbicide	0.282	0.005	1.330
Fertilizer	0.042	0.006	0.369
Return to scale	0.411	1.247	1.791

Table 7: Frequency Distribution of Technical, Allocative and Economic Efficiency from the Stochastic Frontier Model for Small scale Bio-Fortified Cassava Production

Class	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	%	Frequency	%	Frequency	%
<0.2	0	0	0	3.4	29	14.0
0.21-0.40	12	5.8	18	8.7	56	27.0
0.41-0.60	178	86.0	173	83.6	102	49.3
0.61-0.80	17	8.2	9	4.3	20	9.7
0.81-1.00	0	0	0	0	0	0
Total	207	100	207	100	207	100
Mean	0.52		0.56		0.42	
Minimum	0.38		0.20		0.20	
Maximum	0.71		0.62		0.61	

Table 8: Frequency Distribution of Technical, Allocative and Economic Efficiency from the Stochastic Frontier Model for Medium scale Bio-Fortified Cassava Production

Class	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	%	Frequency	%	Frequency	%
<0.2	0	0	0	0	8	7.4
0.21-0.40	0	0	15	13.9	13	12.0
0.41-0.60	92	85.2	12	11.1	72	66.7
0.61-0.80	12	11.1	81	75.0	15	13.9
0.81-1.00	4	3.7	0	0	0	0
Total	108	100	108	100	108	100
Mean	0.60		0.61		0.54	
Minimum	0.53		0.39		0.20	
Maximum	0.82		0.73		0.65	

Table 9: Frequency Distribution of Technical, Allocative and Economic Efficiency from the Stochastic Frontier Model for Large scale Bio-Fortified Cassava Production

Class	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	%	Frequency	%	Frequency	%
<0.2	0	0	0	0	0	0
0.21-0.40	0	0	0	0	0	0
0.41-0.60	6	13.3	12	26.7	11	24.4
0.61-0.80	32	71.1	29	64.4	31	68.9
0.81-1.00	7	15.6	4	8.9	3	6.7
Total	45	100	45	100	45	100
Mean	0.73		0.75		0.63	
Minimum	0.58		0.59		0.51	
Maximum	0.87		0. 82		0.81	

4.5 Distribution of bio-fortified cassava producers according to technical, allocative and economic efficiencies of bio-fortified cassava production by farm size

4.5.1 Distribution of bio-fortified cassava processors according to technical efficiency by farm size

The frequency distribution of the technical efficiency estimates for small scale bio-fortified cassava producers as obtained from the stochastic frontier model were presented in Table 7. It was observed from the study that 8.2% of the small-scale bio-fortified cassava producers had a technical efficiency (TE) of between 0.61-0.80 while 91.8% of the small scale bio-fortified cassava producers operated at less than 0.60 technical efficiency levels as indicated in Table 7. The small scale producers with the best and least practice had technical efficiencies of 0.71 and 0.38 respectively. This implies that on the average, output fell by 8.2% from the maximum possible level attainable due to inefficiency. The study also suggests that for the average small scale bio-fortified cassava producers to achieve technical efficiency of his most efficient counterpart, he could realize about 29 % cost savings while on the other hand, the least technically efficient producer will have about 62% cost savings to become the most efficient producer.

The frequency distribution of the technical efficiency estimates for medium scale bio-fortified cassava producers as obtained from the stochastic frontier model were presented in Table 8. It was observed from the study that 3.7% of the medium scale bio-fortified cassava producers had a technical efficiency (TE) of 0.81 and above while 96.3% of the medium scale bio-fortified cassava producers operated at less than 0.80 technical efficiency levels as indicated in Table 8. The medium scale producers with the best and least practice had technical efficiencies of 0.82 and 0.53 respectively. This implies that on the average, output fell by 3.7% from the maximum possible level attainable due to inefficiency by medium scale farmers. The study also suggests that for the average medium scale bio-fortified cassava producers to achieve technical efficiency of his most efficient counterpart, he could realize about 18 % cost savings while on the other hand, the least technically efficient producer will have about 47% cost savings to become the most efficient producer.

