World Journal of Agricultural Sciences 11 (1): 01-07, 2015
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2015.11.1.1845

# Estimating the Production Efficiency of Food Crop Farmers Under Agroforestry System in Edo State, Nigeria

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**Abstract:** This paper estimated farmers' production efficiency in food crop production under agroforestry system in Edo state, Nigeria. Sixty (60) agroforestry farmers were purposively selected and structured questionnaire was used to elicit information from them. A stochastic frontier production function using the maximum likelihood estimation (MLE) was used as analytical tool. The MLE results revealed that farm size; hired labour and yam seeds are the major factors that influence the output of food crops. The coefficient of farm size, hired labour and yam seeds were positive and statistically significant at 1% and 5% levels respectively. Cassava was significant but negative implying that cassava had a negative effect on the crop combination and output. The mean economic efficiency (EE) of the farmers is 94% while the minimum and maximum EE are 73% and 98%, respectively. The distribution of EE shows that none of the farmers was able to operate at the frontier level implying that all the farmers are inefficient in food crops production. To attain efficiency level in food production in the study area, farmers should be encouraged through the provision of improved yam seeds, land improvement facilities like fertilizer among others.

**Key words:** Efficiency · Agroforestry · Food Crops Production · Nigeria

## INTRODUCTION

Agriculture is a major sector of the Nigerian economy contributing over 45 percent of the GDP. Food production is carried out by over 65% of the Nigerian populace especially the rural dwellers who operate small holding farms at subsistence scale. One of the farming systems practiced by the rural farmers in Nigeria is agroforestry. Agroforestry is a land management farming system that combines the cultivation of food crops along with trees on the same land. These include scattered trees, home gardens, shelterbelt etc. Agroforestry systems aim to maintain or increase production (of preferred commodities) as well as productivity (of the land). It has the potentials to improve productivity in many different way which include: increased output of tree products, improved yields of associated food crops, reduction of cropping system inputs and increased labour efficiency [1]. The question is: how efficient are these agroforestry farmers?.

Farm efficiency and the question of how to measure it, is an important subject in developing countries' agriculture. Measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings. These resource savings have important implication for both policy formulation and farm management. In policy arena, there is a continuing controversy regarding the connection between farm size efficiency and the structure of production agriculture [2]. For individual farms, gains in efficiency are particularly important in period of financial stress. Efficient farms are more likely to generate higher incomes and they stand a better chance of surviving and prospering.

There are three distinct approaches to measurement based on cost, profits and production functions. Technical inefficiency arises when actual or observed output from given input mix is less than the maximum possible; allocative inefficiency arises when the input mix is not consistent with cost minimization [3]. Farrel's model allows the computation of allocative, technical and hence, of economic efficiency, but this computation is restricted to a technology exhibiting constant returns to scale. Earlier works by [4-6] and [7] [4-7] have led to alternative formulation of parametric models which relax the linear homogeneity restriction while enabling the calculation of the various efficiency indexes. An approach for measuring

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efficiency that seeks to correct or ameliorate the extreme observation problem in deterministic frontier models is the stochastic frontier developed by [8, 9] and [9]. The stochastic frontier model assumes an error term with two additive components-a symmetric component that accounts for pure random factors and a one-sided component which captures the effects of inefficiency relative to the stochastic frontier.

Several studies have been conducted in Nigeria to determine the technical and economic efficiencies of farmers and how to improve their efficiency using stochastic production function approach. These include [10] who carried out an investigation into technical inefficiency of production among crop farmers in Ondo State of Nigeria. Also, [11] applied stochastic production frontier for efficiency analysis in smallholder cocoa farmers in Ondo State of Nigeria. The determinants of technical efficiency among the farmers include farmers' age, which was found to be negatively related to production efficiency, while education and age of cocoa trees have positive influence on production efficiency. [12] examined the efficiency of resource use by farmers in South Eastern Nigeria and estimated a stochastic production frontier function through a method of Maximum Likelihood method (MLM). He discovered that based on resource use efficiency and land management practices, the system of farming in the area showed signs of unsustainable crop production in the short-run.

