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# Application of Stochastic Production Frontier in the Estimation of Technical Efficiency of Female Cassava Farmers in Ibadan/ Ibarapa Agricultural Zone of Oyo State, Nigeria

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**Abstract:** This research work broadly examined the technical efficiency of the female cassava production in Oluyole and Akinyele Local Government Areas of Oyo State, Nigeria. The study employed the use of cross-sectional data from farm survey conducted on a sample of 120 cassava farmers from 8 villages in the study areas. The data were collected with the aid of structured questionnaire and were later analyzed. The Econometric analytical models were employed in order to analyze the data collected from the field. Among the female cassava farmers, the significant variables were fertilizer quantity (at 1%), herbicide quantity and pesticide quantity. The estimated sigma square ($\sigma^2$) for the female cassava farmers is 0.4211. The estimated gamma ($\gamma$) parameter of the female cassava farmers revealed that 97% of the variations in the cassava output among the female cassava farmers in the study area are due to the differences in their technical efficiencies. The study also revealed the existence of inefficiency effects among the female cassava farmers in the study area as the farmers whether male or female were not fully technically efficient. The RTS for the female cassava farmers is -1.15 in the study areas.

**Key words:** Stochastic, production, frontier, efficiency, Nigeria

## INTRODUCTION

Nigeria is predominantly an agrarian country with over 70.0% of its population engaged in farming. Agriculture provides the bulk of employment, income and food for the populace. Also, it provides raw materials for the agro-allied as well as market for industrial goods. Nigeria has substantial economic potential in its agricultural sector. However, despite the importance of agriculture in terms of employment creation, its potential for contributing to economic growth is far from being fully exploited. The sector's importance has fluctuated with the rise and fall in oil revenue. Data from the Federal Office of Statistics (FOS, 1999) indicated that poverty levels in the country have been on the increase since 1986. Detailed analysis of the poverty situation in Nigeria revealed that most of the poor people work in the agricultural sector and most of them reside in the rural areas.

Studies in Nigeria (D'Situ and Bysmouth, 1994) and elsewhere (World Bank, 2000) have traced an evident linkage between poverty and agricultural sector performance. Therefore, improvements in performance of the agricultural sector can have far-reaching and beneficial implications for food security, income generation, as well as poverty.

Nigeria has continued to be the largest producer of cassava since the beginning of the 1990s with an estimated contribution of 40 m metric tonnes per annum with an average yield of 10.2 t $ha^{-1}$. In recent years, the demand for Nigeria cassava has increased appreciably due to increased awareness on cassava utilization. The presidential initiative move by the Federal Government of Nigeria in 2002 was geared towards raising the production level of cassava to 150 m metric tonnes by the end of year 2010 and realized an income of US $5.0 billion per annum from the export of 37.6 m tonnes of dry cassava products (Nigerian National Report, 2006).

Cassava is Africa's second most important food staple, after maize in terms of calories consumed. In the early 1960s, Africa accounted for 42% of world cassava production. Thirty years later, in the early 1990s, Africa produced half of world cassava output; primarily because Nigeria and Ghana increased their production four fold. In the process, Nigeria replaced Brazil as the world's leading cassava producer (Nweke, 2004).

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In Nigeria, traditionally, cassava is produced on small-scale family farms. As noted by Nweke (2004) the roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and transported to urban centers. In Congo, Madagascar, Sierra Leone, Tanzania and Zambia, Cassava leaves are consumed as vegetable (Fresco, 1986; Dostie *et al*., 1999; Haggblade and Zulu, 2003). In Nigeria, cassava is primarily a food crop. In the year 2000, 90% of total production in Nigeria was used as food and the balance as livestock feed (Nweke, 2004). In Nigeria, traditionally, cassava is produced on small-scale family farms. As noted by Nweke (2004) the roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and transported to urban centers.

The term efficiency of a firm can be defined as its ability to provide the largest possible amount of output from a given set of inputs. The modern theory of efficiency dates back to the pioneering work of Farrell (1957) who proposed that the efficiency of a firm consist of technical and allocative components and the combination of these 2 components provide a measure of total economic efficiency (overall efficiency). As noted by Farrell (1957) technical efficiency, which is the main focus of this study, is the ability to produce a given level of output with a minimum quantity of inputs and can be measured either as input conserving oriented technical efficiency or output-expanding oriented technical efficiency. Output-expanding oriented technical efficiency is the ratio of observed to maximum feasible output, conditional on technical and observed input usage (Jondrow *et al*., 1982; Ali, 1996). This study aims at using output-expanding orientation to measure technical efficiency effects.

