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Technical efficiency of pineapple production and challenges in Southern Benin

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The need to improve the productivity and quality of pineapple produced to meet demand and supply with international standards necessitates exploring production potentials. So, assessing the technical efficiency of pineapple producers is essential to avoid waste of resources and above all to target advices for improving the productivity of the pineapple producers. Studies conducted on pineapple in Benin have paid less attention to the resource requirements and its determinants. This study estimated technical efficiencies of pineapple producers in Benin and identified some socio-economic factors which influence them. A random sampling was employed to select 253 producers in five districts of pineapple production in southern Benin. Stochastic frontier production function approach using a translog production function was used to estimate the technical efficiencies of pineapple producers, while the inefficiency model was used to determine the socio-economic factor affecting the technical efficiencies. The results showed that the level of technical efficiency ranged from 96.87% to 96.96% with a mean of 96.91%, which suggests that average pineapple output was 3.04% short of the maximum possible level. This implies that producers could still improve the technical efficiency by 3.04%. This study shows that market access, labor, land access, fertilizer access, credit access and soil quality could increase productivity of pineapple production if monitored. Government must take appropriate measures to technically support producers and hope for improved quality of pineapple meeting international standards.

Key words: Stochastic production frontier, efficiency, management, pineapple, Benin.

INTRODUCTION

The rural sector employs 70% of the active population, contributes 36% of the Gross Domestic Product (GDP) and provides more than 80% of export earnings in Benin (MAEP, 2011). The agricultural export sectors in Benin, marked by the preponderance of cotton, have recently been going through a crisis linked to various factors.

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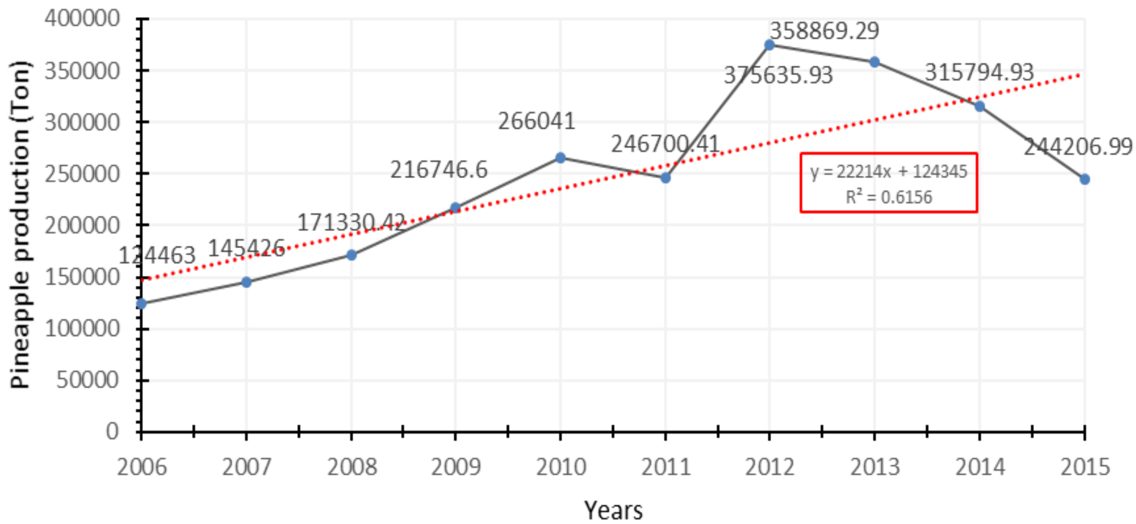

Figure 1. Variation of pineapple production in Benin from 2006 to 2015.
Source: https://countrystat.org/home.aspx?c=BEN&tr=7 (2018).

Thus, in order to reduce poverty and contribute to the visibility of pineapple cultivation, the government of Benin has decided to promote the export of new crops including pineapple (Sohinto, 2016).

Pineapple (*Ananas comosus* L. Merr.) is a plant in the Bromeliaceae family mainly cultivated for its juice and the flavor of its fruit. Its composition makes it basic raw material used in the confectionery industries to make fruit juices and food additives for households (Akhilomen et al., 2015). Pineapple flesh contains 85% water, 0.4% protein, 14% sugar, 0.1% fat and 0.5% fiber (Agbangba, 2016). In addition, pineapple fruit is a good source of vitamins A, B1, B6 and C, copper, manganese and fiber. Pineapple is the main fruit crop in southern Benin, particularly in the Atlantic department which provides employment for farmers and a significant number of women (Sossa et al., 2014). According to Sohinto (2011), this department alone contributes to 90% of total pineapple produced in Benin. It is also the most important cash crop since 1990 for this department's farmers who produce more than 98% of the national production (Yabi, 2014; MAEP, 2013). Its production has grown by an average of 12.77% per year (FAOSTAT, 2014) due to the expansion of areas.

