

Application of the Stochastic Production Frontier Function Model to Cassava Production in the Floodplain Area of Rivers State, Nigeria

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Abstract
This study examined the application of the stochastic production frontier function model to cassava production in the floodplain area of Rivers State, Nigeria. The need to evaluate the physical productivity consideration (technical efficiency) in cassava production in the floodplain necessitated this study. The objectives of the study include; identify socio-economic characteristics of the farmers; level of technical efficiency, determinants of technical efficiency and inefficiency. 170 respondents were randomly selected. Data was collected using questionnaire and farm records. Descriptive statistics and stochastic production frontier function model were the analytical tools used. The result indicated that the average age of the farmers was 44 years and mainly females. The average family size was 8 persons, majority (49.4 %) of the respondents had primary school certificate and 28.8% of the farmers had farm size of less than 0.4 hectare. The result of the technical efficiency indicated that farm size and number of labour used positively influenced the technical efficiency at 1 percent level of significance. The estimated gamma parameter of the model was 0.62, which implied that 62 percent of the total variation in cassava output among the producers could be attributed to differences in the technical efficiencies. The mean technical efficiency was 70 percent. None of the variables included in the model exerted a significant relationship on the technical inefficiency of the farms. Farmers were advised to increase the volume of input use of farm size and quantity of labour in order to achieve the best frontier in cassava production in the study area.
Keys words: stochastic frontier model, cassava production, floodplain area, Rivers State, Nigeria

1 INTRODUCTION

Cassava is a major crop produced by farmers in the flood prone areas or low land areas in Rivers State (Rivers State Agricultural Development Progarmme, 2009). It is an important crop in south-south states and Nigeria at large as most households are regular consumers of the products. It is an important source of dietary carbohydrate, and provides food for over 60 million people in Nigeria (Abdulahi, 2003). The roots are processed into *garri*, *fufu,* tapioca, chips and cassava flour for human consumption as well as paper, pellets, adhesive, and a carrier for pharmaceuticals etc. (Nigeria National Report, 2006, Nwokoro, *et al.* 2007; Azaino, 2008). The main industrial use of cassava is for the manufacture of starch, presently cassava is produced for production of ethanol. Other uses include animal feed formulation, agro-industrial uses (e.g. starch, ethanol, adhesive, fructose/glucose syrup), the peels is used in organo-mineral fertilizers formulation (Ojeniyi, 2001; Akanbi, *et.al.* 2007, Iyagba, 2010). The roots contain about 25 to 35 percent starch; the leaves, though unimportant as a source of calories, contain a significant amount of protein and other nutrients (Azaino, 2008). It is currently cultivated in around 40 Africa countries covering a wide belt from Madagascar in South Eastern Africa to Cape Verde in the North West. Cassava has longed played an important role in ensuring food security, particularly among the poor. In sub-Saharan Africa, where food security is a concern for many, about 95 percent of the cassava produced is used for human consumption (Nweke, 2009).

Smallholder agriculture is the dominant occupation of rural Nigerians, which is mainly rain-fed and characterized by low land and labour productivity. Yet, Nigeria has a potential comparative advantage in the production of a variety of fresh and processed high value crops during the dry season (Oredipe, 2005). This is because the country is endowed in underground and surface water reserves, rich pastures and favorable agro-ecological conditions in the country's low-lying plains with alluvial deposit called Fadama. A floodplain is a flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding (Judson and Kauffman, 1990).

Nigeria as a country is endowed with a large expanse of land with tremendous potential resources and favorable climate for producing food and other raw materials for export and domestic industries use. Although, about 70% of her population is engaged in agriculture, Nigeria is yet not self sufficient in agricultural production

(Obasi and Agu, 2000). The reality is that Nigeria has not yet been able to attain self-sufficiency in annual food production (Udoh, 2005). With more than 140 million inhabitants in 2006, Nigeria is by far the most populous country in Africa. Small farmers dominate the sector and provide the bulk of the nation's domestic food supply (Sumer Global Network Ltd, 2008).

