Technical Efficiency in Producing Cashew Nuts in Benin's Savanna Zone, West Africa

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Abstract

In Benin, cashew nut represents the second major cash crop after the cotton. It is, therefore, an important source of income in rural areas. Accordingly, we investigated in this paper, the technical efficiency of producers in the management of their cashew orchards. Data were collected on 180 randomly selected producers, in the Central and Northern parts of Benin. We adopted a Cobb-Douglas functional form to estimate a production function using a stochastic production frontier approach. Results show that the cashew nut production in Central and Northern Benin was not optimal. The average technical efficiency score of cashew nut producers was to 0.63 (minimum 0.10, maximum 0.88) with a modal class of [0.70–0.80]. According to these results, the cashew nuts production system in the current settings is very extensive and could be improved through intensive use of labor and capital.

Keywords: cashew nuts, technical efficiency, stochastic production frontier, Benin
JEL: Q12, Q19

1 Introduction

In Benin, cashew nut is the second most exported agricultural commodity after cotton, and one of the major sources of rural income and employment (ISSAKA, 2007; MAEP, 2008). With an annual average production of 69.305 tons and an annual production growth rate of about 14% during the last decade, Benin was ranked 11th of the world market, 4th of West Africa. In fact, Benin produces the 2nd best quality of cashew nuts in West Africa (MAEP, 2003; SOGLO and ASSOGBA, 2009). From 1996 to 2002, the cashew cultivated surface increased from 30,000 ha to 74,000 ha. Therefore, the cashew is very important for both many farmers and other economic actors in Benin (MAEP, 2008). Although all the six main administrative Departments of Benin are concerned by the cashew nut production, the central and the northern parts of the country are the most important producers' areas. The Departments of Atacora and Donga in the Northern Benin alone have more than 53 cashew orchards, representing 55% of the total cashew nut cultivated area of the country (ISSAKA, 2007). The cashew nut production in rural area played several important roles. It played economic, social and environmental role. Cashew nut production:

– as an important economic factor provides relatively stable farm incomes and endogenous agricultural financing (AGAÏ, 2004; SINGBO et al., 2003; ISSIAKA, 2007; ALINGO, 2008; BACO, 2008),
– as social factor generates employment and is an indicator of social status (DEGLA, 2010),
– as environmental factor restores soil fertility in degraded cultivated areas (AÏNA, 1996; TANDJIÉKPON et al., 2005).

Because of this large importance of cashew nut production in Benin, the government decided in 2007, through its agricultural development program, to increase cashew nut production from 62,281 tons to more than 70,000 tons per year from 2011 (MAEP, 2008). Although there are currently no reliable statistics to check these results, it is clear that such production perspectives could be reached only when the cashew nut sector is based on efficient producers who are able to achieve the best possible economic performances. These performances could be measured in terms of economic efficiency, i.e. technical and allocative efficiency (COELLI, 1996; COELLI et al., 2001). Therefore, the estimation of efficiency can be viewed as an important and useful step to improve cashew nut production at the farm level.

In that respect we investigated, through the present study, whether or not cashew nut producers are efficient in the management of their cashew orchards.

In Benin cashew nut production, in contrast with cotton production, is essentially based on the use of not fully tradable factors such as land, labor and small capital investments in terms of basic equipment. Consequently, efficiency analysis of cashew producers can be limited to the estimation of their technical efficiency. Hence, by investigating the technical efficiency of producers in the use of resources for the upkeep and management of their plantations, this study attempts to contribute to a better knowledge on the economics of cashew production in Benin. The study, indeed, provided a database accessible to any researcher and political decision maker involving in the agricultural development and interested by the improvement of the economic performance of cashew nut production in the country.