Pineapple production has increased dramatically in recent years, from 124,463 tons in 2006 to 244,207 tons in 2015, an increase of 96%. The production peak was observed in 2012 with 375,636 tons. With national production which increased from 220,800 tons in 2010 (Faostat, 2015) to reach 315,794.93 tons in 2014 (DSA, 2015), Benin occupied the 17th place among the pineapple-producing countries in the world and 3rd place in Africa. In terms of policy, pineapple is one of the thirteen priority sectors with high export potential selected by the Beninese government in its strategic plan for the development of the agricultural sector (PSDSA). Its production is mostly classified in small areas of less than 2 ha in most cases. However, some producers have large farms of up to 150 ha (Gnimadi, 2008) (Figure 1).

Indeed, the cultural practices adopted until then for the cultivation of pineapple have not yet allowed producers to reach their production potential which is around 114 tons per hectare for the sugarloaf variety and 165.6 tons per hectare for the smooth cayenne variety (Agbangba, 2016). However, despite the potential of Benin for the production of pineapple (more than 490,000 ha of land suitable for growing pineapple), the production of this fruit, which is largely assured by small-scale family farmers, remains very weak to meet export needs in the sub-region and to the European Union. This low production of pineapple in Benin is due to a number of factors including, among others: i) the unavailability of quality suckers; ii) the lack of mastery by producers of fundamental concepts such as traceability and the very vital quality standard for fruit intended for export; iii) the scarcity and high cost of specific inputs which negatively impact the quality and conservation of fruit; and iv) the lack of mastery of sustainable methods of soil fertility management and post-harvest conservation.

In addition, it is regrettable that in Benin there is a lack of standards in terms of doses and combinations of mineral fertilizers applicable to pineapple crops which are economically profitable and better preserve the environmental components including in particular the soils and resources in water risks of pollution or degradation. As a result, Beninese pineapple producers apply various doses and forms of mineral fertilizers as they see fit. This affects not only the quality of the pineapple produced (Fassinou et al., 2015) but also the production costs due to the excessive use of chemical fertilizers by certain

Table 1. Sampling distribution.

Category of producers	Municipality					Total
	Abomey-Calavi	Allada	Toffo	Tori-Bossito	Zê	
Small	10 (25.00)	22 (53.66)	20 (48.78)	17 (43.59)	66 (71.74)	135 (53.36)
Medium	11 (27.50)	7 (17.07)	10 (24.39)	7 (17.95)	10 (10.87)	45 (17.79)
Large	17 (42.50)	12 (29.27)	9 (21.95)	11 (28.21)	9 (9.78)	58 (22.92)
Industrial	2 (5.00)	0 (0.00)	2 (4.88)	4 (10.26)	7 (7.61)	15 (5.93)
Total	40 (100)	41 (100)	41 (100)	39 (100)	92 (100)	253 (100)

Source: Survey (2015).

producers. Knowledge of the level of efficiency of producers makes it possible to define strategies that can guide interventions, given that producers today do not always have access to specific inputs and quality releases (Fassinou et al., 2012). Also, the Beninese state has provided in the PSDSA incentives and massive investments to improve yields from 60 to 80 tons per hectare and bring the level of exports to 24,000 tons to the European Union. It therefore seems important to analyze the determinants of the level of efficiency of pineapple producers in order to contribute to a better understanding of the new requirements of the agricultural sector in Benin. The objective of this paper is to analyze the determinants of the technical efficiency level of pineapple producers in the face of new directions in agricultural production in Benin.

METHODOLOGY

Study area

This study was carried out in southern Benin in the Atlantic department, a region of high pineapple production. It covers an area of 3,233 km² and brings together 500 villages and eight municipalities, namely Abomey-Calavi, Allada, Kpomassè, Ouidah, So-Ava, Toffo, Torri-Bossito and Zè. The Atlantic Ocean forms the southern limit of the department which is bounded to the west by the department of Mono. Lake Ahémé, the Couffo River and the Aho River constitute the natural limits of its borders. To the north, the Atlantic department is limited by the Zou department. This border is located at the geographic level by the villages of Sêhouè, Kpomè and Djigbé and passes through the Lama depression. In the east, it is limited by the department of Ouémé. The border runs through the middle of the Ouémé valley and crosses Lake Nokoué to reach the coast at the edge of the Littoral department. Five municipalities, namely Abomey-Calavi, Allada, Tori-Bossito, Toffo and Zê, were selected for this study.

