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Productivity Potential and Technical Efficiency of Agro-Forestry-based Technologies in South-Western Nigeria

K. OGUNDARI[1] AND S.O. OJO†
Department für Agrarökonomie und Rurale Entwicklung,Georg- August Universitat, Platz der Göttinger Sieben 5, D-37073 Göttingen, Germany
†*Department of Agricultural Economics and Extension, Federal University of Technology, Akure, Nigeria*
[1]Corresponding author's e-mail: kogundari@yahoo.com

ABSTRACT

This study examined the productivity potential and technical efficiency (TE) of the taungya farming system as one of the agro-forestry-based technologies practiced in Ondo State Nigeria, in ensuring food security without land limitation. Cross-sectional data collected from 200 farmers in 2005 using a multi-stage sampling technique was analyzed using stochastic frontier production (SFP) function technique. About 75% of the variations in output from the frontier are attributed to differences in the farmer's technical efficiency, while the relative contribution of inefficiency to total variance equalled about 64%. The resource productivity revealed that farm size and number of trees, labour and operating expenses are significantly associated with changes in the output of the respondents. The return-to-scale (RTS) of 1.045, which was not significantly different from unity, indicated a constant value among the farmers. This reaffirmed the assumption that the selected Cobb-Douglas form assumed a constant return to scale. The TE of the farmers varied between 0.168 and 0.974 with a mean TE of 0.81. Results showed that the wide range of TE indices among the respondents point to the fact that there is considerable room for improvement. In particular, the size of the mean TE showed that the maize-yam crop production under Taungya farming could be increased by 19% through better use of available resources in the studied area.

Key Words: Taungya farming; Agro-forestry; Productivity; Technical efficiency; Stochastic frontier

INTRODUCTION

In spite of the dominant role of the petroleum sector as the major foreign exchange earner, agriculture remains the mainstream of the Nigerian economy. Apart from contributing as largest share of the gross domestic product (GDP), it is the largest non-oil export earner, a key contributor to wealth creation and poverty reduction, the largest employer of labour. According to Azeez (2002), a large percentage of Nigeria population derive their income from agriculture and agricultural related activities in which over 75% of rural inhabitants are farmers. However, over the years, the rate of growth in agricultural production has stagnated and failed to keep pace with the needs of rapidly growing population, resulting in a progressive rise in import bills for food. The gap between demand and supply of food continues to widen (CBN, 2005).

Nair (1997) identified land accessibility as part of the determinants of food security in the western part of Nigeria, because of an increasing demand for land for non-agricultural purposes, such as road construction, residential house and so on. In view of this, the agro forestry system regarded as the oldest land use system in Nigeria with the aim of solving problems of land hunger, traditional shifting cultivation and bush fallowing is of the opinion that under continuous cultivation will be a suitable farming system for a region that want to increase her food production, ensure stream of income and maintain the fragile and limited land resources. Oladokun and Egbe (1990) highlighted that a systems can be modernized for the purpose of adoption as an alternative to shifting cultivation in Nigeria.

The Taungya farming system is a form of agro forestry-based technology, which integrates arable crops with forest trees on the same piece of land (Ehiagbonare, 2006). It is a system in which arable crops are cultivated on the same piece of land in between rows of young forest trees thus ensuring the optimum utilization of free and fertile forest land and at the same time checking hazards such as degradation of farm land and increased infestation by weeds associated with traditional shifting cultivation. Allison *et al.* (1986) reported that Taungya, as an agro-forestry system, could be a cost-effective method of establishing forest plantation.

However, the difference between this system of farming and the conventional system of farming is that the land in question belongs to forestry department under Taungya farming that allows farmers to raise annual crops, while the farmers in turn are required to tend the tree seedlings as a complement for the free fertile land pending the time the forest species will grow and expand their canopy. This agreement usually lasts for about 2 to 3 years. Although, the ultimate goal of the Taungya system is wood production and the immediate motivation for practicing the system is food production, but for meeting family food security, the system is occasionally hampered by the problem of land availability.

There are many of agro-forestry technologies researches of which Taungya farming is one of such practices. This study was designed to examine the productivity potential and technical efficiency of food crop production under Taungya farming system as a form of land use in Ondo State, Nigeria, with the aim of improving the current level of food production in the country within the limited land resources.

MATERIALS AND METHODS

Study area. This study was based on farm level data on yam-maize crop production under Taungya farming system in Ondo state. The state lies in the South-Western Nigeria. Climatically, the state falls within the rainforest belt of the country with vast agricultural potential. The state enjoys luxuriant vegetation with vast rainforest found in the south, while the northern fringe is mostly sub-savannah forest .The people are predominantly peasant farmers cultivating mainly food crops such as yam, maize, cocoyam, sweet potato and cassava for family consumption and market. The state has vast forest resources and suited for the production of tree crops such as cocoa, kola nut and cashew OSMARD (2004). Mixed cropping system of farming is common in the state. Farming practices in the study area involve the use of hand tools and simple implements with majority of the farmers cultivating less than one hectare of farm land. The species of trees found in the study area include: Terminalia superba, Nauclea dideroichii, Chrysophyllum deleroyl, Chrysophyllum abidum and Terminalia ivorenesis.