The frequency distribution of the technical efficiency estimates for the large scale bio-fortified cassava producers as obtained from the stochastic frontier model were presented in Table 9. It was observed from that 15.6% of the large scale bio-fortified cassava producers had a technical efficiency (TE) of 0.81 and above while 13.3% of the large scale bio-fortified cassava producers operated at less than 0.40 technical efficiency levels as indicated in Table 9. The large scale producers with the best and least practice had technical efficiencies of 0.87 and 0.58 respectively. This implies that on the average, output fell by 15.6% from the maximum possible level attainable due to inefficiency by medium scale farmers. The study also suggests that for the average large scale bio-fortified cassava producer to achieve technical efficiency of his most efficient counterpart, he could realize about 13% cost savings while on the other hand, the least technically efficient producer will have about 42% cost savings to become the most efficient producer.

4.5.2 Distribution of bio-fortified cassava producers according to allocative efficiency by farm size

The distribution of the allocative efficiency estimates of the small scale farmers presented in Table 7, indicate that it ranged from 0.20 to 0.80; the mean allocative efficiency of the small scale farmers was 0.56. The result indicates that average small scale bio-fortified cassava producers would enjoy cost saving of about 38% if he or she attains the level of the most efficient producer among the small scale bio-fortified cassava producers. The most allocative inefficient small scale bio-fortified cassava farmer will have an efficiency gain of 80% in bio-fortified cassava production if he or she is to attain the efficiency level of most allocative efficient bio-fortified cassava producer on a small scale.

The distribution of the allocative efficiency estimates of the medium scale farmers presented in Table 8, indicate that it ranged from 0.21 to 0.80; the mean allocative efficiency of the medium scale farmers was 0.61. The result indicates that average medium scale bio-fortified cassava producers would enjoy cost saving of about 27% if he or she is to attains the level of the most efficient producer among the medium scale bio-fortified cassava producers. The most allocative inefficient medium scale bio-fortified cassava farmer will have an efficiency gain of 61% in bio-fortified cassava production if he or she is to attain the efficiency level of most allocative efficient bio-fortified cassava producer on a medium scale.

The distribution of the allocative efficiency estimates of the large scale farmers presented in Table 9, indicate that it ranged from 0.41 to 1.0; the mean allocative efficiency of the large scale farmers was 0.75. The result indicates that average large scale bio-fortified cassava producers would enjoy cost saving of about 18% if he or she is to attains the level of the most efficient producer among the large scale bio-fortified cassava producers. The most allocative inefficient large scale bio-fortified cassava farmer will have an efficiency gain of 41% in bio-fortified cassava production if he or she is to attain the efficiency level of most allocative efficient bio-fortified cassava producer on a large scale.

4.5.3 Distribution of bio-fortified cassava producers according to economic efficiency by farm size

The frequency distribution of the economic efficiency estimates for small scale bio-fortified cassava producers obtained from the stochastic frontier model were presented in Table 7. It was observed from that none of the small scale bio-fortified cassava producers had economic efficiency (EE) of 0.81 and above while 100% of the small scale producers operate at less than 0.8 efficiency level. The mean economic efficiency of the sampled small scale bio-fortified cassava producers was 0.42. The small scale bio-fortified cassava producers with the best and least practice had economic efficiencies of 0.61 and 0.20 respectively. This implies that on the average, output fall by 39% from the maximum possible level due to inefficiency among the small scale bio-fortified cassava farmers. The study also suggests that for the average small scale bio-fortified cassava producer to achieve economic efficiency of his most efficient counterpart, he could realize about 39% cost savings while on the other hand, the least economic efficient small scale producers will have about 80% cost savings to become the most efficient producer on a small scale. However, the average economic efficiency of the small scale bio-fortified cassava producers was 42%. This indicates that small scale bio-fortified cassava producers were operating on less than average economic efficiency level.