Estimating the determinants of production relationships on the total yield is important in evaluating the nature of relationships that exist between the independent variables and yield but the physical productivity considerations (technical efficiency) are important improvement in production efficiency (Ogundari and Ojo 2007). Computing technical efficiency therefore, constitutes a more important source of information for policy makers than the partial vision offered by analyzing cost efficiency (Maudus, *et. al.* 2002). Although considerable efforts have been directed at examining productive efficiency of farmers that is exclusively focused on technical efficiency of the farmers in Nigeria (Ajibefun, *et. al*, 2002; Ojo, 2004 and Ogundari and Ojo 2007). These farmers are supposedly dry land farmers, but not much research had been carried out on floodplain small-scale cassava farming especially in the floodplain areas of Rivers State. In addition, little attention has also been given to measuring technical efficiency of farmers adopting stochastic frontier method in the study area. It is on this background that a study of this nature was initiated to apply stochastic production frontier function model to cassava production in the floodplain area of Rivers State.

1.1 Objectives of the Study

The broad objective of the study was to apply the stochastic production frontier function model to cassava production in the floodplain area of Rivers State.

The specific objectives of the study were to:

1 identify some of the socio-economic characteristics of floodplain farmers in the study area
2 determine the major variables which influenced technical efficiencies of cassava farms in the floodplain area of Rivers State.
3 estimate the farm level of technical efficiencies of floodplain cassava farms in Rivers State
4 evaluate the factors which influenced the farm level inefficiencies on cassava farms in the study area.

2 METHODOLOGY

2.1 Area of the Study

This research was carried out in Rivers State of Nigeria, the state is one of the 36 states of Nigeria, which was created from then eastern region of Nigeria by decree No. 19 of 1967 with Port Harcourt as the capital. It is bounded on the south by the Atlantic Ocean, to the north by Imo, Abia and Anambra States, to the east by Akwa Ibom State and to the west by Bayelsa and Delta states.

Rivers State has features of tropical climate, numerous rivers and vast areas of arable land, the people of the State are engaged in agricultural activities such as fishing and farming (Rivers State Government, 2007).

The provisional population figure of the state is presently 5,199,716 million people having 2,673,026 males and 2,525,690 females (NPC, 2006). The state lies between longitude 6^{o} 50^{1} E and Latitude 4^{o} 45^{1} N (Rivers State Government Website, 2010).

2.2 Sampling Procedure / Data Collection

Data for the study were collected through a combination of multi-stage random sampling technique. The choice of the study area was purposive because of the high activity of floodplain cassava farming in the area. Selection of the floodplain cassava farmers in the sample area was through simple random sampling of 170 farmers from the 479,170 farming families in Rivers State (RSADP Annual Report, 2009).

The first selection process was choosing Local Government Areas (LGAs) from each of the agricultural zones of the state.

In Zone 1 Emuoha LGA, Gokana LGA and Tai LGA were selected, Abua/Odual LGA was selected **in Zone 2** while Ahoada West LGA and Ogba/Egbema/Ndoni LGA were selected in **Zone 3** making a total number of six local government areas in Rivers State. The choice of the local government areas was based on the locations where floodplain cassava production is presently practiced. The next stage was the random selection of three (3) communities from each local government area giving a total of 18 communities in Rivers State and 170 cassava farmers were randomly selected from the 18 communities in Rivers State.

2.3 Methods of Data Analysis

Data generated from the study were analyzed using econometric techniques

Objective 1 was analyzed using descriptive statistics why objectives 2 and 3 were achieved using stochastic production frontier function model.