The term frontier involves the concept of maximality in which the function sets a limit to the range of possible observations (Forsund *et al*., 1980). It is therefore, possible to observe points below the production frontier for firms producing below the maximum possible output, but there cannot be any point above the production frontier, given the available technology. Deviations from the frontier are attributed to inefficiency. The need to measure inefficiency effects is the major motivation for the study of frontiers.

Frontier studies are classified according to the method of estimation. Kalaitzandonakes ***et al.*** (1992) grouped these methods into 2 broad categories-parametric and non-parametric methods-. For the parametric methods, it can be deterministic, programming and stochastic depending on how the frontier model is specified. Many researchers, including Schmidt have argued that efficiency measures from deterministic models are affected by statistical noise. This however, led to the alternative methodology involving the use of the stochastic production frontier models. Aigner ***et al.*** (1977) and Meeusen and Vander Broek (1977) independently proposed the idea of stochastic measurement.

The major feature of the stochastic production frontier is that the disturbance term is a composite error consisting of two components, one symmetric and the other one-sided. The symmetric component, V, captures the random effects due to measurement error, statistical noise and other influences outside the control of the firm and it is assumed to be normally distributed. The one-sided component Ui, captures randomness under the control of the firm. It gives the derivation from the frontier attributed to inefficiency. It is assumed to be half-normally distributed or exponential. The major weakness of the stochastic frontier model is its failure to provide an explicit distribution assumption for the inefficiency term (Sharma *et al*., 1999).

By definition, stochastic frontier production function is (1) Where $Y_i$ is the output of the ith farm; X, is the corresponding (MX2) vector of conventional physical inputs; P is a vector of unknown parameter to be estimated; F (.) denotes an appropriate functional form, V, is the symmetric error component that accounts for random effects and exogenous shock; while, U <0 is a one sided error component that measures technical inefficiency.

In recent times, econometric modeling of stochastic frontier methodology associated with efficiency estimation has been important aspect of economics research. Both time varying and cross-sectional data have been used in studies based mostly on Cobb-Douglas function and transcendental logarithmic functions that are specified either as production function or cost function to estimate individual firm efficiency (Bagi and Hunag, 1983; Bagi, 1984; Ali, 1996; Apeziteguia and Garate, 1997; Yao and Liu, 1998; Udoh and Akintola, 2001a, b; Udoh, 2005; Etim *et al*., 2005; Udoh and Etim, 2006). However, this study uses a Cobb-Douglas production function to estimate technical efficiency effect at farm levels by assuming a stochastic nature of production.

## MATERIALS AND METHODS

**The study area, sampling and data collection procedure:** This study was carried out in Oluyole and Akinyele local government areas of Oyo state. The study area represents two out of the eleven local government areas under Ibadan/Ibarapa zone of Oyo State Agricultural Development Programme (Oysadep). The study area is situated within the tropical rainforest region and agriculture is the predominant occupation in the study area. The climate in the study area is of tropical type with two distinct rainfall patterns. The rainy season, which marks the agricultural production season is normally between the months of April and October. The heaviest rainfall is recorded between the months of June and August while driest months are November to March. The average total annual rainfall ranges between 1000 and 1500 mm with high daily temperature ranging between 28 and 30°C. Agriculture is the main occupation of the people and the major food crops grown in the study area include maize, rice, yam cassava and cocoyam while the major cash crops grown are: cocoa, kola nut and oil palm.

The data collected include socio-economic characteristics of farmers such as age, gender, years of formal education or educational level, marital status, household size, years of experience in farming, income level, off-farm activities, income sources, amount of farm credit and loans, expenditure and problems encountered in agricultural production. Input-output data were also collected. Output data included quantity and values of cassava output, market prices while input data include quantity and cost of inputs such as farm size, hired labour, family labour, fertilizers, seeds, chemical and amount on farm implements. The data obtained pertained to 2006 season and were obtained between the months of September and November, 2006.