In the area of economic efficiency, studies have also been conducted by [13]. Oyekale *et al.* [14] Adopted the stochastic production frontier to carry out an investigation into the production efficiency of food crops farmers in Gombe State, Nigeria. They also discovered that family labour, farm size, hired labour and fertilizer were the major factors that are associated with changes in the output of food crops in the study area.

However, no known study has been conducted to determine the efficiency of farmers operating under agroforestry system in Nigeria hence this study. The objectives of the study are to estimate the economic efficiency of the farmers and determine the various factors responsible for their efficiency or otherwise.

Theoretical Framework: Two techniques are commonly used to estimate efficiency-parametric and non-parametric. Under the parametric technique we have deterministic parametric frontier [15] and stochastic parametric frontier [8]. The parametric stochastic frontier production approach [8], [9] deals with stochastic noise and permits statistical test of hypotheses pertaining to production structure and the degree of inefficiency. As in [16] and [17] the parametric technique cost decomposition procedure is used to estimate technical, allocative and economic efficiencies.

The firm's technology is represented by a stochastic production frontier as follows:

$$Yi = f(Xi;\ \beta) + \varepsilon i \quad (1)$$

where,

Yi denotes output of the ith firm, Xi is a vector of function of actual input quantities used by the ith firm; $\beta$ is the vector of parameters to be estimated and $\varepsilon i$ is the composite error term [8] and [9] defined as:

$$\varepsilon i = vi + ui \quad (2)$$

where,

vis are assumed to be independently and identically distributed N $(0,0^2)$ random errors, independent of the uis; and the uis are nonnegative random variables, associated with technical inefficiency in production which are assumed to be independently and identically distributed and truncation (at zero) of the normal distribution with mean $\mu$ and variance $\sigma_u^2$ $|N(\mu u;\sigma_v^2)|$. The maximum likelihood estimation (MLE) of Eq (1) provides estimation for $\beta$ and variance parameter $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $v = \sigma_u^2 / \sigma_v^2$. Subtracting vi from both sides of Eq (1) yield.

$$\tilde{Y} i = Yi - vi = f(Xi{:}\beta) - ui \quad (3)$$

where,

i is the observed output of the ith firm adjusted for the stochastic noise captured by vi.

Following [18], technical inefficiency for each observation is calculated as the expected value of uj conditional on $\varepsilon j = vj - uj$

$$E(U/\varepsilon) = \frac{\sigma u \sigma v}{\theta}\left[\frac{(\varepsilon\lambda/\varnothing(\theta)}{1-\phi(\varepsilon\lambda/\theta)}\right] - \frac{\varepsilon\lambda}{\theta} \quad (4)$$

where,

E is the expected operator Ø, standard normal density Ö and distribution function.

$$\delta = \delta^2 u / \delta^2 v \quad (5)$$

$$\lambda = \delta u / \delta v$$

$$\gamma = \delta^2 u + \delta^2 \quad (6)$$

which,

is defined as the total variation of output from the frontier which can be attributed to technical inefficiency. Given a multiplicative production frontier for which Cobb- Douglas production (Eqn) was specified, the farm specific (TE) of jth farmers was estimated by using the expectation of uj conditional in the random variable εj as shown by [19]. That is.

$$Tej = \exp(-Uj), \tag{7}$$

So that $0 \leq Tej \leq 1$ that is technical efficiency is between 0 and 1.

## MATERIALS AND MATHODS

This study was carried out in Sapoba Forest Area in Orhionmwon Local Government Area of Edo state. Edo state is located between latitude 5°5'N-7°33' N and longitudes 5°E-6°40'E. It shares common boundaries with Ondo state in the west, Delta State in the east and Kogi state in the north. The vegetation of the state is moist rain forest in the south and derived savanna in the north. Sakpoba Forest Reserve lies between latitudes 4°-4° 30' and longitudes 6°-6° 5'E. It is located in Orhionmwon Local Government Area, about 30 kilometres South-East of Benin City.

Orhionmwon LGA has a population of about 182,717 according to the 2006 census with a land area of 2.382$km^2$ [20]. The people of the area are farmers and traders. Crops grown in the area include: yam, cassava, maize, plantain and cocoyam planted with some tress like *Tectona grandis*(teak) *Gmelina arborea*, *Terminalia ivorenisis*, *Khaya ivorensis* etc. The primary data were obtained using structured questionnaire. A total of 60 farmers were purposively selected and interviewed among 5 villages namely: Ageka, Evbuosa, Ona, Iguomokhua and FRIN Camp in the LGA where agroforestry system is practiced.