Data collection and sampling techniques. The data mainly from primary sources were recorded from 200 farmers practicing Taungya system on government forest reserve. The sample was selected from four Local Government Areas [Owo, Ose, Idanre & Akure North (LGAs)] using multistage sampling techniques. Four LGAs were purposively selected, because of high prevalence of farmers practicing Taungya farming in the LGAs. The second stage was a simple random selection of 50 farmers from each of the four LGAs, thus making 200 respondents. Data were recorded using structured questionnaire on farm output in kg per annum. Information collected on inputs include and farm/farmers socio-economic variables: farm size (hectare), tree density (number of trees on the farm), labour in man-days, cost of planting materials and age of the farmers.

Analytical framework. A stochastic Frontier Production function technique in efficiency studies is employed in this study to simultaneously estimate the productivity potential (resource-use efficiency) and technical efficiency of Taungya farming system. The modelling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following the works of Aigner *et al.* (1977) and Meeusen and Van Den Broeck (1977). They independently proposed the stochastic frontier production function to account for the presence of measurement errors and other noise in the data, which are beyond the control of the firms by building on previously used deterministic approach that accounts for inefficiency as the only source of deviation from the frontier output (Afriat, 1972).

The standard methodology for measuring farm level production efficiency is to estimate a production frontier. Within this context, technical efficiency of a farm is measured relative to the input/output performance of all other farms in the sample. A farm located on the production frontier is considered efficient, while a farm located inside is considered inefficient because the farm is generating less output given its level of inputs. Technical efficiency is the ability of a firm to produce on the isoquant frontier or ability of a firm to obtain maximum output from a given set of inputs.

The stochastic frontier production function model is implicitly specified as follows:

$$Y_i = f(X_j; \beta_j)\, e^{(vi - \upsilon i).} \qquad (1)$$

Where

Y_i is the output in a specified unit, X_j denotes the actual vector of inputs used in the production process, β_j is the vector of production function parameters, while vi and υi are two error terms in the regression model. ν_i is assumed to be independently and identically distributed as N $(0, \sigma^2_v)$ and it is independent of υi. υi is a one-sided component, which reflects technical inefficiency relative to stochastic frontier and identically distributed as $|$ N (μ, σ^2_u) $|$ (Note: when μ = 0,distribution of μ becomes half-normal). μ_i measures the technical inefficiency relative to the frontier and describes the distance of firm i-th from the frontier output Coelli *et al.* (1998).

The technical inefficiency of individual farm is empirically measured from expected value of inefficiency error term (υi) conditional on overall decomposed error ε_i = $(\nu_i - \upsilon_i)$ such that technical efficiency can be calculated as:

$$TE_i = 1 - E[(U_i)/\varepsilon] \qquad (2)$$

Where

$$E(U_i|\varepsilon_i) = \frac{\sigma_u \cdot \sigma_v}{\sigma} \cdot \left[\frac{f(\varepsilon_i \lambda | \sigma)}{1 - F(\varepsilon_i \lambda | \sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right]$$

Jondrow *et al.* (1982) (3)

$E[(U_i)/\varepsilon]$ = Technical Inefficiency (TI)

That is $0 \leq TE \leq 1$.

Model specification. The choice of suitable functional form for the analysis was subjected to generalized likelihood ratio test, which led to the choice of Cobb-Douglas functional form (see result & discussion for this) defined as follows:

$$\ln Y_i = \ln\beta_i + \beta_1 \ln_{landi} + \beta_2 \ln_{treesi} + \beta_3 \ln_{labouri} + \beta_4 \ln_{materialsi} + \beta_5 \ln_{agei} + \nu_i - \upsilon_i \qquad (4)$$

Where

Y_i denotes total farm of output of maize-yam crop production in kg; land denotes farm size in hectare; trees denotes number of trees on the farm (tree density); labour denotes total man-day of labour; materials denotes cost of planting materials (naira), while age denotes the age of the farmer. The β's are scalar parameters to be estimated.

Hypotheses testing. The generalized likelihood ratio test was conducted on certain hypotheses relating to the estimated parameters such as: (1) The production function of the farmers is specified by a Cobb-Douglas functional form (that is, H_0: β_{jk} =0); (2) There is absence of inefficiency effects that is there is stochastic effects in the production (H_0: $\gamma = 0$); (3) The presence of trees on the farm has no effect on the production ($\beta_2 = 0$).