2 Materials and Methods

2.1 Concept of Efficiency

In a production process, any rational producer seeks to obtain the maximum possible output from a given quantity of input. So, performance and resource allocation can be analyzed based on the relationship between inputs and outputs. Besides the concept of productivity that expresses the ratio between outputs and inputs, one refers in economic analysis to the concept of efficiency to stress the possibility of maximal output from minimal inputs (ELLIS, 1993; COLLI et al., 2001). Three types of efficiency are usually used in the literature: technical efficiency, allocative efficiency and economic efficiency (COELLI et al., 2001)

Technical efficiency is defined as the maximum producible output for a given level of production inputs using alternative technologies available to the farmer (ELLIS, 1993). It refers to the ability of a firm to obtain maximal production from a given set of inputs (COELLI et al., 2001). For a given technology and a given set of inputs, one can represent a curve of production (Figure 1). If the technology is replaced by another more efficient, the more efficient curve will be located above the first one (Figure 1).

Allocative efficiency or price-efficiency (cf. FARELL, 1957), on the contrary, reflects the ability of a producer to use inputs in optimal proportions given their respective prices (ELLIS, 1993; AMARA and ROMAIN, 2000; COELLI et al., 2001; ALBOUCHI et al., 2005). Hence, it expresses in a production process, adjustments of inputs and outputs on the base of their relative prices, given a technology of production. These adjustments are according to ELLIS (1993) the familiar marginal conditions for profit maximization, which stipulates equality between the marginal productivity value and the marginal factor cost for any single variable input. Achieving efficiency, farms could face four possible alternatives (ELLIS, 1993):

- a farm might display both technical and allocative inefficiencies;
- a farm might show allocative efficiency but not technical efficiency;
- a farm might display technical efficiency but not allocative efficiency and
- a farm might have achieved both technical and allocative efficiencies.

The last situation defines the term of economic efficiency (ELLIS, 1993; COLLI et al., 2001). Therefore, the achievement of one of these efficiencies is necessary but not sufficient to ensure economic efficiency; only the simultaneous achievement of both technical and allocative efficiencies provides economic efficiency (ELLIS, 1993).

However, as mentioned above, this study is limited to the technical efficiency. It aims to analyze performances of cashew nut producers in terms of physical production, the use of available resources mainly the land, the labor and small equipment.

2.2 Frontier Approach to Measure Efficiency

Among the different methods related to efficiency measurement[1] displayed by the economic literature, there are two close alternative approaches to estimate frontier functions and thereby measure production efficiency: the deterministic frontier and the stochastic frontier (COELLI et al., 2001). Besides the error term of the production function used to estimate the technical inefficiency by the two approaches, stochastic frontier approach stresses the importance of random factors such as effects of weather and other factors on the output variable value. Accordingly, the difference between the two approaches results from the kind of gaps between the observed production and the production frontier. Deterministic approach implies the use of linear programming whereas stochastic frontier implies the use of econometric methods. Some authors such as ALBOUCHI et al. (2005) argue that the choice of the deterministic or the stochastic approach depends on the researchers, since the two approaches provide results that are not statistically different from each other (SHARMA et al., 1999). However, we can notice that the choice is not often optional but depends on data availability and the use of the results. According to COELLI et al. (1996), the stochastic frontier may provide results that are more reliable than those of the deterministic frontier.

The stochastic approach is widely used in the economic analysis, especially in agricultural economic because of the importance of random factors in this field (AUDIBERT, 1997; BRAVO-URETA and PINHEIRO, 1997; XIAOXONG and JEFFREY, 1997; ISSIAKA, 2002; ADÉGBOLA et al., 2005; MIDINGOYI, 2008; YABI, 2009). Following these authors, the stochastic frontier is considered as more pertinent for the present study. The theoretical model used is based on COELLI et al. (2001) and is presented as follow:

$$\ln(Y_i) = X_i\beta + v_i - u_i \qquad i = 1,2,\ldots N \tag{1}$$

Where $\ln(Y_i)$ is the Neperian logarithm of the output of the i-th farm;

X_i is the (K+1)-row vector, whose first element is “1” and the remaining elements are the logarithms of the K-input quantities used by the i-th farm;

$\beta = (\beta_0, \beta_{1,\ldots}\ \beta_k)$ is a (K+1)-column vector of unknown parameters to be estimated; and