Model Specifications
Cobb- Douglas Production Function Model

i Technical Efficiency for Cassava

$LnY = Ln\, b_0 + b_1 LnX_1 + b_2 LnX_2 + b_3 Ln\, X_3 + V_i - U_i$ eq 1

Where

b_0= Intercept
$b_1 – b_4$= Estimated parameters
Y = Output of cassava in kg
X_1 = Quantity of cassava cuttings in kg
X_2 = Quantity of fertilizer used in Kg
X_3 = Amount of labour in (man days)
X_4 = Farm size (ha)
$(V_{ij}-U_{ij})$ = A composed error term
V_i = random error due to stochastic noise
U_i = randomness (technical inefficiency)

ii *A-priori* expectations of the technical efficiency of cassava model

Y	=	Quantity of cassava yield from the farm per annum
$dy/dx_1 >0$		Quantity of cassava produced is expected to be positively related to the quantity of cassava cuttings used.
$dy/dx_2 >0$		Yield of cassava realized is expected to be positively related to quantity of fertilizer applied.
$dy/dx_3 >0$		Output of cassava produced is expected to be positively related to number of labour used in the farm
$dy/dx_4 >0$		Yield of cassava realized is expected to be positively related to the farm size.

iii Floodplain Cassava Technical Inefficiency Model

$U_{ij} = \delta_0 + \delta_1 \ln Z_{1ij} + \delta_2 \ln Z_{2ij} + \delta_3 \ln Z_{3ij} + \delta_4 \ln Z_{4ij} + \delta 5 \ln Z_{5ij}$ eq .2

Where

U_{ij} = Technical inefficiency
Z_1 = age of farmer (years);
Z_2 = sex in dummy
Z_3 = household size in number
Z_4 = years of formal education in number
Z_5 = farming experience (years)
$\delta_0 – \delta_5$ = coefficients of the “Z” variables (d*elta*)

iv *A-priori* expectations of cassava technical inefficiency model

Uij	=	Technical inefficiency
$dy/dz_1 >0$		Age of the farmers is expected to be negatively related to technical inefficiency of farmers in floodplain cassava farm.
$dy/dz_2 >0$		Technical efficiency of floodplain cassava is expected to be positively related to the sex of the farmers.
$dy/dz_3 >0$		Technical inefficiency of farmers in floodplain is expected is expected to be negatively related to their household size
$dy/dz_4 >0$		The farmers number of years spent in schooling is expected to be negatively related to the technical inefficiency of cassava floodplain farm.
$dy/dz_5 >0$		Technical inefficiency of farmers in the floodplain farm is expected to be negatively related to the farmers farming experience.

2.5 Analytical Framework

Stochastic frontier production model

The stochastic frontier model was simultaneously proposed by Aigner, *et.al*, (1977) and Meeusen and Van den Broeck (1977) who drew their works upon the Farrell (1957) seminar paper on efficiency measurement in which he defined productive efficiency as the ability of a firm to produce a given level of output at lowest cost. Farrell (1957) distinguishes between technical and allocative efficiency (or price efficiency) in production through the use of a “frontier” function. Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under a given technology.

A stochastic frontier production function comprises a production function of the usual regression type with a composite disturbance term equal to the sum of two error components (Meeusen and Van den Broeck, 1977). One error component represents the effect of statistical noise (e.g. weather, topography, distribution of supplies, measurement error, etc.. The other error component captures systematic influences that are unexplained by the production function and are attributed to the effect of technical inefficiency. Allocative efficiency refers to the ability to choose optimal input levels for given factor prices. Efficiency is also an important factor in productivity growth. In an economy where resources are scarce and opportunities for new technologies are lacking, inefficiency studies will be able to show that it is possible to raise productivity by improving efficiency without increasing the resource base or developing new technology. Estimates of the extent of inefficiency also help in deciding whether to improve efficiency or to develop new technologies to raise agricultural productivity.

