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Technical Efficiency of Village Sugarcane Growers in Ivory Coast

Efficacité Technique des Producteurs de Canne à sucre Villageoise en Côte d'Ivoire

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Abstract

This study evaluates the technical performance of village sugarcane farms in northern Ivory Coast. To this end, 246 village farms were randomly identified and analysed using a Cobb Douglas Stochastic Frontier model. The regression results show that the gap between the observed and potential production of sugarcane farm units is partly due to technical inefficiency. In the light of these same results, fertiliser, herbicide and labour have a significant and positive influence on technical efficiency at the 10% threshold. The farmed area also has a positive and significant effect on the technical efficiency of sugarcane growers at the 1% threshold. On the other hand, rudimentary capital (tools) has a significant and negative effect at the 5% threshold. Site 1(Ferkessedougou 1) had the lowest level of technical efficiency (35%). However, the average technical efficiency score of farmers in the study area is around 71%. The factors that influence the technical efficiency of sugarcane growers are otherwise, age, agricultural training, access to credit and years of experience.

Keywords : Efficiency; sugar cane; Ivory Coast.

Résumé

Cette étude évalue la performance technique des exploitations villageoises de canne à sucre au Nord de la Côte d'Ivoire. Pour y parvenir, 246 exploitations villageoises ont été identifiées par façon aléatoire. Le modèle de Frontière Stochastique de type Cobb Douglas a été pour l'analyse. Des résultats, l'on peut retenir que l'écart entre la production observée et celle potentielle des unités des exploitations de canne à sucre est en partie due à l'inefficacité technique. A la lumière de ces mêmes résultats, l'engrais, l'herbicide et la main d'œuvre influencent significativement et positivement l'efficacité technique au seuil de 10%. La superficie exploitée impacte également positivement sur l'efficacité technique des producteurs de canne. Par contre, le capital rudimentaire (outillage) a un effet significatif et négatif au seuil de 5%. Aussi l'on note que le site 1 (Ferkessedougou 1) réalise le plus faible niveau d'efficacité technique (35%). Toutefois, le score moyen de l'efficacité technique des exploitants de la zone d'étude est d'environ 71%. Par ailleurs, les facteurs qui influencent l'efficacité technique des producteurs de canne à sucre sont l'âge, la formation agricole, l'accès au crédit et le nombre d'année d'expérience.

Mots clés : Efficacité ; canne à sucre ; Côte d'Ivoire.

Introduction

As a sub-sector of agriculture, the sugar cane industry contributes to the economic and social development of several countries around the world, and plays an important role in improving people's living conditions. Sugar cane (*Saccharum officinarum L. Poaceae*) is grown in over 100 countries on around 20 million hectares worldwide. It is grown by several million small farmers and by large agro-industrial companies (Gilbert et al., 2013). World production of sugar cane is 1,889,268,880 tonnes. Although sugar production has increased in Brazil and other smaller producing countries such as the Russian Federation, South Africa and Australia, this trend has not been enough to offset the decline in Europe and some key Asian countries. Stocks have been falling and remaining low for several decades (OECD/FAO, 2016). Brazil, the world's largest sugar producer and supplier, with 768,678,382 tonnes of sugar cane produced per year, continues to play a key role on world markets, but the use of sugar cane, to produce ethanol or sugar, continues to respond to competition between relative prices on the world sugar market and the largely domestic ethanol market. World sugar production is expected to increase by 2.1% per year to reach 210 Mt in 2025, an increase of almost 39 Mt, which means 19% more than during the reference period (OECD/FAO, 2016). Growth is expected to be faster in developing countries, which will account for 79% of world sugar production in 2025, compared with 77% during the reference period (OECD/FAO, 2016). This expansion is expected to result mainly from the acceleration of production in sub-Saharan African countries (OECD/FAO, 2016).