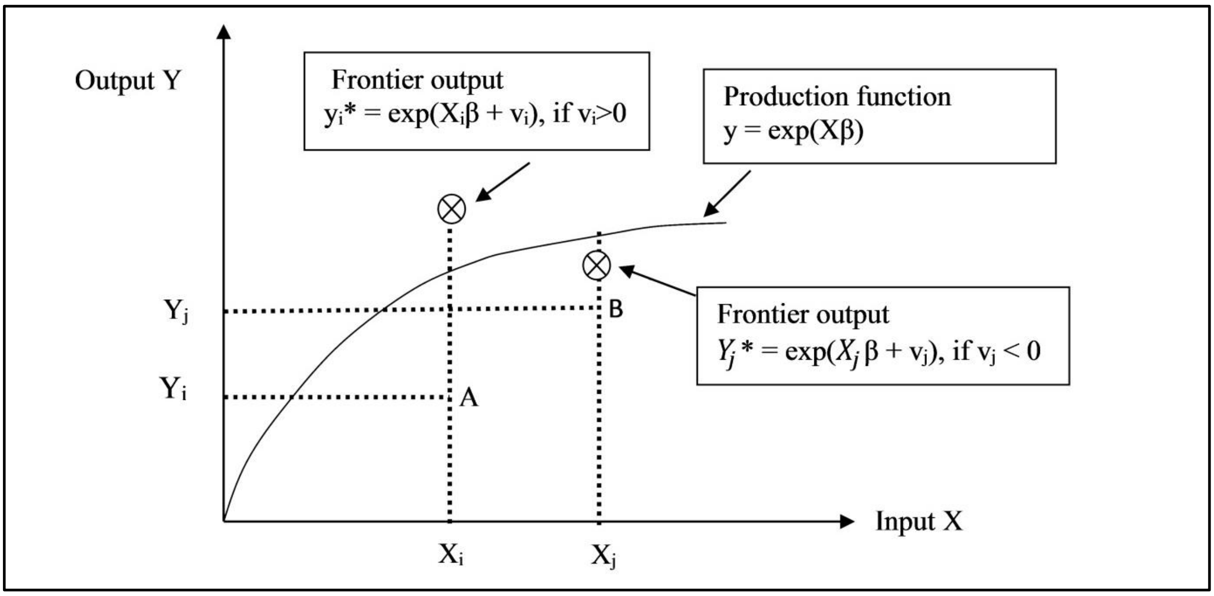
[1] See GSTACH (1996), GRANDERSON and LINVILL (1999), COOPER and LOVELL (2000), MURILLO-ZAMORANO and VEGA-CERVERA (2000), SINGH et al. (2000), THRALL (2000), COELLI et al. (2001), WHO (2001), FORSUND and HjaLmarsson (2002), SENA (2003).

$v_{i,}$ is the random error or random factors, non-controllable by the producers, such as effects of weather, unexpected events etc. on the value of the output variable. This term is identically and independently distributed with mean equals to zero and a constant variance $N(0, \sigma_v^2)$;

u_i, is a non-negative random variable, associated with technical inefficiency in production of the producers. This term is assumed to be identically and independently exponential or half-normal distributed $N(0, \sigma_u^2)$.

According to COELLI et al. (2001), that model is called the stochastic frontier production function because the output values are bounded by the stochastic (random) variable $\exp(X_i\beta + v_i)$. As the random error v_i can be positive or negative, the stochastic frontier outputs vary with the deterministic part of the frontier model $\exp(X_i\beta)$. The basic features of the stochastic frontier are illustrated in the following figure:

Figure 1. The Stochastic Frontier Production Function of a single firm



Source: COELLI et al. (2001)

Let us consider two farmers i and j, whose observed outputs and inputs are presented on the Figure 1. The i-th farmer using the level X_i of inputs, produces the output Y_i. The observed input-output value is indicated by the position A. The value of the stochastic frontier output $Yi^* \equiv \exp(Xi\beta + v_i)$, is indicated by the point with the circled cross, above the production function because the random error, v_i, is positive. In the same way, the j-th farmer using the level of inputs X_j, produces the output Y_j. But, because the random error here is negative, the frontier output, $Y_j^* \equiv \exp(X_j\beta + v_j)$, is below the production function. We must, however, notice that the stochastic frontier outputs Y_i* and Y_j*are not observed because the random errors v_i and v_j are not observable. The deterministic part of the stochastic frontier \ lays between the stochastic frontier outputs. The observed outputs will be allowed to be greater than the deterministic part of the frontier if the corresponding random errors are greater than the corresponding inefficiency effects, i.e., $Y_i > \exp(X_i\beta)$ if $v_i > u_i$ (COELLI et al., 2001).

