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The relative advantage of agroforestry system over arable crop farming: Empirical evidence from cocoa based agroforestry and arable crop farming systems in Oyo State, Nigeria

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Abstract

Data obtained from 57 cocoa based agroforesters and 67 arable crop farmers were analysed using stochastic frontier production function. Cocoa based agroforestry system had higher value of output than arable crop farming. Although cocoa based agroforestry system is more labour and capital intensive than arable crop farming, it is relatively more technically efficient than arable crop farming. The technical efficiencies of arable crop farmers ranged from 0.19 to 0.96 (mean value 0.82) and those of cocoa based agroforestry farmers from 0.10 to 0.99 (mean value 0.85). Age of the farmers, educational level and farming experience explained the existence of inefficiency effects in the farming systems. While age was positively related to inefficiency, educational level and experience were negatively related to inefficiency of the farmers. More output can be gotten from arable crop farming by increasing labour supply (family labour) while output of cocoa based agroforestry system can be increased by expanding the farm size. The study consequently recommends agroforestry farming system as efficient farming system option.

Key words: Stochastic, frontier, technical, efficiency, agroforestry, arable, farming.

Introduction

Modern technologies adopted from temperate zone agriculture with its admirable characteristics have not always been successful on fragile and degraded upland soil of tropics[8]. The rapid decline in the productivity of tropical soils under continuous cultivation, even with supplementary fertilization has been documented[6]. The failures of various mechanized arable farming methods highlight the need for a different approach for continuous arable farming on low activity clay soil[10]. Lal[7] stressed the importance of mulching and minimum tillage to maintain the physical productivity of soil. However, it appears that a more important factor in the maintenance of soil productivity is the ecological manipulation of soil organic matter[14,15]. This can be done through a planned fallow system providing adequate *in situ* mulch and green manure termed agroforestry[6].

The conservation benefits of agroforestry have been widely discussed in the literature and include maintenance of and/or improvement in soil fertility, lower levels of water and wind erosion, lower levels of transpiration and shortening of fallow period without adverse consequences[11]. Soil nutrients levels have been improved using trees in some agricultural systems. In West Africa where *Acacia albida* is commonly used in parkland system (matured trees widely dispersed in cropped fields), VanDen Beldt[15] have found 40% more organic carbon and nitrogen, 42% more exchangeable cations and moderate increases in phosphorus and potassium in soil away from the trees. It was found that green manure addition of over 100 tons ha^{-1} would be necessary to provide equivalent soil improvement. Another major advantage of agroforestry system over traditional shifting cultivation and bush fallow system is that the 'cropping' and fallow phases can take place concurrently on the same land, thus allowing the farmers to crop an extended period without returning the land to bush fallow[17]. Agroforestry systems are less risky with regard to physical outputs that is mono production[4]. Historical reviews have shown that agroforesty systems are viable[16], the system has been proved to have ecological advantages and offers economic advantages over mono production system. In economic terms, agroforestry land use systems, when compared to non–agroforestry land use systems will have a higher output value at the same resources cost and/or have the same output at a lower resource cost. The superiority of the technical efficiency of agroforestry system has not been sufficiently investigated. The past studies suffer from various weaknesses. They are merely descriptive and agronomic analyses. Those that evaluated the economic returns[5, 9,11,13] used experimented station data that may be unrealistic under farm conditions[14]. The objective of the study is the comparative analysis of technical efficiencies of agroforestry system and arable farming system in Oyo State of Nigeria. The factors that determine the efficiencies of the farming systems were also investigated. The differences in economic returns of the systems were also examined.

Methodology

Data source and collection: The study was carried out in Oyo State in the South West of Nigeria. South Western Nigeria produces 85% of total cocoa produced in Nigeria. The state lies in latitude 6°N and 8°N with maximum temperature of 31°C and minimum 22° C. The annual rainfall is between 1200–2200 mm and the relative humidity 80–85%. Rainy period is between 240–260 days/year and dry period between 96–125 days/year. The main crops grown are cocoa, kola, yam, cassava and maize. Majority of the farmers in the area are small-scale farmers with average farm size of about one hectare. Part-time farming, in which farm households are involved in non-farm jobs, is common in the study area. Farming practices in that study area involve the use of hand tools and simple implements. The stages of production include slashing and burning, land preparation, planting, weeding, fertilizer application and harvesting, all of which are labor intensive.

Given that farmers have limited production resources, they are conscious of what to produce and what method of production to use. They normally limit the hectare of particular crop to what they could effectively manage and the choice of crops and farm size is based on the need for family food security and cash income for both farm operations and other cash needs. Cocoa has been proved to the major cash income in Oyo State. In fact, the foundation of prosperity of Oyo State was based on cocoa cash income[12].