The study used a multi-stage stratified random sampling technique. The first stage involved purposive selection of Oluyole and Akinyele local government areas noted for cassava production in Oyo State. The second stage involved random selection of major villages from the list of cassava-growing villages obtained from the information units of each LGA. A total of 8 villages were sampled, that is, four villages from each of the LGAs. In Oluyole local government, the villages sampled include: Onidajo, Alata, Olosa and Onipe while the villages sampled in Akinyele local government included Elekuru, Agbedo, Alore and Oreku. The last stage involved a stratified random sampling selection of cassava farmers from each of the 4 villages in each of the 2 LGAs (Oluyole and Akinyele) in Oyo State. A total of 120 female cassava farmers out of the 128 female cassava farmers interviewed with the aid of a structured questionnaire had complete information necessary for data analysis as 8 of the respondents had their questionnaire not proper filled.

**The empirical model:** In congruent with the works of several scholars like the one of Seyoum where the Cobb-Douglas stochastic frontiers was used in estimating the technical efficiency and productivity of maize farmers within and outside the Sasakawa-Global 2000 project in Ethiopia. Therefore, for the sake of this study, the stochastic frontier production functions in which Cobb-Douglas as proposed by Battese and Coelli (1995) represents the best functional form of the production frontier and also as confirmed by Yao and Liu (1998) was applied in the data analysis in order to better estimate the efficiency of the female cassava farmers.

The model of the stochastic frontier production for the estimation of the TE is specified as:

$$\text{In } Y_i = \beta_0 + \beta_1 \text{ In } X_{1i} + \beta_2 \text{ In } X_{2i} + \beta_3 \text{ In } X_{3i} + \beta_4 \text{ In } X_{4i} + \beta_5 \text{ In } X_{5i} + \beta_6 \text{ In } X_{6i} + \beta_7 \text{ In } X_{7i} + V_i - U_i \quad (1)$$

where, subscript i refers to the observation of the ith farmer and

- $Y$ : Output of cassava tubers (Kg).
- $X_1$ : Stem Cuttings (bundles).
- $X_2$ : Farm Size (ha).
- $X_3$ : Fertilizer Quantity (litre).
- $X_4$ : Herbicide Quantity (litre).
- $X_5$ : Pesticide Quantity (litre).
- $X_6$ : Hired Labour (Manday).
- $X_7$ : Family Labour (Manday).
- $\beta_i$'s : The parameters to be estimated.
- ln's : Natural logarithms.
- $V_i$ : The two-sided, normally distributed random error.
- $U_i$ : The one-sided inefficiency component with a half-normal distribution.

**The inefficiency model:** For this study, it is assumed that the technical inefficiency measured by the mode of the truncated normal distribution (i.e. $U_i$) is a function of socio-economic factors (Yao and Liu, 1998). Thus, the technical efficiency was simultaneously estimated with the determinant of technical efficiency defined by:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta Z_{5i} \quad (2)$$

where,

- $U_i$ : Technical inefficiency of the ith farmer.
- $Z_1$ : Age of farmer (years).
- $Z_2$ : Household Size.
- $Z_3$ : Year of farming experience.
- $Z_4$ : Educational level.
- $Z_5$ : Extension Contribution.

The Eq. (2) was used to examine the influence of some of the female farmers' socio-economic variables on their technical efficiency. Therefore, the socio-economic variables in Eq. (2) were included in the model to indicate their possible influence on the technical efficiencies of the female cassava farmers. In the presentation of estimates for the parameters of the above frontier production, 2 basic models were considered. Model 1 is the traditional response function in which the inefficiency effects ($U_i$) are not present. It is a special case of the stochastic frontier production function model in which the parameter $\gamma = 0$. Model 2 is the general frontier model where there is no restriction in which $\gamma$, $\sigma^2$s are present. The estimates of the stochastic frontier production function were appraised using the generalized likelihood ratio test and the T-ratio for significant econometric relevance.