To estimate the technical efficiency (TE) of the i-th farmer, given the input vector, X_i, the ratio of the observed output for the i-th farmer, related to the potential output, defined by the frontier function was used by Aigner and Chu (1968). Therefore, using equation (1) without the random error (v), these authors defined the technical efficiency, as followed:

$$TE_i = \frac{Y_i}{\exp(X_i\beta)} = \frac{\exp(X_i\beta - u_i)}{\exp(X_i\beta)} = \exp(-u_i) \qquad (2)$$

where exp (.) represents the exponential function.

In empirical studies two specifications are generally used: the specification of Cobb-Douglas and the Translog functional form

The Cobb-Douglas specification is, however, the most commonly used functional form (COELLI et al., 2001; STADELMAN, 2005) of $g(X_i\ \beta)$, especially in the estimation of agricultural farms efficiencies (cf. AUDIBERT, 1997; BRAVO-URETA and PINHEIRO, 1997; TEWODROS, 2001; YABI, 2009). Dealing with Cobb-Douglas specification, the production factors are directly supposed to be substitutable and the elasticities of each production factor are assumed to be constant for all the producers. We used a Cobb-Douglas functional form in this study.

Specifying our production function we take into account particularities related to cashew nut production in Benin. Indeed, cashew nut production occurs in a very extensive system in which land and labor are the main production factors. Moreover, because of the relatively long life of the cashew orchards that can produce during more than 20 years, we consider the land used as variable factor in our model. That methodological approach similar to those of AUDIBERT (1977), BRAVO-URETA and PINHEIRO (1997), TEWODROS (2001), leads to the following production function:

$$\mathbf{ln}(Q_i) = \beta_0 + \beta_1 \mathbf{ln}(SUP_i) + \beta_2 \mathbf{ln}(CAP_i) + \beta_3 \mathbf{ln}(PEST_i) + \beta_4 \mathbf{ln}(MOF_i) + (v_i - u_i) \qquad (3)$$

Where β_0 is the constant and β_i parameters to be estimated, representing in this case the elasticities; i represents the producer i.

Q_i, the total production of cashew nut (kg); SUP_i, the total cultivated area (ha); CAP_i, investment capital including the depreciation of equipment (FCFA/year); $PEST_i$, quantity of pesticides used (L); MOFi, quantity of family labor used (Man-day)., v_i, is the random error for measurement error and other random factors such as effects of weather; u_i, is the random variable associated with technical inefficiency of the producer i. It is important to notify that hired labor for the upkeep of the plantations is insignificant in the sample.

To be sure that the model is free from multicolinearity of the variables used, we referred to the estimation of the parameters VIF (Variance Inflating Factors) and TOL (Tolerance). As pointed out by GUJARATI (2003), the multicolinearity of a given variable X_j to other become a problem when its indicator (VIF) exceeds 10, i.e. the tolerance (TOL_j/VIF_j) is lower than 0.1. In addition we used White Heteroskedasticity and Jarque and Bera normality test to testify the consistence of the model. Furthermore we used Wald test to prove possibilities of return-to scale (e.g. constant, decreasing, or increasing) that can result from our production function.

As the level of technical efficiency of a farm is defined by the relation between the observed production and maximum production (GREENE, 1993), the measure of the technical efficiency is based on the estimation of the gap between the observed production and the possible optimum on the production frontier. This gap is measured using the indexes of technical efficiency that varies from 0 to 1. The score 1 characterizes the farmers that are perfectly and technically efficient.