For this study, the selection of respondent farmers involved a three–stage selection method. The state was divided into two parts: North and South. Cocoa and arable crop production are predominant occupation of the Southern part of Oyo state[1]. The villages in the southern part of Oyo state were divided into five strata based on economic and socio-cultural considerations. One village was randomly selected from each stratum. The final stage of random selection involved 20 arable farmers and 20 cocoa farmers (more than 97% of cocoa farmers practiced cocoa based agroforestry farming system), making a total of 100 arable crop and 100 cocoa farmers. However, because of lack of some important information and due to some inconsistencies in some of the data collected, analyses were based on the data from 67 arable crop farmers and 57 cocoa farmers. Information was collected on the total value of agricultural output, since the farmers generally practice mixed cropping. The total value of output was obtained by adding cash receipts from selling farm products to those consumed in the households. Inputs were categorized into three groups: land, labour and capital, with capital comprising of seeds, implements and agrochemical. Data were also collected on the socio-economic variables, such as age, farming experiences and level of education of the respondent farmers. Generally, the major inputs for agricultural production in the area are land, labour and minor farm implements, such as cutlasses and hoes, which are used for land preparation. Very few farmers made use of agrochemicals, such as fertilizers, herbicides and insecticides. Data on the depreciation values of the farm implements were obtained. For this study, the value of farm output was recorded in Naira, land was measured in acres and human labor in man days (for family and hired labour). Costs of the other inputs refer to the costs of depreciation of farm implements and costs of agro-chemicals, measured in Naira. Farming experience was measured by the number of years the farmer had been involved in agricultural production, while level of education was measured as the number of years of schooling.

Statistical model: The stochastic frontier production function for this study is defined as

$$(1) \qquad In\ Y_i = B_o + In \sum B_j X_{ji} + (Vi - Ui)$$

where *In* represents the natural logarithm. The subscript i represents the i-th sample farmer Y = the value of farm output for farmers i; X_s represent the input variables in the model, where X_1 = total area of land (in acres) on which crops were grown

X_2 = family labour

X_3 = hired labour

X_4 = cost of capital

B_s represents the input coefficients for the resources used in production.

The Vis are assumed to be independent and identically distributed normal random errors having zero mean and unknown varianceδ_v^2. The Uis are non-negative random variables called technical inefficiency effects which are associated with technical inefficiency of production of the respondent farmers, which are assumed to be independent of the Vis, such that Uis is the non–negative truncation (at zero) of the normal distribution with mean, U_i, and variance, δ^2 where U_i is defined by

$$(2) \qquad U_i = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3$$

where z_1, z_2 and z_3 represent the age, farming experience and level of education of the i-th farmer. The B_s and a_s are unknown parameters to be estimated from Equations (1) and (2) for arable crop farmers and cocoa based agroforesters.

The socio-economic variables of age, farming experience, and level of education are included in the model for the technical inefficiency effects to indicate possible effects of farmer characteristics on the efficiency of production.

The inefficiency model of equation (2) implies that the stochastic frontier model is non–neutral frontier model, which is a special case of Huang and Lui[3] model. The technical efficiency of the i-th farmer, given the specifications of the model, is defined by

$$(3) \qquad Tei = \exp(-Ui)$$

Various tests of hypothesis for the parameters of the frontier model are conducted using generalized likelihood-ratio statistic, defined by

$$(4) \qquad \lambda = -2\ In\ [L(H_o)/\ L(H_1)\ ]$$

where L (H_o) is the value of the likelihood function for the frontier model in which parameter restrictions specified by the null hypothesis, H_o are imposed and L(H_1) is the value of the likelihood function for general frontier model. If the null hypothesis is true, then λ has approximately a chi-square (or mixed square) distribution with degrees of freedom equal to the difference between the parameter estimated under H_1 and H_o respectively.

Empirical Results

Table1 presents summary statistics of the variables of arable croppers and cocoa based agroforesters. The mean age of the arable croppers (45.5 years) was less than the average age of the cocoa based agroforesters (47.7 years). This shows that cocoa farmers were older than arable crop farmers in the study area. Cocoa based agroforesters had more farming experience (24.62 years) than arable croppers (17.00 years). Cocoa based agroforesters had more family labour (421.21), hired labour (78.10) and capital (₦4883.7) than arable croppers with family labour (231), hired labour (57.7) and capital (₦3949). The arable croppers had more land cultivated (4.3 acres) than cocoa based agroforesters (3.7 acres). This is because cocoa farming is more tedious to establish than arable farming. Table 1 confirms that cocoa based agroforestry is more labour and capital intensive than arable farming but with higher value output (₦130,246) compared with arable faming with value of output of [₦ 26,639] per farmer per annum.

Stochastic Frontier Production Estimates and Hypothesis Testing

The maximum likelihood estimates of the parameters of the stochastic frontier model (1) and (2) were obtained using the program FRONTIER 4.1[2] which estimates the variance parameters in terms of

$$\delta_S^2 = \delta^2 + \delta_v^2 \quad and \quad \wp = \delta^2 / \delta_S^2$$

These estimates of the parameters are presented in Table 2. The estimates for the $\wp$ - parameters is 0.88 for arable croppers and 0.69 for cocoa based agroforesters. It shows that there are more inefficiency effects in arable crop farming than cocoa based agroforestry system.