There are four major approaches to measure and estimate efficiency (Dey, et.al, 2000). These are the non-parametric programming approach, the parametric programming approach (Aigner and Chu, 1968; Ali and Chaudhry, 1990), the deterministic statistical approach (Afriat, 1972) and the stochastic frontier production function approach (Aigner.et. al, 1976; Meeusen and Van Den Broeck, 1977). Among these, the stochastic frontier production function and non-parametric programming, known as data envelopment analysis (DEA), are the most popular approaches. The stochastic frontier approach is preferred for assessing efficiency in agriculture because of the inherent stochastic involved (Fare, et.al, 1985; Kirkley,et.al,1995; Coelli, *et al.*1998). Both methods estimate the efficiency frontier and calculate the firms' technical, cost and profit efficiency relative to it. The frontier shows the best performance observed among the firms and it is considered as the efficient frontier. The SFA approach inquires that a functional firm be specified for the frontier production function while DEA approach uses linear programming to construct a piece-wise frontier that envelops the observations of all firms. An advantage of the DEA method is that multiple inputs and output can be considered simultaneously, and inputs and outputs can be quantified using different units of measurement. However, a strong point of SFA in comparison to DEA is that it takes into account measurement errors and other noise in the data. This point is very important for studies of farm level data in developing economy like Nigeria as data generally include measurement errors.

The SFA, which is also referred to as the econometric frontier approach, specifies the relationship between output and input levels and decomposes the error term into two components: (a) a random error, and (b) an inefficiency component. The random error which is assumed to follow a symmetric distribution is the traditional normal error term with zero mean and a constant variance while the inefficiency term is assumed to follow an asymmetric distribution and may be expressed as a half-normal, truncated normal, exponential or two-parameter gamma distribution.

Economic application of stochastic frontier model for production efficiency analysis include: Numerous studies (Obwona, 2000; Son, et al, 1993) have attempted to determine technical efficiencies of farmers in developing countries because determining the efficiency status of farmers is important for policy purposes. Amaza and Maurice, (2005) applied stochastic model to identify of factors that influence technical efficiency in rice-based production systems in Nigeria. Also (Kariuki., et.al, 2008) used the same model to determine technical efficiency in smallholder crop production in Kenya. Jiang, (2008) also applied stochastic frontier model to estimate technical efficiency of Chinese commercial banks and effects of institutional changes on bank efficiency.

The maximum likelihood estimates of the parameters in the Cobb-Douglas and translog stochastic frontier production function models given the specification for the technical inefficiency effects in the equations on the model specification was obtained using FRONTIER 4.1 a computer software frontier version 4.1 package (Coelli, 1994). The unknown parameters of the stochastic frontier and the inefficiency effects are estimated simultaneously.

3 RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Cassava Floodplain Farmers

Table 1 Socio-economic characteristics of Rivers State farmers

Age in years	Frequency	Percent
15-20	1	.6
21-30	20	11.8
31-40	60	35.3
41-50	57	33.5
51-60	26	15.3
61 & above	6	3.5
Total	170	100.0
Mean Age	44	
Sex in dummy		
Male	59	34.7
Female	111	65.3
Total	170	100.0
Household size in persons		
1-5	68	40.0
6-10	75	44.1
11-15	23	13.5
16-20	3	1.8
21 & above	1	.6
Total	170	100.0
Mean Household size	8	
Educational level of farmers		
NCE/Diploma level	12	7.1
Secondary level	57	33.5
Primary level	84	49.4
Non formal education	17	10
Mean		
Total	170	100.0
Mean Years Spent in Education	8	
Farming experience (years)		
1-5	26	15.3
6-10	50	29.4
11-15	50	29.4
16-20	15	8.8
21-25	9	5.3
26-30	8	4.7
30 & above	12	7.1
Total	170	100.0
Mean Years Spent in Farming	14	
Farm size in hectare		
< 0.4	49	28.8
0.4-0.9	20	11.8
1-1.4	25	14.7
1.5-1.9	10	5.9
2-2.4	40	23.5
2.5-2.9	3	1.8
3 & above	23	13.5
Total	170	100.0
Mean Farm Size	1.4	