In fact, in sub-Saharan Africa, the current policy expects increasing sugar production by 4% per year between now and 2025, thanks to the continued development of production capacity on farms and in processing companies (FAO et al., 2022). This increase is due to strong domestic demand for sugar, but also to the commercial opportunities offered by the Economic Partnership Agreement (EPA) and the European Union's "Everything but Arms" (EBA) initiative (FAO et al., 2022). However, the lifting of the sugar quota in the European Union, which will bring EU prices closer to world prices, is likely to have a negative impact on exports from the African, Caribbean and Pacific (ACP) countries, which have high production costs and have benefited from the higher EU price (FAO et al., 2022).

In Ivory Coast, sugar cane accounts for around 1% of national GDP and 3.3% of agricultural GDP. Sugar cane production provides over 10,000 jobs, with production dominated by two companies: Sucrivoire, which operates in Borotou-Koro and Zuenoula area, covering 14,000 ha in the north-west and centre of the country respectively, and SUCAF (Sucrerie Africaine), in the Ferkessédougou department in the north of Ivory Coast, covering 14,600 ha, including 5,000 ha under village cultivation (Edouard et al., 2021),. Their productions are respectively equal to approximately 91,000 and 105,000 t of sugar per year (MINADER, 2017).

Total average annual sugar production is around 180,000 tonnes/year for an estimated need of at least 200,000 tonnes. The average yield is around 78 tonnes in industrial cultivation compared with 40 tonnes of cane per hectare in village cultivation (MINADER, 2017).

whereas, under natural conditions comparable to those in Ivory Coast, some African countries such as Malawi record sugarcane yields well in excess of 160 tonnes per hectare under industrial cultivation and 70 tonnes per hectare under rainfed cultivation. This justifies the low level of production and falling productivity of village sugarcane farms in Ivory Coast. Moreover, despite major studies on this agricultural sub-sector, no empirical study has assessed the technical performance levels of village farms in Ivory Coast in order to determine the factors likely to improve productivity. So what are the determining factors of the performance of sugarcane production in Ivory Coast? What factors are likely to contribute to improving productivity? The main objective of this study is to contribute to knowledge of factors likely to improve sugarcane production in Ivory Coast. In other words, the aim is to:

- determine the village sugarcane production function;
- estimate the technical efficiency indices of village sugarcane growers;
- assess the determinants of the technical efficiency of village sugarcane growers.

This paper is structured around four (4) points. The first analyses the literature review. The second highlights the methodology used. The third presents the results, and the final point is devoted to discussion.

1. Review of literature

Several studies have assessed the technical performance of farms.

Kouakou (2014) assessed the performance of cotton growing in Ivory Coast using a stochastic production frontier and a cost frontier. His analysis shows that the observed inefficiency can be explained by the low level of supervision and fluctuations in field-edge prices.

Kouakou (2017) used the stochastic approach proposed by Aigner and *al.* (1977) to determine the technical efficiency of urban vegetable production in Ivory Coast. According to his study, the application of insecticides and pesticides is positive but not significant. In addition, the total area in hectares gets a negative and significant impact on the technical performance of urban farmers.

Gniza (2022) analysed the efficiency of rice growers in allocating the resources available to them for production by collecting cross-sectional data from 255 growers in west-central Ivory Coast using a Cobb-Douglas type function. According to Gniza (2022), the results indicate that seed has a positive effect on production but is underused, while labour has a positive effect on production but is overused by growers.

Ndiaye (2018) determined the technical efficiency of family farms in Mauritius using the Data Envelopment Analysis (DEA) and showed that 46.5% of the sample are technically efficient under variable returns to scale.

Ndiaye and Diallo (2022) measured the technical efficiency of family millet farms in the groundnut basin of Senegal and showed that average technical efficiency was estimated at 69% for the SFA and 60% for the DEA.

Moustafa and *al* (2022) estimated the level of technical efficiency of maize producers participating and not participating in warrantage in a region of Benin. According to Moustafa and *al* (2022), the results showed that not all farmers operate on the production frontier and the average level of technical efficiency was 74%, with 78% for beneficiaries and 70% for non-beneficiaries.