The important economic activities are trade (32%) and agriculture (30%). In the Atlantic department as everywhere else in Benin, the peasants continue to practice slash-and-burn agriculture with rudimentary tools such as hoes, cutters, axes, etc. This limits the production which is used mainly for the subsistence of rural populations. The food crops that dominate are corn and cassava, the staple food for the people of the department, and they come first. Over 80% of the sown areas are devoted to these two crops. The peanut tops the list of annual oilseed crops. Vegetable crops are developing to meet the needs of urban centers; they are tomato and leafy vegetables. There are currently almost 283 private farms which annually plant nearly 4,350 ha, including 3,354 ha of pineapple and 500 ha of citrus groves.

Sampling

The sample is made up of producers grouped into four categories: small, medium, large and industrial producers. These different categories have been defined in accordance with the literature (Tossou, 2001). In total, 253 producers were selected, with 40 in the municipality of Abomey-Calavi, 41 each in the municipalities of Allada and Toffo, 39 in the municipality of Tori-Bossito and 92 in the municipality of Zê because of the important proportion of producers in this municipality. Farmers were selected according to the category of small producers (53.36%), medium producers (17.79%), large producers (22.92%) and industrial producers (5.93%). In order to integrate the gender approach in the study, the sample takes into account 40% of all women producers in the study area. These producers were randomly selected (Table 1).

Method

Data were collected in 2015 from 253 pineapple producers spread across the Atlantic department which alone accounts for more than 99% of the 5,496 ha of pineapple grown in Benin (INSAE, 2013; Kpènavoun et al., 2014). The pineapple production regions in Benin are located in the south of the country, where rainfall levels are the highest. These include the departments of Atlantic, Ouémé, Plateau, Mono, Couffo, Zou (Abomey) and Collines (Savè).

Several types of data were collected at the level of each category of producer. These are data relating to socio-demographic characteristics, area sown, land use, inputs (suckers, fertilizers, insecticides, hormone products, etc.), cropping systems, labor, prices, source of financing of activities, different production operations, varieties, production equipment (quantity, price and lifespan) and sales.

Data analysis

Data analysis based on the stochastic frontier approach proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) was used. This approach takes into account the limits of the stochastic frontier production approach. Jondrow et al. (1982) contributed to the improvement of this method to allow the estimation of technical efficiency indices specific to each producer. This approach also assumes that the error is composed of a residual term taking into account the risks linked to the random effects and a component which represents the ineffectiveness of the producer. This approach is used in this study because it is compatible with African realities characterized by random factors

Table 2. Frontier model variables and their expected sign.

Variable	Description	Expected sign (+/-)
QRejet	Quantity of suckers used (kg)	+
QEngr	Total amount of NPK and urea fertilizer used (kg)	+
QPesti	Total amount of pesticide used (liter)	+
QMot	Total amount of labor used (man-days)	+
Sup	Area planted with pineapple (ha)	+
Capit	Amortization value of materials used	+

Source: Authors

that cannot be controlled by producers. The model can be presented as follows:

$$Y_i = f(X_i, \beta) + V_i$$

where $V_i = \epsilon_i - t_i$.

In this equation, $f(X_i, \beta)$ represents a production function of a Cobb-Douglas form whose parameters β are unknown, and V_i represents the error term which has two components. The first component ϵ_i is a purely residual term taking into account the output variations of the producer which are not under its control (this is the example of external factors such as climate, luck, and topography) which may explain that production is not exactly on the efficient frontier. This component gives the actual interpretation of the frontier. Also, this error term can take into account observation errors or the possibility of missing variables in the model. As for the second component t_i, it is positive and represents the technical ineffectiveness of producer *i*. In this type of model, Farrell's efficiency measures are in principle given by the following formula:

$$F_i = \frac{Y_i}{[f(X_i, \beta) + \epsilon_i]}$$

This function makes up for the difference between ineffectiveness and other random sources of production that are not under the control of the producer. However, we realize the difficulties inherent in this approach to estimate inefficiencies because, even if the parameters are assumed to be known, we cannot observe in V_i the parts ϵ_i and t_i separately. These residues make it possible to determine an average efficiency of the sector analyzed. Said average efficiency will be provided by the average of V_i, seeing that $E(\epsilon_i) = 0$.

Data analysis was carried out with Stata 14 software. The 2016 version of Word processing software was used for writing.