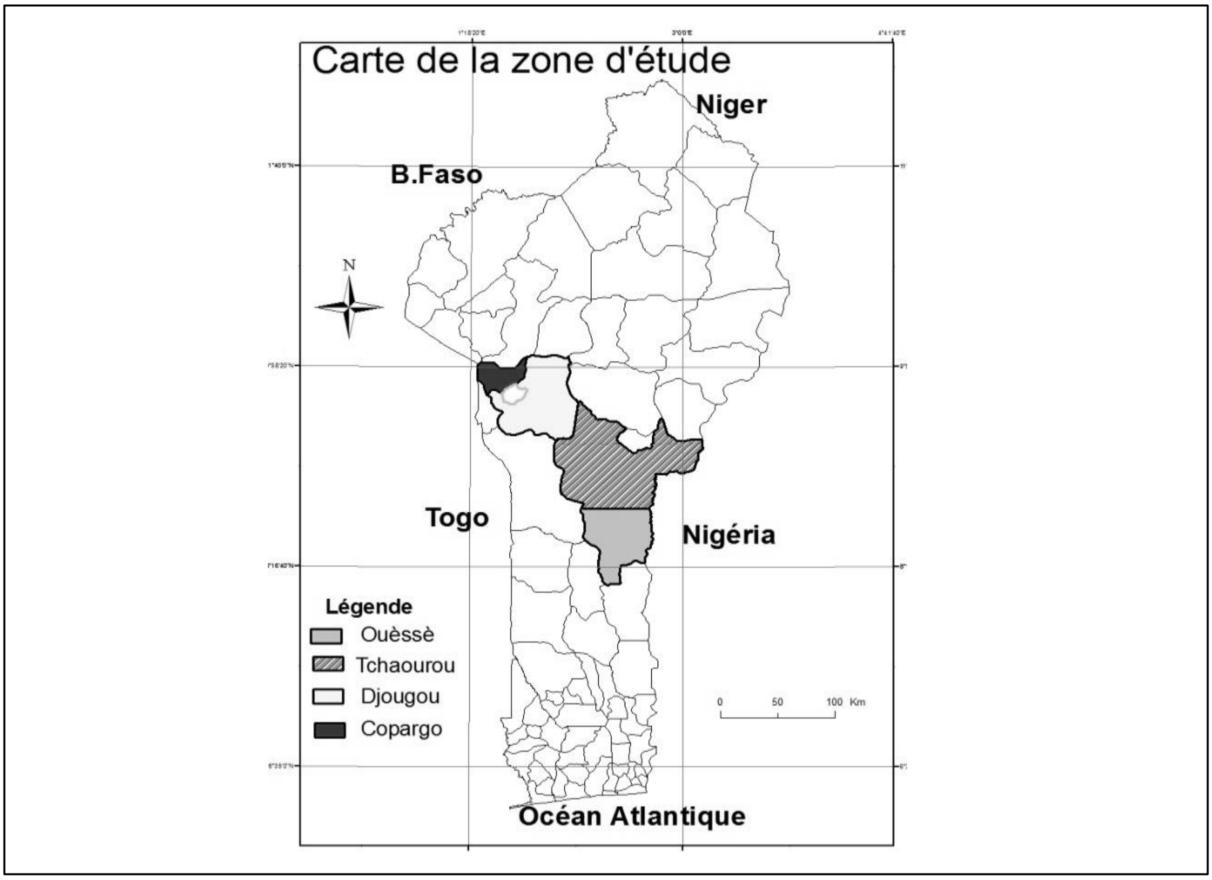
The parameters of the stochastic frontier production defined above are estimated using the maximum-likelihood (ML) method. Due to that fact and the estimation of the indexes of the technical efficiency of each producer we used Frontier 4.1.

2.3 Study Area and Data Collection

The study was conducted in the central and northern parts of Benin, located between the parallels 7°10'N and 10°25'N, and favorable to the cashew nut production because of the agro-climatic conditions. This zone is characterized by an annual rainfall varying from 800 to 1,300 mm and is a woody savannah with scattered trees. Four districts: Ouesse (Central part), Tchaourou, Djougou and Copargo (Northern part) have been selected because of the importance of their cashew nut production (cf. Figure 2).