Chogou and *al* (2017) analysed the technical efficiency of pineapple producers using the stochastic production frontier method applied to a representative sample of 135 farmers who are members of the Benin Pineapple Producers Network (RéPAB). The results obtained by Chogou and *al* (2017) show that, on the whole, pineapple growers are not technically efficient. According to Chogou and *al* (2017), the average level of efficiency is 67%, showing that there is scope for improving production using the same amount of resources as are currently available.

Abikou (2023) studied the economic efficiency of low land rice production systems using a stochastic approach to production and cost frontiers and showed that efficiencies differ from one production cycle to another and from one production system to another.

Mamam and *al*. (2016) estimated the technical efficiency of a sample of 411 maize farms in the main production zones in Benin using the Cobb-Douglas stochastic production frontier model. The results by Mamam and *al*. (2016) indicate that variables such as access to fertilisers and herbicides, use of animal traction and tractors, technical supervision and access to credit have a significant influence on the technical efficiency of the surveyed maize farms.

Waigalo (2023) assessed the production performance of producers of improved mango varieties in the production basin of the Sikasso region. The results of the stochastic production function show that the coefficients of the variables farmed area, expenditure on equipment and orchard maintenance are respectively significant at the 1%, 10% and 10% thresholds and have a positive effect on the mango production of producers.

Sawadogo and *al* (2022) determined the effect of intercropping on the technical efficiency of farming households in Burkina Faso using the directional distance function approach. They found that intensification of intercropping improved technical efficiency, as did education and animal traction.

In Benin, Chogou and *al* (2018) used the stochastic production frontier method on a random sample of 93 soybean farmers. The results that the use of good quality soya seed, the application of chemical insecticides to reduce pest pressure and gender were the factors that positively influenced growers' technical efficiency (Chogou and *al*, 2018).

2. Methodology

2.1. Data collection

The department of Ferkessedougou was chosen for this study because of the importance of this activity. According to Kouakou (2024), the production of the Ferkessedougou department sugar mill contributes more than 50% of the local market share (52.9% in 2015/2016 and 54.2% in 2017/2018). The different production areas are: Ferkessedougou 1 and Ferkessedougou 2. The choice of sites was designed to ensure that contrasts within the study area were taken into account, taking into account the gradient in the spread of sugarcane cultivation, as well as the socio-economic and demographic aspects of the area. The surveyed households were selected on the basis of the criterion of 'being a sugarcane grower'. The survey collected information on technical, socio-economic and socio-demographic characteristics from administered questionnaires to randomly sampled village sugarcane growers. The information was collected between December 2023 and June 2024. A sample of two hundred and forty-six (246) stakeholders in the sugarcane industry was drawn up using the following Giezendanner (2012) formula:

$$\text{n} = \frac{s^2 \times p \times (1-p)}{m^2}$$

Where, according to Giezendanner (2012),

- n = Minimum sample size for obtaining significant results for a given event and risk level.
- s = Confidence level (the standard value of the 95% confidence level, i.e. t = 1.96).
- p = Estimated proportion of the population with the characteristic estimated at 20%.
- m = Margin of error (set at 5%).

The number of surveyed village cane growers per locality is shown in Table 1.

Table 1 : Respondents by village sugarcane production site

Production areas	Total workforce	Number of people to be surveyed	Proportion %
Ferkessedougou 1	335	87	35.37
Ferkessedougou 2	609	159	64.63
TOTAL	944	246	100.0

Source: Author, based on survey data, 2023

2.2. Selection of Variables

To estimate efficiency levels, quantitative variables such as sugarcane production (in kilograms), farm area (in hectares), quantities of herbicides (in litres) and fertilisers (in kilograms), labour (in man/day), seeds (in quantities of cuttings) and rudimentary capital (amount of depreciation in FCFA) were chosen.

To measure the determinants of the technical inefficiencies of sugarcane farms, variables such as the age of the farm manager, marital status, level of education, number of years of experience, agricultural training, nature of the activity and access to credit were taken into account.