**Empirical Model Specification:** In traditional agriculture, multiple outputs and inputs are common features and for the purpose of efficiency analysis output is aggregated into one category and inputs are aggregated into seven categories namely – farm size, fertilizer, labour, capital, land, rental value of land, other variable inputs. An approach to the measurement of efficiency employed in this study is the stochastic frontier approach that combines the concept of technical and allocative efficiency in the quantity relationship [3]. The derived measure of inefficiency is then related to socio-economic, demographic and farms size variable.

The stochastic frontier production function used in this study is a linearized version of Cobb-Douglas production function. The stochastic frontier production function in equation (4) and the inefficiency model in equation (5) were simultaneously estimated as proposed by [21].

Specification of Technical Efficiency Model:

$$lnY = \beta o + \beta_1 lnX_{1i}j + \beta_2 lnX_{2i}j + \beta_3 lnX_3 ij + \beta_4 lnX_4 ij + \beta_5 lnX_5 ij + \varepsilon i \tag{9}$$

where subscripts ij refer to the ith observation on the $j^{th}$ farmer

In = denotes logarithm to base e;
Y = represents the farm output in (N);
$X_1$ = total farm size under cultivation (in hectares)
$X_2$ = household size (number in the family)
$X_3$ = hired labour used in production (in man-days)
$X_4$ = Yam seeds (number of setts)
$X_5$ = Maize (seeds in kgs)
$X_6$ = Cassava (number of cuttings)
$X_7$ = Plantain (number of suckers)
$\varepsilon i$ = error term ( vi-ui)

It is assumed that the economic efficiency effects are independently distributed and varies and uij arises by truncation (at zero) of the normal distribution with mean μ and variance $\sigma^2$; where uij is defined by equation.

Inefficiency Model:

$$uij = \alpha o + \alpha_1 lnZ_1 ij + \alpha_2 lnZ_2 ij + \alpha_3 lnZ_3 ij \tag{10}$$

where:

uij = represents the economic inefficiency of the ith farmer;
$Z_1$ = denotes age
$Z_2$ = represents year of schooling
$Z_3$ = represents years of farming

The β and α coefficient are unknown parameters to be estimated together with the variance parameters. The parameters of the stochastic production function are estimated by the method of maximum likelihood, using FRONTIER 4.1 program [22]. The maximum likelihood estimation (MLE) procedure is used because it is asymptotically efficient, consistent and asymptotically normally distributed.

## RESULTS AND DISCUSSION

This section discusses the socio-economic characteristics of farmers which are known to influence resource productivity and returns on the farms. The summary of the demographic and socio-economic characteristics of farmers is presented in Table 1. The demographic and socio economic variables considered include age, gender of farmers, household size, farm size, years of farming, level of education and marital status.

About 83.3% of the farmers are married while 82% are male. About 63.3% of the sampled farmers were between the age bracket 20-50 years. This suggests that majority of the farmers were middle aged and this implies that the farmers were still in their economic active age which could result in a positive effect on production [23]. This result agrees with the findings of [24] Alabi *et al*., (2005) who observed that farmer's age has great influence on maize production in Kaduna state with younger farmers producing more than the older ones possibly because of their flexibility to new ideas and risk. Furthermore 83.3% of the sampled respondents had one form of formal education or the other. [25] Observed that formal education has positive influence on the acquisition and utilization of information on improved technology by the farmers as well as their adoption of innovations. Some of the farmers (73.3%) have been farming for over 5 years. This means that they must have acquired good experience in agroforestry farming. [26] Indicated that the length of time in farming business can be linked to age. Age, access to capital and experiences in farming may explain the tendency to adopt innovation and new technology.

Table 2 shows the summary statistics of some of the socioeconomic variables and farm outputs. It reveals that the average age of the farmers was 49.2 years. An average farmer has a fairly large household of 6.5, cultivating about 1.12 hectares of land typifying a small scale holding with no one having more than one field thus suggesting that land fragmentation is not common in the forest reserve because farm lands are allocated to them by the government on year to year basis.