The final hypothesis although not tested with generalized likelihood ratio test but based on the assumption, that the selected Cobb-Douglas functional form is characterized by constant return to scale and fixed elasticity of output with respect to production inputs, such that the sum of the estimated coefficients for the input factors not significantly different from unity (that is, $\sum\varepsilon_\rho = 1$). The generalized likelihood ratio test, which is defined by the test statistic, chi-square (χ^2) is defined as:

$$\chi^2 = -2\,[L\,(H_0) - L\,(H_a)] \qquad (5)$$

The χ^2 has a mixed chi-square distribution with the degree of freedom equal to the number of parameters excluded in the restricted model; L (H_0) is the log – likelihood value of the restricted model. While L (H_a) is the Log- likelihood value of the un-restricted model.

Maximum likelihood estimation procedure is used to estimate the parameters of the stochastic frontier equation 1. The parameters to be estimated include β and variance parameters such as $\sigma^2 = \sigma^2_u + \sigma^2_v$ and $\gamma = \sigma^2_u/\sigma^2$. Where σ^2 is the sum of the error variance, while γ measures the total variation of output from the frontier attributed to the existence of random noise or inefficiency as γ is bounded between zero and one, where if γ = 0, inefficiency is not present, hence deviation from the frontier is entirely due to random noise and if γ = 1, indicates that the deviation is due entirely to inefficiency (Battese & Coelli, 1995). However, according to Coelli *et al.* (1998), γ does not equal the ratio of the variance of inefficiency to total residual variance. The reason is that the variance of μ equals:

$$\frac{[(\pi-2)]\,\sigma^2}{\pi} \qquad (6)$$

And not σ^2 Thus, the relative contribution of variance inefficiency to total variance σ^2 equals:

$$\frac{\gamma}{[\gamma + (1-\gamma)\,\pi/(\pi-2)]} \qquad (7)$$

Hence, FRONTIER 4.1 c (Coelli, 1996) was used to obtain the maximum likelihood estimates (MLE) for the study.

RESULTS AND DISCUSSION

Production performance. The mean farm output of yam-maize crop production under Taungya farming was 36, 431.13 kg and given the average farm size was 0.80 ha, this implies that about 45,500 kg was produced per ha (Table I). The average number of trees on the farm (tree density) was 38.61, translated to an average of 48 trees per ha. A large number of trees recorded indicated that it prevented the farmers from expanding their present level of yam-maize production. The mean labour used was estimated as 307.43 man-days. This showed that maize-yam crop production under Taungya farming is highly labour intensive as most operations are done manually because of high prevalence of trees within the farms. Such operations include: land clearing, burning, packing, heaping, planting, weeding, harvesting and pruning. The cost of maize seeds, yam setts/seeds as planting materials was ₦24, 181.21, while the average age of the farmers from the findings was estimated as 47.31 years, showing that the farmers were relatively younger.

Results of hypotheses tests. The results of the likelihood ratio tests are presented in Table II. The first hypothesis that the Cobb-Douglas functional form was the best-fit functional form for the data was accepted. The second hypothesis that there was absence of inefficiency effects in the production process was rejected, while the third hypothesis that the number of trees present on the farms as a variable had no effect on the production frontier was also rejected.

Productivity analysis. The estimates of the stochastic frontier production function for the farmers in the study area are presented in Table III. The estimated coefficients of the explanatory variables showed that farm size, labour, operating expenses and age of the farmers had positive effect on the change in output, while the coefficient of number of trees on the farm had a negative sign. This means an increase in the number of trees on the farm decreases farm output vice-versa. Hence, the results follow *a priori* expectations meaning that as these variables increase, the value of the output (maize-yam) increases *ceteris paribus*. Farm size, number of trees, labour and cost of planting materials were significant at 5% level of significance, indicating that these factors were different from zero and thus important in maize–yam crop production under Taungya farming system. However, the result of the signs and significant of the coefficients of the farm size, labour and operating expenses is in conformity with the works on peasant farming setting in Nigeria by Ojo (2004), Ogundari and Ojo (2005) and Udoh (2005).

The return-to-scale (RTS) presented in Table IV was estimated as 1.045 indicating constant return to scale meaning that food production under Taungya farming in the study area increased at the same pace with the quantity of input applied. This further confirm the hypothesis ($\sum\varepsilon_\rho = 1$) on the assumption related to the selected functional form

(Cobb-Douglas) for the specified production function that the summation of the elasticities (coefficients) of input used was not far from unity. However, the RTS from this study was in conformity with the work of Udoh (2005) on technical inefficiency in vegetable farms of humid region in Nigeria. Using Cobb-Douglas functional form the study revealed RTS of 1.004, which was not significantly different from unity and not far from 1.045 obtained from this study.