2.3. Model specification

The stochastic approach proposed by Aigner and *al* (1977) was used for this study. This approach assumes that the error is a composite of a residual term that takes into account the risks associated with random effects and a component that represents the inefficiency of sugarcane farms (Aigner and *al*, 1977).

In addition, the stochastic frontier approach was chosen to take account of the fact that it allows a distinction to be made between inefficiency linked to producers and inefficiency due to random effects that cannot be controlled by farmers (Aigner and *al*, 1977). The Cobb-Douglas functional form was also used to estimate the sugarcane production frontier in order to avoid iteration and correlation problems between independent variables (Aigner and *al*, 1977).

According to Aigner and *al*. (1977), the overall form of the Cobb Douglas production model is as follows:

$$Y = X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} X_6^{\beta 6} e^{\varepsilon i} \quad (1)$$

In the specific case of this study, the linear form of the model is:

$$Ln(Y_i) = \beta_0 + \beta_1 Ln(X_1) + \beta_2 Ln(X_2) + \beta_3 Ln(X_3) + \beta_4 Ln(X_4) + \beta_5 Ln(X_5) + \beta_6 Ln(X_6) + \varepsilon_i - t_i \quad (2)$$

Where:

i: The sugar cane producer i,

Y_i : harvested total production (Kg),

X_1: The used quantity of fertiliser (in kg/ha),

X_2: The used quantity of seed (in cuttings),

X_3: The used quantity of herbicide (in litres),

X_4: The used amount of labour in man/day per hectare,

X_5: Agricultural area (in hectares),

X_6: Rudimentary capital (total annuity value of used equipment in sugar cane production in CFA francs).

With, according to Aigner and *al*. (1977), Y_i the output of sugarcane farm i, β_0 the constant expressing the value of productivity that is not influenced by production factors, $\beta_i$the elasticity of output with respect to each factor, ε_i the purely random variable out of control, t_i measures the technical inefficiency of farm i and i represents a sugarcane farmer. X_i represents the dependent variables shown in Table 2 with the expected signs.

The frontier parameters and density functions are estimated using the maximum likelihood method. The technical efficiency indices are calculated using the following formula defined by Coelli et al (1998): $ETi = Exp\ (-t_i);$, where ETi is the technical efficiency.

Table 2: Variables used to estimate the production function and expected signs

Variables	Variable significance	Expected signs (- / +)
Y	Sugarcane production	+
X_1	Quantity of fertilizer used (kg/ha)	+
X_2	Quantity of used seed (in cuttings)	+
X_3	Quantity of used herbicide (in liters)	+
X_4	Quantity of manpower used in man/day per hectare	+
X_5	Agricultural area (in hectares)	+
X_6	Rudimentary capital (in CFA francs)	+

Source: Author, based on survey data, 2023

In the Ivorian environment, the factors likely to impact on the level of technical performance of farms are as follows: age of the farm manager (continuous variable); experience in sugarcane production (continuous variable); level of education (binary variable : 0=no and 1=yes); access to credit (binary variable: 0=no and 1=yes); agricultural training (binary variable: 0=no and 1=yes); main activity (binary variable: 0=no and and 1=yes) and marital status (0=no and 1=yes). According to Coelli et al. (1998), to determine the sources of sugarcane farm inefficiency, the Tobit regression model was used, given the truncated nature of the efficiency indices, which are between 0 and 1.

The effects of technical efficiency are expressed by the following equation (Coelli et al (1998):

$$TE = b_0 + b_1Z_1 + b_2Z_2 + b_3Z_3 + b_4Z_4 + b_5Z_5 + b_6Z_6 + b_7Z_7 + \omega_i$$

With:

TE= Technical Efficiency,

b_0= Constant,

Z_1= Age of the farm manager,

Z_2= Marital status,

Z_3= Level of education,

Z_4= Agricultural training,

Z_5= Access to credit,

Z_6= Experience in sugarcane production,

Z_7= Main activity,

ω_i= Usual error term.

Estimates were made using STATA 15 software. The variables likely to influence sugarcane farm efficiencies are listed in Table 3.