Table 1: Socio economic characteristics of sampled farmers N=60

| Variables | Respondents | Percentage | Cumulative Percentage |
|---|---|---|---|
| Age in Years | | | |
| 21-30 | 12 | 20 | 20 |
| 31-40 | 12 | 20 | 40 |
| 41-50 | 14 | 23.3 | 63.3 |
| 51-60 | 9 | 15 | 78.3 |
| 61-70 | 3 | 5 | 83.3 |
| 71-80 | 4 | 6.7 | 90 |
| Above 80 | 6 | 10 | 100 |
| Total | 60 | 100 | |
| Educational qualification | | | |
| Informal | 10 | 16.7 | 16.7 |
| Primary | 23 | 38.3 | 55 |
| Secondary | 22 | 36.7 | 91.7 |
| Vocational | 3 | 5 | 96.7 |
| Tertiary | 2 | 3.3 | 100 |
| Total | 60 | 100 | |
| Marital status | | | |
| Single | 4 | 6.6 | 6.6 |
| Married | 46 | 76.7 | 83.3 |
| Divorced/ widow/widower | 10 | 16.7 | 100 |
| Total | 60 | 100 | |
| Year of farming experience | | | |
| 5-Jan | 16 | 26.7 | 26.7 |
| 10-Jun | 8 | 13.3 | 51.7 |
| 15-Nov | 7 | 11.7 | 100 |
| 16and above | 29 | 48.3 | 100 |
| Total | 60 | 100 | 25 |
| Household size | | | |
| 5-Jan | 15 | 25 | 100 |
| 6-10 above | 45 | 75 | 83.3 |
| Total | 60 | 100 | 100 |
| Gender | | | |
| Male | 50 | 83.3 | 83.3 |
| Female | 10 | 16.7 | 10 |
| Total | 60 | 100 | 41.7 |
| Farm size(Ha) | | | |
| 0-5-1.0 | 6 | 10 | 10 |
| 1.5-2.0 | 19 | 31.7 | 41.7 |
| 2.5-3.0 | 11 | 18.3 | 60 |
| 3.5-4.0 | 2 | 3.3 | 63.3 |
| Above 4.0 | 22 | 36.7 | 63.3 |
| Total | 22 | 100 | |

Source: Caculated from Field Survey

**Maximum Likelihood Estimate Results:** The model specified was estimated by the maximum likelihood (ML) method using a FRONTIER 4.1 software developed by [22]. The ML estimates and inefficiency determinants of the specified frontier are presented in Table 3. The sigma square (0.0121) is positive and different from zero. This indicates goodness of fit and the correctness of the specified distribution assumption of the composite error term.

The variance defined as $\sigma^2 = \sigma_u^2 + \sigma_v^2$ is estimated to be 91.94%. The result implies systematic influences that are unexplained by the production function as the dominant sources of random errors. In other words, the presence of technical inefficiency among farmers explains about 91.94% in the output level of production. The presence of one-sided error component in the specified model is thus confirmed suggesting that the ordinary least square estimation would be inappropriate and inadequate representation of the data.

Table 2: Summary statistics of some socioeconomic variables of respondents in Sapoba N= 60

| Variables | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| Age(years) | 20 | 90 | 49.18 | 18.02 |
| Household size | 3.0 | 11 | 6.5410 | 1.68 |
| Years of Farming (years) | 4.0 | 65 | 19.66 | 16.56 |
| Farm size (hectares) | 0.20 | 2.02 | 1.1179 | 0.52 |
| Hired labour (mandays) | 0 | 98 | 35.03 | 26.20 |

Source: Calculated from field data.