The elasticities of mean output with respect to the four input variables were estimated at the values of the means of the inputs and the inefficiency variables. The estimates are presented in Table 3. For arable croppers, the estimated elasticity of farm output with respect to land was 0.22, which is the smallest of the four elasticities. The elasticity of labour family was the largest with a value of 0.38. It means that more arable crop can be produced by increasing family labour than by increasing any other factor input. For agroforesters, the reverse was the case; more output can be experienced by increasing the land area cultivated than by increasing any of the four factors inputs because land has largest elasticity with a value of 0.42 and family labour the smallest one 0.13.

The return to scale parameter of 1.17 and 1.12 estimated for arable croppers and cocoa based agroforesters respectively indicate increasing returns to scale. This implies that the farmers are in stage 1 in the production function curve. At this stage, every addition to the production inputs would lead to more than proportionate addition to the output.

The estimated coefficients in the explanatory variables in the model for the technical inefficiency effects are of interest and have important implications. The positive coefficient for the age variable implies that the older farmers are more technically inefficient than the younger farmers. This could be explained in terms of the adoption of modern technology. Older farmers tend to be more conservative and less receptive to modern and newly introduced agricultural technology. The negative coefficient for farming experience implies that farmers with more experience tend to be less inefficient. The negative coefficients of education indicate that farmer's level of technical inefficiency tends to decline with education.

The technical efficiencies differed substantially among the farmers, ranging between 0.19 and 0.96 with the mean technical efficiencies estimated to be 0.82 for arable croppers. The technical efficiencies of cocoa based agroforesters ranged from 0.10 to 0.99 with mean 0.85. It is confirmed in Table 4 that technical efficiency of cocoa based agroforesters is statistically higher than the technical efficiency of arable crop farmers.

Table 1. Summary statistics of the variables of arable croppers and cocoa based agro-foresters.

Variable	Arable croppers	Cocoa based agroforesters
Value of output (₦)	29639	130246
Land area cropped (acre)	4.3	3.7
Family labour (man days)	231.0	421.21
Hired labour (man days)	57.7	78.10
Capital (₦)	3949	4883.7
Mean age of the farmers	45.5	47.70
Mean years of experience.	17.0	24.62

Source: Computed from field survey data, 2002.

Table 2. Maximum likelihood estimates of parameter of frontier production function for arable croppers and cocoa based agroforesters.

Variable	Arable croppers	Agroforesters
Land	0.22 (0.10)	0.42 (0.12)
Family labour	0.38 (0.12)	0.13 (0.01)
Hired labour	0.34 (0.19)	0.36 (0.11)
Capital	0.23 (0.14)	0.21 (0.01)
Constant	7.72 (0.97)	29.3 (0.09)
Inefficiency model		
Constant	6.01 (2.52)	-22.2 (9.5)
Age	0.037 (0.01)	243.8 (118.7)
Experience	-0.093 (0.03)	-64.8 (17.3)
Education	-0.079 (0.01)	-42.1 (17.3)
$\wp$	0.88	0.69
Log likelihood function	-6.644	-661.8

Source : Computed from field data, 2002.

Table 3. Elasticities of mean output and return to scale of arable croppers and cocoa based agro-foresters.

Variable	Arable croppers	Cocoa based agroforesters
Land	0.22 (0.10)	0.42 (0.12)
Family labour	0.38 (0.12)	0.13 (0.01)
Hired labour	0.34 (0.19)	0.36 (0.11)
Capital	0.23 (0.14)	0.21 (0.01)
Returns to scale	1.17 (0.55)	1.12 (0.25)

Source: Computed from field data, 2002.

Summary and Conclusions

The study showed that cocoa based agroforestry system is more labour and capital intensive than arable crop farming. Cocoa based agroforestry farming system has higher value of output than arable crop farming. Although production of both arable crop farmers and cocoa based agroforesters can be increased by using more of inputs because they are operating at increasing returns-to-scale

Table 4. Hypothesis testing. H_o: There is no significant difference between the technical efficiency of arable crop farmers and cocoa based agroforesters.

Farmers	Log likelihood function	λ	Critical value*	Decision
Arable crop farmers	- 6.644	1310.31	18.31	Reject
Cocoa based agroforester	- 661.8			H_o

Source:Computed from field data, 2002.
Critical Value at 5%.

stage in the production function curve, more output can be derived from arable crop production by increasing the use of family labour than any other factor input. The output of cocoa agroforestry system can be enhanced by the cropping of more land than by increase in any other factor input.

Age of the farmers is positively related to the inefficiency on the farms, while educational level and experience are positively related to technical efficiency of the farmers. The technical efficiencies of arable crop farmers vary from 0.19 to 0.96 with mean 0.82, while cocoa based farmers have technical efficiencies that vary from 0.10 to 0.99 with mean of 0.85[the difference is statistically significant].

This study confirms higher economic superiority of cocoa based agroforestry system over arable crop farming in Oyo State, Nigeria. In order to increase agricultural production in the study area, farmers should be encouraged to embrace agroforestry farming system. Land expansion can result in increased output of the farmers, hence efforts should be directed at making more land available, accessible and affordable to farmers by liberalizing land markets.

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