Source: Field Survey, 2010

Socio-economic characteristics are important factors that may influence farmers' production decisions as well as their overall technical efficiency in production. The result as shown in Table 4.1 presents the socio-economic characteristics of the respondents which indicates that about 35.3% of them were between the age bracket 31- 40years, 33.5% of the respondents were of the age bracket between 41-50 years of age. The age range of 15 - 20 years and 21- 30 years above had a percentage of .6% and 11.8 percent respectively. The mean age of the farmers was 44 years. The result also shows that about 34.7 % of the farmers were males while 65.3% are females. Sex of an individual influences the type and quality of work carried out at any given time. The results obtained showed that there are more females involved in the floodplain cassava production in Rivers State than males. This is most likely to be that men in Rivers State are engaged in other high revenue yielding business activities in the area and are live in the urban areas of the state. The result further shows a household size of 1 to 10 persons constituting 84.1%, having an average members of 8 persons per household. It was also found that the household size between 16-20 persons and 21 persons and above had 1.8% and .6% respectively.

The result as shown in Table 4.1, indicated that a greater percentage of the participants (90%) had some form of formal education and about 49.4 % of them had primary school certificate education. This implies that the participants are not likely to have much difficulty in understanding and adopting modern agricultural technologies and innovations. The result also shows that respondents were mainly composed of members who were able to attain primary level of education. A farmer's level of education is expected to influence his ability to adopt agricultural innovations and make decisions on various aspects of farming.

Farming experience generally correlates with acquisition of improved skills in agricultural production. The results shows that on the average, a farmer in the study area had farming experience of about 14 years in floodplain farming. About 58.8% of the farmers had been practicing farming in the floodplain area between 6-15years while only about 15.3% of the farmers had spent between 1- 5 years in farming in the floodplain area. The result clearly shows that the farmers are not new entrants in the floodplain cassava production in the floodplain area. The result further found that about 28.8% of the farmers had farm size less than 0.4ha while 23.5% of them had farm size between 2-2.4 ha indicating that these farmers were small scale farmers. Only about 13.5% of the respondents had farm land area of 3 hectares and above and the average farm size was recorded as 1.4 hectares.

3.2 Determinants of technical efficiency of cassava farms in the floodplain areas of Rivers State: The result of factors affecting level of technical efficiency in cassava farms in the floodplain areas of Rivers State is presented in the table 2

Table 2 Estimates of efficiency of cassava farms in Rivers State

Variables/Parameters	Coefficient	standard-error	t-ratio	Remarks
Intercept	8.61	0.41	20.81	***
Planting materials	0.02	0.04	0.38	NS
Mandays of labour	0.13	0.05	2.54	***
Farm Size	0.64	0.05	13.29	***
Mean Efficiency				0.70
Returns to Scale				0.79

NB: (***) = Significant at 1%; (**) = Significant at 5 percent level; (*) = Significant at 10% alpha level.
Source: Field Survey, 2010.

The result of the estimates for parameters of the frontier model on the determinants of technical efficiency of cassava production in the floodplain area of Rivers State as presented in Table 4.2 shows that only farm size and number of labour used were positively related to technical efficiency at 1 percent level of significance. The significant value of labour input and farm size at 1 percent and their positive effects as shown affirm the fact that these two inputs were the major factors driving the technical efficiency of cassava production in the floodplain areas of Rivers State. This is contrary to the findings of Onoja., *et.al*, (2010) which shows that the input farm size had negative relationship to the yield of cassava in Kogi State. The result in other hand is also contrary to the finding of Edeh and Awoke (2009) which found that the coefficients of educational background and farm size of the farmers were significant while the coefficient of educational background was positively signed, the coefficient of farm size was negative. They emphasized that the efficiency of cassava farmers, who use improved technologies increases with increase in the years of schooling.