Table 3: Variables determining efficiencies and expected signs

Variables	Variables definition	Terms and conditions	Expected signs (+/-)
z_1	Age of farm manager	Continuous variables	+
z_2	Marital status	Binary variable (0=not married, 1=yes, married)	+
z_3	Education level	Binary variable (0=no, 1=yes)	+
z_4	Agricultural training	Binary variable (0=no, 1=yes)	+
z_5	Access to credit	Binary variable (0=no, 1=yes)	+
z_6	Experience in sugarcane production	Continuous variables	+
z_7	Main activity	Binary variable (0=no, 1=yes)	+

Source: Author, based on survey data, 2023

3. Results

3.1. Production frontier and determinants of the technical efficiency of sugarcane farms

The model is globally significant and the value of gamma (γ) is 0.80 according to Table 4. The value of lambda (λ), which is 2 and greater than one, expresses a better fit for the estimated model and the accuracy of the distribution hypothesis determined by the error terms (Table 4).

According to these same results ((Table 4), fertiliser application appears to be significantly positive at the 10% threshold. Herbicide use has a positive and significant influence on the efficiency of sugarcane farms at the 10% threshold. Labour has a positive and significant effect on the technical efficiency of sugarcane growers. The farmed area has a positive and significant influence on the technical efficiency of producers at the 1% threshold. The use of rudimentary capital significantly and negatively affects technical efficiency at the 5% threshold. On the other hand, the results in Table 4 show that socio-economic variables such as marital status, level of education and the nature of the main activity do not have a significant impact on the technical efficiency of village sugarcane growers. However, certain factors such as age, agricultural training, access to credit and the number of years of experience are determinants of the productive efficiency of village sugarcane farms.

Table 4: Cobb-Douglas production function and factors determining sugarcane growers' technical efficiency

Variables	Coefficient	Standard deviation	P > Z
Stochastic frontier			
Constant	11.616^{***}	2.955	0.000
Fertilizer $Ln(X_1)$	0.070^{*}	0.409	0.087
Seed $Ln(X_2)$	0.334	0.213	0.116
Herbicide $Ln(X_3)$	0.255^{*}	0.138	0.063
Labour $Ln(X_4)$	0.056^{**}	0.599	0.009
Area $Ln(X_5)$	1.552^{**}	0.493	0.002
Rudimentary Capital $Ln(X_6)$	-1.403^{**}	0.547	0.010
Determinants of inefficiency			
Constant	0.861^{***}	0.066	0.000
Age (Z_1)	0.001^{*}	0.000	0.019
Marital status (Z_2)	0.017	0.122	0.170
Level of Education (Z_3)	0.007	0.134	0.631
Agricultural Training (Z_4)	0.063^{***}	0.256	0.010
Acces to Credit (Z_5)	0.030^{**}	0.012	0.010
Years of Experience (Z_6)	0.003^{*}	0.001	0.015
Main Activity (Z_7)	0.038	0.027	0.161
Variance parameters			
Sigma-square (δ^2)	0.212		
Gamma (γ)	0.80		
Lambda (λ)	1.99		
Log Likelihood	-33.01		
Number of observations	246		

Source: Author, based on survey data, 2023

Note: * significant at 10%, ** significant at 5% and *** significant at 1%.

3.2. Technical efficiency indices of sugarcane farms

The results (Tables 5 and 6) show that Ferkessedougou 1 has the lowest level of technical efficiency (35%). However, on both sites, some farmers recorded maximum values of technical performance (90%). On the other hand, the average technical efficiency score for farmers in the study area is around 71%.