From these districts, nine villages were chosen based on the importance of cashew nut production and their accessibility, in terms of distance to the main market and the, road network. In each district, 45 cashew nut producers were randomly selected, however, the number of cashew nut producers chosen in each village was not fixed and varied according to the availability of cashew orchards. So, the sample was composed of 180 cashew producers.

Figure 2. Study area in the administrative map of Benin



Source: realized by Degla with data from CARDER Borgou/Alibori

To achieve the study's objectives, both primary and secondary data were used. These primary data were collected through individual structured survey (on the sampled producers) and focus group discussions. Additionally, some participative observations were used to cross-check the collected information and to correct evident errors which might occur during the interviews. The secondary data were collected from different documentation sources.

3 Results

The average inputs allocated by the selected producers are 3.65 ha of land, 73.51 man-days of family labor, 5, 918 FCFA of capital and 3.28 L of pesticide (cf. Table 1). Using these inputs they got an average output of 1,584 kg of cashew nuts with a yield of 431 kg/ha.

The test of multicolinearity showed that the VIF indicator of each explanatory (i.e. independent) variable is lower than 10 and their statistic tolerance (TOL) higher than 0.1. These results, as suggested by GUJARATI (2003), showed that multicolinearity errors are not significant. In addition, White Heteroskedasticity test revealed a non-significant error (p= 0.97> 0.05). As well, Jarque and Bera normality test showed a probability (p= 0.36) higher than 5%, validating therefore our model.

Table 1. Descriptive statistics of the variables introduced in the model

Variables	Mean	Standard deviation	Minimum	Maximum	Indicators of multicolinearity	
					VIF	TOL
Total physical production (Q) in kg	1,584	1,247	50.0	10,000	-	-
Family labor (MOF) in man-day	73.51	60.86	6.64	307.00	5.13	0.20
Land (SUP) in ha	3.65	3.13	0.25	15.00	6.44	0.16
Capital (CAP) in FCFA/year	5,918	4,173	500	28,867	1.09	0.92
Pesticide (PEST) in L	3.28	2.71	0.50	13.00	2.12	0.47

Source: survey data (2013)

The Chi-square value of 16.11 is significant at 0.1% level. Therefore, our model was, globally significant and we could deduce a statistically significant relation between the dependent variable and the explicative variables of the model. The constant and the coefficient of the variable "land" were statistically significant at 1% level; coefficients of both the variables capital and labor were significant at 10%, whereas the coefficient of the variable "Pesticide" was not significant (cf. Table 2).

Partial elasticities of the total production related to the quantities of land, capital, pesticide and labor used were respectively 0.77; 0.11; 0.05 and 0.19. According to the parameter gamma (γ) which is significant at 0.1%, the difference between the observed total production and the production frontier was due, at 79.63%, to the technical inefficiency of the producers in the management of their cashew orchards. The effects of random factors such as effects of weather contributed, therefore, for 20.37%.

The results from the estimation of the efficiency indexes showed that scores of the technical efficiency varied from 0.10 to 0.88 with an average of 0.63 (Table 2).

Table 2. Estimation results of the production frontier by the Maximum-Likelihood method

Variables	Coefficients	Standard-Error	T-Student	Significance (Probability)
Constant (β_0)	4.92	0.62	7.96	1.687e-15 ****
Cultivated area (lnSUP)	0.77	0.12	6.45	1.100e-10 ****
Capital (lnCAP)	0.11	0.06	1.84	0.07 *
Pesticide (lnPEST)	0.05	0.08	0.70	0.49
Family Labor (lnMOF)	0.19	0.11	1.74	0.08 *
σ^2(sigma sq)	0.57	0.12	4.88	1.06e-06 ****
γ (gamma)	0.80	0.11	7.32	2.47e-13 ****
log likelihood value	-139.37			-
Chi-Square	16.11			0.01 ***
Efficiency score summary	Minimum: 0.10 Moyenne: 0.63 Maximum: 0.88			