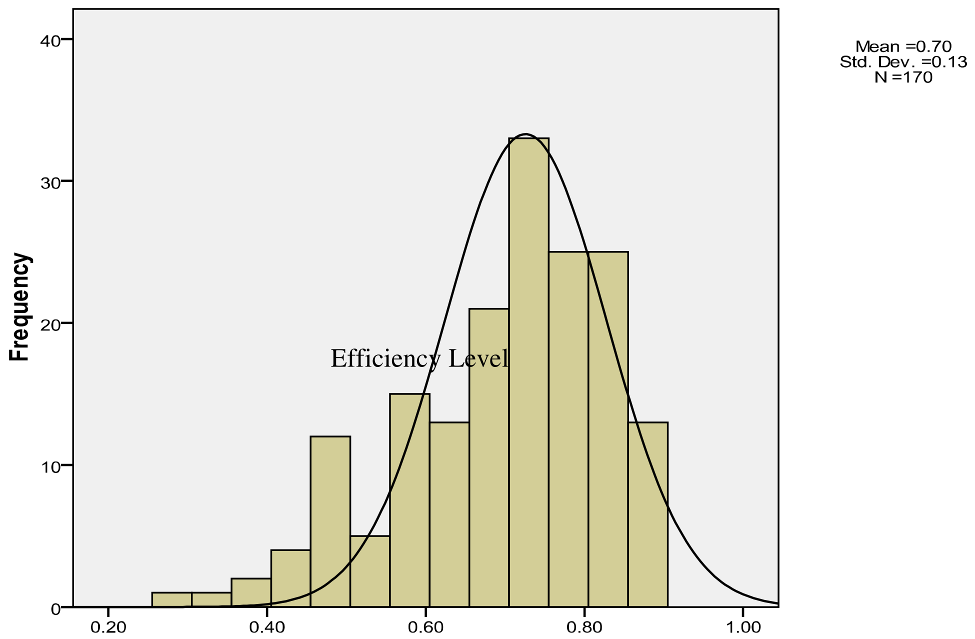
The respective slope coefficients of farm size and labour inputs in floodplain cassava farms in Rivers State had t ratios significant at less than 1 percent significance level (including their intercept). Their respective elasticities with respect to the output of cassava production in the area were 0.13 and 0.64 respectively. They both returned positive signs, which are in line with a priori expectations. This implies that both resource inputs were contributing positively to the increase in technical efficiency of cassava farms in the State. The estimated gamma parameter of the model was 0.62, which indicates that about 62 percent of the total variation in cassava output among the producers could be attributed to differences in their technical efficiencies. The mean technical efficiency recorded in the state was found to be 0.70 (i.e. 70 percent). This implies that the farmers were still far away from their technological frontier by 30 percent. Hence, there is need for the farmers in this state to strive harder to attain the frontier of their technology. This agrees with findings of Onoja, *et.al*, (2010) that the technical efficiency of the farms was very high, averaging 81%, while the inefficiency variables entered were not statistically significant. The Returns to Scale (RTS) recorded from this group's model (0.79) implies that the cassava farmers in the floodplain area of Rivers State were experiencing decreasing returns to scale in their farms. This implies also that they were at Stage II of their production region.

3.3 Deciles efficiency estimates of cassava farms in the floodplain area of Rivers State The result of deciles efficiency estimates of cassava farms in Rivers State is presented in Table 3

Table 3 Deciles of efficiency estimates for floodplain cassava farms in Rivers State

Deciles of TE	Frequency	Percent	Cumulative Percent
0.20-0.29	1	.6	.6
0.30-0.39	2	1.2	1.8
0.40-0.49	16	9.4	11.2
0.50-0.59	19	11.2	22.4
0.60-0.69	31	18.2	40.6
0.70-0.79	56	32.9	73.5
0.80-0.89	45	26.5	100.0
Total	170	100.0	