Table 3: Maximum likelihood estimates of the stochastic production function in agroforestry in Edo State

| Variables | Coefficient | Standard Error | t-value |
|---|---|---|---|
| Constant | 1.110 | 0.0794 | 13.96*** |
| Household size | -0.00387 | 0.02699 | -0.1435 |
| Farm size | 0.3166 | 0.03706 | 8.542*** |
| Hired labour | 0.3194 | 0.0993 | 3.216** |
| Yam seeds | 0.2105 | 0.07189 | 2.929** |
| Maize seeds | -0.00013 | 0.00839 | 0.1579 |
| Cassava cuttings | -0.0182 | 0.00904 | -2.0167** |
| Plantain suckers | 0.00465 | 0.005176 | 0.8993 |
| Inefficiency Factors | | | |
| Constant | 0.492 | 0.439 | 1.111 |
| Age | -0.0787 | 0.0562 | -1.398 |
| Years of Schooling | -0.0374 | 0.0384 | -0.974 |
| Years of Farming | -0.0435 | 0.0807 | -0.539 |
| Sigma-squared | 0.0121 | 0.0127 | 1.166 |
| Gamma | 0.9194 | 0.0757 | 12.14 |
| Log likelihood function | 82.17 | | |

Note *** significant at 1%, ** significant at 5%

Source: Output of Frontier 4.1 by Coelli (1994) [22].

Table 4: Distribution of economic efficiency of agroforestry farmers in Edo State

| Efficiency Class | No of Farmers | Percentage |
|---|---|---|
| <0.50 | 0 | 0 |
| 0.51-0.60 | 0 | 0 |
| 0.61-0.70 | 0 | 0 |
| 0.71-0.80 | 4 | 6.6 |
| 0.81-0.90 | 10 | 16.7 |
| 0.91-1.00 | 46 | 76.7 |
| Mean | 93.6 | |
| Minimum | 73.3 | |
| Maximum | 98 | |
| Total | 60 | 100 |

Source: Derived from Output of Computer Programme Frontier 4.1 by Coelli (1994) [22]

The coefficients of farm size, hired labour, yam seeds are positive and significant at 1 percent for farm size and 5 percent for hired labour and yam seeds respectively while that of plantain was positive but not significant. This shows that farm size, hired labour and yam seeds contribute more to farm output. The positive sign of farm size implies that increasing the size of the farm by 100% will lead to about 31.66% percent increase in farm output and revenue. This conforms with the findings of [27]. This lends credence to the fact that increase in farm output in the developing world is usually a function of farm size. Hired labour is also positive and significant. It implies that increasing labour by 100% will lead to 31.94% increase in output and ultimately in farm revenue. Results conforms with the findings of [28, 29] who noted that labour was the most important resource input in water leaf farming. The coefficient of yam seeds is also positive and significant; an evidence that among the major crops planted by the farmers under agroforestry system, the contribution of yam to the farmers' revenue is very significant. Although the coefficient of plantain is positive it was not significant. The sum of elasticity (0.823) indicates that farmers were operating in the region of decreasing return to scale.

The estimated coefficients of the inefficiency function explain the technical inefficiency levels among individual crop farmers. None of the estimated variables was significant and all showed negative sign implying that all the factors (age, years of schooling and years of farming) are not strong enough to reduce inefficiency of the farmers.

**Distribution of Economic Efficiency:** The results presented in Table 4 below indicate an economic efficiency range from 0.73 to 0.98. The mean estimate is 0.94. The efficiency distribution shows that 76.7 attained between 0.91 and 1.00 efficiency levels while none had below 70 percent level of efficiency. The high level of efficiency is an indication that only a small fraction of the output can be attributed to wastage [30] and also to the fact that farmers in the area engage in multiple cropping that is, planting about 3 or 4 crops on a single plot of land. The distribution corroborates the findings of [31] and [32]. The fact that all the sampled agroforestry farmers are below one implies that none of the farmers reached the frontier of production. With a mean efficiency index of 93.6, there is scope for increasing output and efficiency. The results further showed that there are allowances for farmers to improve their efficiency by 6.4 percent in the area.

## CONCLUSION AND RECOMMENDATIONS

This paper estimated farmers' production efficiency in food crop production under agroforestry system in Edo state, Nigeria. A stochastic frontier production function using the maximum likelihood estimation (MLE) revealed that farm size, hired labour and yam seeds are the major factors that influence the output of food crops. It was observed that agroforestry farmers are not efficient in food production in the study area due to limitations and scarcity of farm resources. To attain efficiency level in food production in the study area, farmers should be encouraged through the provision of improved yam seeds, land improvement facilities like fertilizer among others.

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