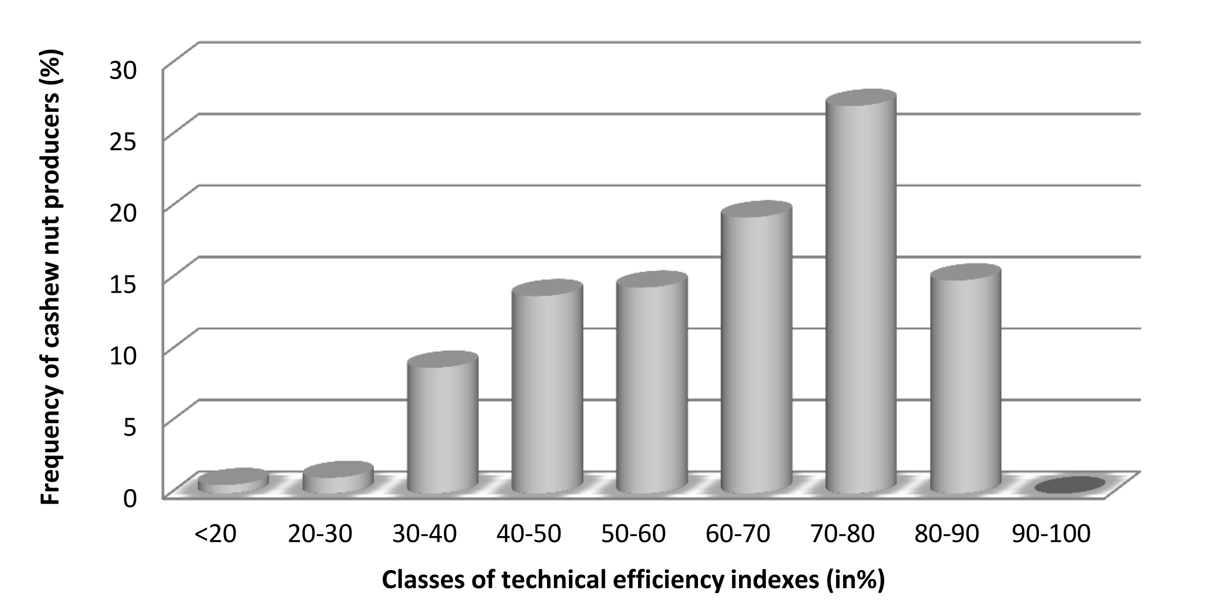
*; **; ***; **** = significant respectively at 10%, 5%, 1%, 0.1%

Source: survey data (2013)

The distribution of the efficiency scores showed that the modal class was 70-80 and included 27% of the selected producers (cf. Figure 3). No producer was on the production frontier. Accordingly, there is no perfectly efficient producer in the sample.

From these results, if we considered efficiency scores above the modal class as closer to 1 and therefore as the bests, producers with those scores could be considered as efficient in our study. Nevertheless, these producers represented only 14.9% of the sample. Thus, most of the producers are not efficient in the management of their cashew plantations. The performance of the efficient producers can be attributed to the capital they invested through regular pruning, weeding and phytosanitary treatment of their cashew orchards. Therefore, technical efficiency can be improved by the other producers in the study area. They would need financial support (credit access) and technical assistance from the agricultural training service. Credit access would help them to take more care of their plantations in order to increase their productivity. One of the principal constraints faced by more than 60% of the selected producers in the management of their cashew orchards was the lack of financial means, especially during the period of the upkeep.

Figure 3. Frequency distribution of scores of technical efficiency



Source: survey data (2013)

4 Discussion

The analysis of the frontier Cobb-Douglas production function shows that cashew nut production depends strongly on land (estimated coefficient was 0.77). That confirms the extensive feature of the cashew nut production in Benin. From this result, similar to the one of AUDIBERT (1997), we can deduce that an extension of the cultivated areas, of 1% would, ceteris paribus, increase the production of 0.77%. However, cashew nut being a perennial crop, any result from a given extension of the cultivated areas would become evident only on the mid or long term. In a short term perspective, it is through timely pruning and weeding that one could expect any improvement of the productivity of these traditional plantations. Lopping could be considered as equivalent to an increase of the area allocated per tree because most cashew orchards are very dense (in average 150-200 trees/ha instead of 100 trees/ha recommended by the agricultural extension services).