Technical efficiency analysis. The estimated gamma parameter (γ) of frontier model was 0.745 and significant (P < 0.05). This showed that a high level of inefficiency exist among the farmers. However, using Coelli *et al.* (1998) derivation described in equation 7, the relative contribution of inefficiency to total variance in the analysis equalled 64.4%. This further confirmed the second null hypothesis on the presence of stochastic effect/inefficiency effects among the Taungya farmers from the study.

The decile range of frequency distribution of technical efficiencies of Taungya farmers is presented in Table IV. The result of the analysis revealed that the predicted farm specific technical efficiencies range between 0.168 and 0.974 with a mean of 0.81. The table further shows that 84% of the farmers had TE of 0.70 and above, indicating that more than half of the farmers under this agro-forestry technology were relatively efficient. The implication of the average TE of 0.81 from the analysis is that maize-food crop production under Taungya farming system could be increased by 19% through better use of available resources as the wide range shows a considerable level of improvement for the farmers.

Comparing the average TE from this study with other studies revealed that the TE from the study is not farm from the findings of Dawson *et al.* (1991), Amara *et al*. (1992), Kumbhakar (1994) and Wilson *et al.* (1998) with an average TE of 89, 80, 75, and 90%, respectively. Similarly, the TE from this study is higher than the one recorded by Ogunyinka and Ajibefun (2004) and Yao and Liu (1998) with an average TE of 67 and 63%, respectively.

CONCLUSIONS

Results showed that Taungya farmers were efficient in use of the included variable inputs, while Taungya farming system of agro forestry-based technology provides an alternative way of simultaneously solving the problem of land hunger and food insecurity in the country, which is an indication that average Taungya farmer's technically efficient as such farmers has nothing to lose at first instance, because it is an efficient ways of managing ones scarce resources (land) and secondly such farmers has the tendency to obtain maximum output from a given set of inputs expended without any waste of resources. However, to derive the benefit of economies of scale, because of the constant return to scale obtained from the analysis, variables such as farm size and operating expenses should be increased. Hence, farmers should be adequately accrue the benefit of engaging in this technology and at the same time educate them on the principles underlining Taungya system so that the system would serve as another ways of solving the problems of food insecurity in the country mostly caused mostly by land availability and at the same time helping to improve the current state of forest trees in Nigeria as this also needed to combat environmental degradation.

Table I. Summary Statistics of Variables of Stochastic frontier production

Variables	Mean	Std. Dev.
Total Farm Output (Yam-Maize) in Kg	36,431.13	12,170.85
Farm size in hectares	0.801	0.7396
Tree density (No of tree on the farm)	38.61	29.92
Total Man-days of Labour	307.43	286.51
Cost of planting materials (₦)	24,181.21	14,836.77
Age of the farmers (years)	47.31	13.63

1US$=₦145

Table II. Generalized Likelihood ratio test of hypotheses for parameters of stochastic production frontier and technical inefficiency factors

Null hypotheses	χ2-calculated value	χ2-critica value	Decision
Production function is Cobb-Douglas (i.e., H_0: β_{jk} =0)	13.11	16.27	Accept
Absence of inefficiency effect (H_0:γ = 0)	17.26	13.40*	Reject
Var. Number of trees does not affect the production frontier (H_0: β_2 = 0)	15.64	11.91	Reject

* This value is obtained from Table 1 of Kodde and Palm (1986) which gives critical values for tests of null hypothesis involving values of the boundary of the parameter space. If the null hypothesis that γ =0 is true ,then there are six other parameters which are not present .Hence, the degrees of freedom for the appropriate critical value in table 1 of Kodde and Palm (1986) is q+1 where q =6

Table III. Estimates of the Stochastic Frontier Production function

Variables	Parameters	OLS-Model	Frontier-Model
Production factors			
Intercept	β_0	-1.484 (1.359)	-1.681(1.502)
In (Farm size)	β_1	0.296* (3.896)	0.332* (5.875)
In (Tree density)	β_2	-2.980*(2.143)	-1.142*(2.364)
In (Labour)	β_3	1.610*(2.871)	0.570*(2.893)
In (Operating Expenses)	β_4	1.434*(1.981)	1.731*(2.074)
In (Age of farmer)	β_5	0.364 (1.685)	0.594 (1.349)
Variance parameters			
Gamma	γ	0	0.745*(23.451)
Log-likelihood function	LLF	-201.02	-192.39

Figures in parentheses are t-ratio
*Estimate is significant at 5% level of significance

Table IV. Deciles Range of Frequency distribution of T.E. of Framers under Taungya farming in Ondo state, Nigeria

Deciles range of T.E	Frequency	Percentage
0.10-0.19	2	1.00
0.20-0.29	4	2.00
0.30-0.39	1	0.50
0.40-0.49	2	1.00
0.50-0.59	5	2.50
0.60-0.69	19	9.50
0.70-0.79	36	18.0
0.80-0.89	59	29.5

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