The frequency distribution of the economic efficiency estimates for medium scale bio-fortified cassava producers in the study area as obtained from the stochastic frontier model were presented in Table 8. It was observed that the medium scale bio-fortified cassava producers had economic efficiency (EE) ranges between 0.20-0.80 efficiency level. The mean economic efficiency of the sampled medium scale bio-fortified cassava producers was 0.54. The medium scale bio-fortified cassava producers with the best and least practice had economic efficiencies of 0.65 and 0.20 respectively. The study also suggests that for the average medium scale bio-fortified cassava producer to achieve economic efficiency of his most efficient counterpart, he could realize about 35% cost savings while on the other hand, the least economic efficient medium scale producers will have about 80% cost savings to become the most efficient producer on a medium scale. The average economic efficiency of the medium scale bio-fortified cassava producers was 54%. This indicates that medium scale bio-fortified cassava producers were operating above the average economic efficiency level and are thus economic efficient.

The frequency distribution of the economic efficiency estimates for large scale bio-fortified cassava producers as obtained from the stochastic frontier model were presented in Table 9. It was observed that the large scale bio-fortified cassava producers had economic efficiency (EE) ranges between 0.41-1.00 efficiency level. The mean economic efficiency of the sampled large scale bio-fortified cassava producers was 0.63. The large scale bio-fortified cassava producers with the best and least practice had economic efficiencies of 0.81 and 0.51 respectively. The study further suggests that for an average large scale bio-fortified cassava producer to achieve economic efficiency of his most efficient counterpart, he could realize about 19% cost savings while on the other hand, the least economic efficient large scale producers will have about 49% cost savings to become the most efficient producer on a large scale. The average economic efficiency of the large scale bio-fortified cassava producers was 63%. This indicates that large scale bio-fortified cassava producers were also operating above the average economic efficiency level and are thus economic efficient.

4.5.4 Analysis of Variance (ANOVA)

Presented in Table 10 is the result of the Analysis of variance (ANOVA). The result showed that the efficiency of small scale bio-fortified cassava farmers were significantly different from medium scale efficiency at 1% probability level. Furthermore, small scale efficiency was significantly different from large scale efficiency of bio-fortified cassava farmers at 1% level of probability. Consequently, the medium scale efficiency was significantly different from large scale efficiency of bio-fortified cassava farmers at 5% probability level. This implies that there is a significant difference in the level of efficiency of small, medium and large scale bio-fortified cassava farmers in Nigeria as Large scale were more efficient than medium and small scale farmers while medium scale farmers were more efficient than small scale farmers in Nigeria.

Table 10: ANOVA result on the profitability level among the different categories of bio-fortified cassava producers

Farm Scale	Model	Df	Sum of Squares	Mean Square	F-cal	Sig
Small X medium	Regression Residual	25 290	6.542 19.531	0.435 0.634	19.46	0.01***
Small X Large	Regression Residual	18 234	3.258 32.636	0.625 0.383	32.87	0.01***
Medium X Large	Regression Residual	15 138	2.693 41.249	0.462 0.815	26.47	0.04**

*****,**,* significant at 1%, 5% and 10% level**

5. CONCLUSIONS

The study specifically looked at the farm size efficiency differentials of bio-fortified cassava production in Nigeria. Our study concluded that the production of bio-fortified cassava in Nigeria is profitable enterprise irrespective of the scale of production, although large scale bio-fortified cassava farmers realized more profit than the other categories. However, the estimated coefficients of the parameters of production variables for small, medium and large scale bio-fortified cassava farm size played a major role in bio-fortified cassava production in Nigeria. The study concluded that small scale bio-fortified cassava producers were operating on less than average economic efficiency level in Nigeria, the medium scale bio-fortified cassava producers were operating slightly above the average economic efficiency level in Nigeria and are thus are averagely economic efficient. The large scale bio-fortified cassava producers were operating above the average economic efficiency level in Nigeria and are thus economic efficient. It was therefore recommended that policies intended to increase the popularization and cultivation of bio-fortified cassava in Nigeria should be targeted toward the small and medium scale biofortified cassava farmers as they carried the majority of the producer of bio-fortified cassava in Nigeria. Furthermore, agencies, stakeholders and government should made available the production inputs such as bio-fortified cassava stems, herbicide, labor and fertilizers for the bio-fortified cassava farmers in Nigeria at a subsidized rate.

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