With a coefficient of the labor of 0.19, the effect of this factor on the quantity of cashew nut production is relatively more powerful than the effect of the capital (coefficient was 0.11). The effect of the labor is in accordance with the results of AUDIBERT (1997) and TEWODROS (2001) but it contrasts, with those of ADEGBOLA et al. (2005) who reported a negative coefficient attributed to the effect of robberies of the collected cashew. Partial elasticities of the production of cashew nut showed that an increase, ceteris paribus, of 1% of the labor or the capital would lead to an increase of the cashew nut quantity, respectively of 0.19% and 0.11%. These results predict the possible significant effect of intensification of cashew nut production through these factors.

Taking into account estimators related to capital, land and labor in our production function, we got a homogeneity degree of 1.53, implying increasing returns to scale. That result was confirmed by the Wald test (*P*= 0.002). Thus, on average, a simultaneous and identical increase in all resources (land, labor, and investment capital) is likely to imply a more than proportional increase in the quantity of produced cashew nut.

The analysis of the partial elasticities showed that the available productive resources, especially labor and capital, are not overused. There are possibilities to use them more in a perspective of intensification of the cashew nut production. That result confirms those of ELEGBE (2005) and DANHOUNSI (2008). Indeed, these authors respectively pointed out the necessity of an optimal use of factors such as capital and labor to increase the agricultural production in farming systems where fertilizers and pesticides are not usually used. According, however, to TOUZARD and BELARDI (2009), intensification does not always lead to an increase of the productivity in traditional agriculture. It needs adequate agricultural policies including strong innovations to impulse an increase of productivity. As well, the use of a Cobb-Douglas production function supposed that partial elasticies are constant. Using a trans-log production function may yield different results as the partial elasticities are supposed variable (COELLI et al., 2001). Although our findings allow easily interpreting the return to scale of the production, the estimated coefficients are likely more biased than those of trans-log specification. Indeed, Coob-Douglas functional form does not explore the effects of inputs inter-actions in the production process. In the case, DEBERTIN (2012) found that the robustness of the results seems to be higher than a trans-log functional form, but quite enough if the targeted objective of the study is not to estimate the inter-action effects of production inputs.

The significant effects of inefficiency in the management of the orchards shows, concordantly with ADÉGBOLA et al. (2005), that production of cashew nut in the study area is not optimal. Our average efficiency score of 0.63 is, however, higher than that observed by these authors, who acknowledged that the inefficiency decreases with time. Through the present technology level, cashew nut producers realize, in average, little more than 60% of the potential level of production, having still about 37% of margin of productivity. Compared with rice producers (YABI, 2009) or cotton producers (MIDINGOYI, 2008), with respectively 0.82 and 0.71 efficiency indexes in the study area, cashew nut selected producers are less efficient. Among the technically efficient producers 27% lay in the modal class (70-80) of the efficiency scores distribution. Similar results were obtained by BRAVO-URETA and PINHEIRO (1997), ADEGBOLA et al. (2005) and MIDINGOYI (2008) in their respective studies.

5 Conclusion

This study shows that cashew nut production system in Central and Northern Benin is very extensive, strongly depending on the factor land. The intensification through labor and capital factors could have in a short term a positive impact on the increase of the cashew nut production in Benin.

Actually, the effects of inefficiency are significant in the deviation of the total production obtained from the optimal level of production. Using 63% of their productive ability, efficient producers could increase their production by 37%, without increasing the volume of their inputs. Such improvements tend to be conditional on accompanying agricultural policies, including easier access of producers to credits, innovations in the management of the cashew orchards, better market conditions for the cashew nuts, and skilled use of inputs such as fertilizers.

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