## RESULTS AND DISCUSSION

Among the female cassava farmers, the significant variables include: fertilizer quantity (at 1%), herbicide quantity (at 1%) and pesticide quantity (at 1%) while the other variable like stem cuttings, farm size, herbicide quantity used, family labour and hired labour were all not significant at all known levels of significance. The implication of the above findings is that the productive inputs that greatly impact on cassava output of the female farmers were the fertilizer quantity (to boost the soil nutrient status of their marginal lands allotted to cassava production), herbicide quantity (to curtail the adverse economic effects of weeds and herbs) and pesticide (to control the major pests and vectors of major endemic diseases of cassava). Among the above 3 major inputs, pesticide has the highest coefficient with a value of 0.3572 (Table 1) in the preferred models (model 2) and therefore, it existed as the most limiting factor that greatly determine what cassava output would be like among the female farmers. In the preferred model, stem cuttings, fertilizer quantity and pesticide quantity had positive signs while farm size, herbicide quantity, hired labour and family labour had negative signs. The implication was that any increase in quantities of stem cuttings, fertilizer quantity and pesticide quantity would lead to an increase in cassava output of the female farms while any increase in farm size, herbicide quantity, hired labour and family labour would greatly reduce the returns to be realized from the sales of cassava output among the female farmers as extra costs incurred on these inputs does not translate into better returns. The estimated sigma square ($\sigma^2$) of the female cassava farmers is 0.4211 (significant at 10%). The value is large and significantly different from zero (Table 1). This indicates a good fit of the model and the correctness of the specified distributional assumptions. The estimated gamma ($\gamma$) parameter of the female cassava farmers is 0.97 and is highly significant at 5% level of significance. This means that 97% of the variations in the cassava output among the female cassava farmers in the study area are due to the differences in their technical efficiencies. This result is consistent with the findings of Yao and Liu (1998) and Ajibefun and Daramola (1999).

Table 1: Maximum likelihood estimates for the parameters of the stochastic frontier production function for female cassava farmers in the study area

| Variable | Parameter | Model 2 | T-value |
|---|---|---|---|
| **General model (production function)** | | | |
| Constant | $\beta_0$ | 0.9899 | 17.43 |
| Stem cutting | $\beta_1$ | 0.1005 | 0.1221 |
| Farm size | $\beta_2$ | -0.5849 | -1.134 |
| Fertilizer quantity | $\beta_3$ | 0.3094 | 2.608* |
| Herbicide quantity | $\beta_4$ | -0.3545 | -2.934* |
| Pesticide quantity | $\beta_5$ | 0.3572 | 3.488* |
| Hired labour | $\beta_6$ | -0.6450 | -0.5956 |
| Family labour | $\beta_7$ | -0.3374 | -0.7062 |
| **Inefficiency model** | | | |
| Constant | $\delta_0$ | -0.8588 | -0.3872 |
| Age of farmer | $\delta_1$ | -0.1252 | -0.2043 |
| Household size | $\delta_2$ | 0.1266 | 0.4237 |
| Year of farming experience | $\delta_3$ | 0.1363 | 0.8908 |
| Educational status | $\delta_4$ | 0.2435 | 0.9877 |
| Extension contributions | $\delta_5$ | 0.8674 | 1.576 |
| **Variance parameters** | | | |
| Sigma squared | $\delta^2$ | 0.4211 | 1.820*** |
| Gamma | $\gamma$ | 0.9853 | 0.7247 |
| Log likelihood function | | -22.84 | |
| $X_c^2$ | | 34.54 | |
| $X^2_{(0.05,7)}$ | | 14.07 | |

Notes: ** = 5% level; *** = 10% level (Figures in parentheses are t-values)

**Inefficiency model:** Among the female cassava farms in the study area, the coefficient of age was negative thereby conforming to a priori expectation. The coefficients of household size, educational level, years of farming and extension contacts had positive relationship with the technical inefficiency of the female farmers and this was against the a priori expectation and as well incongruent with the findings of Obwona (2000) and Kalirajan (1981). The findings revealed that the age had a negative relationship with their technical inefficiency level and this means that the younger the female farmers, the less technically inefficient they will be, as such the more technically efficient they will be. The findings also revealed that years of farming experience, education level, household size and extension contribution had positive relationship with the technical inefficiency level of the female cassava farm; these imply that the larger the household size and the more educated coupled with relevant extension contributions, the more inefficient the female cassava farmers in the study area will be and the reasons may be due to inefficient family labour input, lack of proper supervision of their farms to availability of other lucrative off-farm activities as well as trivialization of extension information on personal grounds.