Table 5: Technical efficiency index

Efficiency index	Ferkessedougou **1**	Ferkessedougou **2**
Average	0.709653	0.706763
Standard difference	0.136366	0.148934
Minimum	0.352139	0.41118
Maximum	0.907969	0.894446

Source: Author, based on survey data, 2023

Table 6: Breakdown of sugar cane growers by technical efficiency range

	Technical efficiency	
Technical efficiency index	**Number of producers**	**Frequency (%)**
]0.30; 0.40]	6	2.53
]0.40; 0.50]	19	7.59
]0.50; 0.60]	28	11.39
]0.60; 0.70]	47	18.99
]0.70; 0.80]	68	27.85
]0.80; 0.90]	75	30.38
]0.90; 1.00]	3	1.27
Total	**246**	**100**
Average efficiency	**71%**	
Standard difference	**14%**	
Minimum efficiency	**35%**	
Maximum efficiency	**90%**	

Source: Author, based on survey data, 2023

4. Discussion

The value of gamma (0.80) confirms that technical inefficiency effects are important in the estimated model. In fact, according to Ndiaye (2018), the differences between observed and potential production are then linked to random effects, random exogenous shocks independent of sugarcane growers (climatic hazards for example), including measurement errors.

What is more, fertiliser application appears to be significantly positive at the 10% threshold. This could be justified by control over fertiliser application, better allocation of fertiliser, excess of which would be unfavourable to a better vegetative cycle, and also by the quality of the used fertiliser (Kouakou (2014) and Moustafa and *al* (2022).

Seed (cuttings) has a positive but not significant influence on the technical performance of sugar cane growers and justifies that farmers use poor quality cuttings and even more often insufficient quantities according to Mamam and *al* (2016). On the other hand, herbicide use has a positive and significant impact on the efficiency of sugarcane farms and this could be due to the rational and optimal use of herbicides in weed control, which could otherwise reduce sugarcane farm yields (Abikou, 2023). Labour has a positive and significant effect on the technical efficiency of sugarcane growers. This correlation could be explained by the level of qualification in cultivation tasks of the players in the sector and also by a better allocation of labour (Nuama, 2010) and Gniza, 2022). The farmed area, which has a positive and significant influence on the technical efficiency of producers indicates a better allocation of this resource (Kouakou, 2017). The use of rudimentary capital significantly and negatively affects technical efficiency and justifies the non-productive nature of the small tools used by farmers according to Chogou and *al* (2017). In other respects, factors such as age, agricultural training, access to credit and the number of years of experience are determinants of the productive efficiency of village sugarcane farms. According to Mamam and *al* (2016), these variables benefit sugarcane production. This could be justified by the fact that the older farmers have several years' experience of this delicate activity (Mamam and *al*., 2016). These results are in line with those of Ndiaye (2018). In addition, the trained producers on good agricultural practices and visited from supervisory agents are technically more efficient. Sawadogo et al (2022) and Nuama (2006) support this assertion. According to Ndiaye and Diallo (2022), obtaining credit reduces certain production constraints, mainly the acquisition of inputs and the use of hired labour.

Conclusion

The main objective of this study is to contribute to knowledge of factors likely to improve sugarcane production in Ivory Coast. It is justified by the decline in production and productivity of village sugarcane farms. The regression results show that the gap between the observed and potential production of sugarcane farm units is partly due to technical inefficiency. In the light of these results, fertiliser, herbicide and labour have a significant and positive influence on technical efficiency at the 10% threshold. The farmed area also has a positive and significant influence on the productive performance of sugarcane growers. On the other hand, rudimentary equipment has a negative impact on farmers' productive performance. Ferkessedougou 1 also had the lowest level of productive efficiency (35%). However, on both sites, some farmers recorded maximum values of productive efficiency (90%). Furthermore, the results show that no farmer is on the production frontier. However, the estimated productive efficiency indices indicate that, in general, the productive performance of sugarcane farms is relatively acceptable (71%). Finally, the determinants of productive performance of sugarcane growers are age, agricultural training, access to credit and the experience. In order to improve the productivity of sugarcane farms, it is, therefore recommended that the technical services intensify the training of farmers in good agricultural practices. In addition, it is desirable that a policy facilitating sugarcane growers' access to agricultural credit be favoured to enable them to acquire inputs, modern equipment, etc.

Despite the significant results obtained, this study is limited by the fact that data is not available over a long period, and that not all sugarcane-growing areas are taken into account.

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