Source: Analysis of field survey using stochastic frontier 4.1c software, 2010



The result on efficiency estimates of cassava farmers in Rivers State as indicated in Table 4.3.2 shows that in terms of deciles of technical efficiencies recorded in the area, it could be said and observed that most of the farmers (33%) recorded technical efficiencies in the range of 0.70 (i.e. 70%) to 0.79 (i.e. 79%). Those who had TEs in the range of 0.80-0.89 constituted 26.5% of the sampled farmers under this technology in Rivers State, thus ranking as the next highest range in terms of TEs. Those with TEs of below 0.69 constituted only 40.6% of the sample for this group. This is contrary to the findings of Onoja, *et.al*, (2010) and who found that the mean efficiency estimate among cassava farmers in Kogi State was 81 percent (0.81%). The range of efficiency indicated as follows; minimum was 0.62, maximum was 0.99. Only 0.60 percent had a low technical efficiency estimate in the study area while 21.8 percent had a moderately high estimate of less than 0.50 to 0.60 which is higher than what is estimated in cassava production in Rivers State study area. The findings also disagree with Ogunyika and Ajibefun (2004) who observed that the mean technical efficiency in Nigeria between 1964 and 1993 have been 1.00.

Table: 4 Determinants of technical inefficiency in cassava farms in Rivers State

Variables		Coefficient	Standard-error	t-ratio	Remarks
Intercept		0.90	0.57	1.59	NS
Age in yrs		-0.02	0.02	-1.03	NS
Sex M = 1 F = 2		0.16	0.25	0.62	NS
Household size		-0.01	0.04	-0.22	NS
Educational level in years		-0.03	0.04	-0.69	NS
Experience in years		0.00	0.01	0.32	NS
sigma-squared		0.28	0.18	1.55	NS
Gamma		0.62	0.20	3.13	***
Log Likelihood Function =			-94.59		
LR test of the one-sided error		12.94*			
No of restriction =			7.00		
Chi square critical values	18.475 (0.01)	14.067 (0.05)			
Critical t Values	2.576 (0.01)	1.96 (0.05)	1.645 (0.10)		

NB: (***) = Significant at 1%; (**) = Significant at 5 percent level; (*) = Significant at 10%
Source: Field survey, 2010 using stochastic frontier 4.1C software

The result on Table 4 shows the determinants of technical inefficiency in cassava farms in Rivers State. The results indicated that none of the variables included in the model exerted a significant relationship on the technical inefficiency recorded on the farms in this technology in Rivers State even though it was earlier confirmed that inefficiency existed in cassava floodplain farms in Rivers State. This could mean that the variables that could explain inefficiency in these farms were probably omitted from the model. In further studies, the socio-economic variables to be studied need to be expanded. The foregoing leads us to accept the null hypothesis, $Ho_{1,}$ which held that "cassava productivity in the floodplain area is not affected by socio-economic variables of the farmers in Rivers State" especially concerning the socio-economic variables included in the inefficiency model estimated in this study. The estimated gamma parameter of the model was 0.62, which indicate that about 62 percent of the total variation in cassava output among the producers could be attributed to differences in their technical efficiencies.

Conclusion

The study applied the stochastic frontier production function model in the determination of technical efficiency of cassava production in the floodplain area of Rivers State. It was found that majority of floodplain cassava farmers in Rivers State are females having an average age of 44years.Number of labour and farm size significantly influenced the technical efficiency with a mean technical efficiency of 0.70 (i.e. 70 %).

Recommendations

1 Floodplain farming in Rivers State is dominated by the youths mainly aged 44 years, therefore programmes to enhance cassava production in the floodplain area of Rivers State should be targeted at the youths.

2 Since labour input increased technical efficiency of cassava production in Rivers State, it is advisable to increase the use of these inputs to increase productivity in the cassava farms in the study area.

3 Since a mean technical efficiency of 70% was achieved by the farmers, implying that the farmers were still far away from the technological frontier by 30%. Hence, there is need to increase the farm inputs especially labour in order to achieve the best frontier in cassava production.

4 Further Research study on floodplain farming should consider the using the Stochastic production frontier function to estimate the economic efficiency ie the farm specific profit level in floodplain cassava production in Rivers State

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