**Elasticities of Production (εP):** Among the female cassava farmers, the estimated elasticities of the explanatory variables of the preferred model (Model 2) show that farm size, herbicide quantity, hired labour and family labour were negative (decreasing) functions to the factors. This showed that an over-use of these variables and therefore a unit increase in these inputs will bring a decline in the cassava output among the female cassava farmers. Stem cutting, fertilizer quantity and herbicide quantity were positive (increasing) functions to the factors which indicate that the use and allocation of these variables was profitable and as such a unit increase in these inputs will eventually result in an increase in the cassava output of the female farmers.

The elasticity of cassava output with respect to hired labour prevailed among the female cassava farmers. These findings indicated that among the female farmers, hired labour existed as the most important factor of production; hence, there should be wage control scheme in order to enable female farmers maximize its usage on their farms considering their restricted access to credit facilities for farm activities.

**Returns to Scale (RTS):** The analysis of results in Table 2 shows that the RTS for the female cassava farmers is-1.15 in the study areas, respectively. The female cassava farmers had diminishing returns to scale and this revealed that they were operating in the stage 3 (a highly irrational zone of production) with the implication that the resources are not efficiently allocated and used on their farms.

**Technical efficiency analysis of the female cassava farmers in the study area:** The predicted cassava farm specific technical efficiency (TE) for the female cassava farmers, it ranged from a minimum of 26.56% to a maximum of 96.06% with a mean of 70.28% (Table 3). Thus, in the short run, an average female cassava farmer have the scope of increasing her cassava production by about 29.72% by adopting the technology and techniques used by the best practiced (most efficient) female cassava farmers. Such female cassava farmers could also realize 26.83% cost savings (i.e.1-[70.28/96.06]) in order to achieve the TE level of her most efficient counterpart (Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997). The above findings unfolds the capacity of an average female cassava farmers to increase her technical efficiency level to a tune of 29% and in turn attain a cost-saving status of about 26% that the most technically efficient female cassava farmer had enjoyed in her cassava production enterprise using the available production techniques and technology in the study area.

Table 2: Elasticities (εP) and Returns-to-Scale (RTS) of the Female Cassava Farmers in Oluyole and Akinyele Local Government Areas of Oyo State

| εP | Female |
|---|---|
| Stem cutting | 0.1005 |
| Farm size | -0.5849 |
| Fertilizer quantity | 0.3094 |
| Herbicide quantity | -0.3545 |
| Pesticide quantity | 0.3572 |
| Hired labour | -0.6450 |
| Family labour | -0.3374 |
| RTS | -1.15 |

Source: Computed from field survey data.

Table 3: Decile range of frequency distribution of technical efficiencies of the female cassava farmers in oluyole and akinyele local government areas of Oyo State

| Decile range (%) | Technical efficiency No | (%) |
|---|---|---|
| >90 | 20 | 13.70 |
| 81-90 | 26 | 16.13 |
| 71-80 | 23 | 15.32 |
| 61-70 | 15 | 14.52 |
| 51-60 | 17 | 16.13 |
| 41-50 | 10 | 13.70 |
| 31-40 | 4 | 7.25 |
| 21-30 | 7 | 16.13 |
| Mean | 70.28% | |
| Minimum | 26.56% | |
| Maximum | 96.06% | |

Source: Computed from field survey data, 2006

Table 4: Summary of cost savings according to efficiency indicator by female cassava farmers in oluyole and akinyele local government areas of Oyo State

| Efficiency indicator | | Value of savings (%) |
|---|---|---|
| | Most technically efficient | 29.72 |
| TE | Most technically inefficient | 72.35 |

Source: Computed from field survey data, 2006

A similar calculation for the most technically inefficient female cassava farmer reveals cost saving of about 72.35% (i.e., 1-[26.56/96.06] as shown in Table 4. The decile range of the frequency distribution of the TE indicates that about 57.02% of the female cassava farmers had TE of over 70 and about 26.45% had TE ranging between 51 and 70%, respectively. The above findings from the analyses of the most technically inefficient female cassava farmer revealed that she has an untapped ability to realize a cost-saving of about 72%. To realize this latter cost-saving status, the female cassava farmers would have to employ the right amount of the various production inputs, maximize the use of available technology as well as proper supervision of their cassava farms to the activities of thieves and intruders on their farms.

**Test of hypothesis for the absence of inefficiency effects:** The null hypothesis specifies that the female cassava farmers were technically efficient in their production and that the variation in their output was only due to random effects. The hypothesis is defined thus: $H_{02}$: $\gamma = 0$. The generalized likelihood ratio test was conducted and the Chi-square ($X^2$) statistics was computed. Table 5 shows the results of the generalized likelihood ratio test for the absence of technical inefficiency effects. The null hypothesis, $\gamma = 0$, was rejected among the female cassava farmers in the study area. This revealed that the technical inefficiency effects existed among the female cassava farmers in the study area and that the variations in their production processes may be due to certain inefficiency factors in the study area.

**Test of the significance of coefficients of the socio-economic variables of the inefficiency model:** The null hypothesis states that each of the estimated coefficients of the explanatory variables of the inefficiency model of the stochastic frontier production function is not statistically significant (i.e. socio-economic variables do not have any significant relationship with TE of the male and female cassava farmers).

The hypothesis is defined thus: $H_{03}$: $\delta_i = 0$, where $\delta_i$ is the individual explanatory coefficient. The test used was the t-ratio test and was conducted at $\alpha = 0.05$ given a degree of freedom 119 for the female cassava farmers, respectively. Table 6 showed the results of t-ratio tests for the coefficients of the inefficiency model of the stochastic frontier production function for the female cassava farmers, respectively. It has been seen that among the female cassava farmers, none of the inefficiency variable was significantly different from zero, hence; the null hypothesis was accepted for each of these variables. Therefore, it can be concluded that the only the production function variables determine TE among the female.

Table 5: Test of Hypotheses on Technical Efficiency

$H_{02}$: Female Cassava farmers are fully technically efficient ($\gamma = 0$)

| L.G.A | L ($H_0$) | L ($H_a$) | $X^2_{(computed)}$ | d.f | $X^2_{(7,0.05)}$ | Decision |
|---|---|---|---|---|---|---|
| Female | 40.10 | 22.84 | 34.54 | 7 | 14.07 | Reject $H_0$ |

Source: Computed from field survey data, 2006

Table 6: T-ratio test for the significance of coefficients of the socio-economic variables of the inefficiency models of the female cassava farmers

$H_{03}$: Socio-Economic variables have no significant relationship on the farmers' TE ($\delta_I = 0$)

| | Female | | | |
|---|---|---|---|---|
| Variables | Coefficient | T-ratio | T-critical | Decision |
| Age of Farmer | -0.1252 | -0.2043 | 1.645 | Accept $H_0$ |
| Household size | 0.1266 | 0.4237 | 1.645 | Accept $H_0$ |
| Years of farming experience | 0.1363 | 0.8908 | 1.645 | Accept $H_0$ |
| Educational level | 0.2435 | 0.9877 | 1.645 | Accept $H_0$ |
| Extension | 0.8675 | 1.576 | 1.645 | Accept $H_0$ |

Source: Computed from field survey data, 2006

## CONCLUSION

This study has empirically examined technical efficiency of women cassava farmers in Oluyole and Akinyele Local Government area of Oyo State. The following conclusions were drawn based on the major findings of this study:

The female cassava farmers were not fully technically efficient in the use of production resources. In the short run, an average female cassava farmer have the scope of increasing their cassava production by about 29.72% by adopting the technology and techniques used by the best practiced (most efficient) female cassava farmers. Such female cassava farmers could also realize 33.08 and 26.83% cost savings, respectively in order to achieve the TE level of his most efficient counterpart (Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997).

The most technically inefficient female cassava farmer revealed cost saving of about 74.77 and 72.35%. About 57.02% of the female cassava farmers had TE of over 70% and about 26.45% had TE ranging between 51 and 70%. The analysis of the influence of socio-economic variables on technical efficiencies of the female cassava farmers showed that none of the socio-economic variables had significant influence on their TE in the study area.

For the female cassava farmers, the variables that significantly affect their technical efficiencies include stem cutting, fertilizer quantity and pesticide quantity. Stem cuttings, farm size, fertilizer quantity, pesticide quantity and hired labour had positive signs while herbicide quantity and family labour all carried negative sign.

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