Empirical estimation of the technical efficiency model

The stochastic frontier approach is the one used in this study, taking into account the fact that it is possible to draw a distinction between inefficiency linked to the producer and that due to effects that are not controllable by producers. The Cobb-Douglas functional form was used for estimation of the production function in order to avoid problems of iteration and correlation between explanatory variables. The general form of the model is presented as follows:

$$\ln(Y_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(X_{ji}) + \epsilon_i - t_i$$

where Y_i is the yield of producer i, β_0 is the constant expressing the value of productivity which is not influenced by the factors of production, β_j is elasticity of production with respect to each factor, ϵ_i is a random variable, and t_i is the technical inefficiency of the producer. X_{ji} represents the dependent variables presented in Table 2 with the expected signs.

In statistical terms, ϵ_i has a normal distribution $N(0, \sigma^2_{\varepsilon_i})$, and t_i has a semi-normal distribution $N(0, \sigma^2_{t_i})$. According to Midingoyi (2008), the parameters of the stochastic frontier function and the density functions of ϵ_i and t_i are estimated using the Ordinary Least Squares (OLS) method. In this study, the indices of technical efficiency were determined by the formula proposed by Coelli et al. (1998) and Coelli (1996).

$$TE_i = \exp(-t_i),$$

where TE_i is the technical efficiency of producer i.

The Cobb-Douglas parametric function of the stochastic frontier function, using data from a sample of *n* producers (Biaou, 2008), is as follows:

$$Ln(Prod_i) = Ln(A) + \beta_1 Ln(Qrejet_i) + \beta_2 Ln(QEngr_i) + \beta_3 Ln(QPesti_i) + \beta_4 Ln(QMot_i) + \beta_5 Ln(Sup_i) + \beta_6 Ln(Capit_i) + V_i - t_i$$

where i is the producer, $Prod$ is harvested production (kg), V_i is the random variable beyond producer control, and t_i is the random variable of technical inefficiency of the producer.

Empirical estimation of the model of the determinants of technical efficiency

According to Ray (1988), the determination of the level of producer efficiency must be made through an econometric regression of the efficiency indices. In this study, the Bootstrap method and the Tobit model were used given the truncated nature of the efficiency indices which are between 0 and 1 (Greene, 1993) and also to have a better approximation of the Tobit model. The motivation of the

Table 3. Tobit model variables and their expected sign.

Variable	Description	Expected sign (+/-)
Proind	Industrial producer	+
Concliss	Known variety: smooth cayenne	+
Prinagri	Farmer as main activity	+
Commala	Municipality of Allada	+
Commze	Municipality of Zê	+
Comabcal	Municipality of Abomey-Calavi	+
Cultcliss	Cultivated variety: smooth cayenne	+
Subvetat	State subsidy	+
Abitum	Accessibility of the village: paved road	+
Religio	Religion	+

Source: Authors

Bootstrap is to approach by simulation the distribution of an estimator when we do not know the law of the sample or, more often, when we cannot assume that it is Gaussian (Efron, 1982; Efron and Tibshirani, 1993). The basic principle of this resampling technique is to substitute for the distribution of unknown probability F which gives weight $1/n$ at each empirical distribution. So, we obtain a sample of size *n* called the Bootstrap sample according to the empirical distribution $\hat{F}$ by n random draws with replacement among the *n* initial observations. According to Efron (1981), it is easy to build a large number of Bootstrap samples on which to calculate the concerned estimator. The simulated law of this estimator is an asymptotically convergent approximation under reasonable assumptions of the law of the estimator. This approximation provides estimates of the bias, of the variance, therefore of a quadratic risk, and even of the confidence intervals of the estimator without assumption (normality) on the real law. The simplified and direct Bootstrap method is described in four steps as follows:

(1) Construct the probability distribution of the sample $\hat{F}$ by assigning a probability of J^{-1} for each producer in the sample observed: $x_1, x_2, x_3, \ldots, x_n$.

(2) Take a random sample of size *n* with a replacement for $\hat{F}$ while $\hat{F}$ is fixed at its observed value, that is,

$$X_i^* = x_i^*, X_i^* \sim_{ind} \hat{F}, i = 1, 2, \ldots, n.$$

The sample $X^* = (X_1^*, X_2^*, \ldots, X_n^*)$ is defined as the Bootstrap sample.

(3) The random variable distribution $R(X, F)$ is determined by the Bootstrap distribution: $R^* = R(X^*, \hat{F})$.

(4) Run the Tobit model for each Bootstrap sample: the Tobit form of technical efficiency can be written as follows:

$$ET_i = c_0 + \sum_j^n c_{ji} Z_{ji} + \varepsilon_i,$$

$$ET_i = \begin{cases} 0, & ET_i \leq 0 \\ ET_i, & 0 < ET_i < 1 \\ 1, & ET_i \geq 1 \end{cases}$$

where Z_{ji} are the independent variables, c_0 is the constant term, c_{ji} are the regression variables, and ε_i is the error term. The independent variables are presented in Table 3 with the expected signs.

RESULTS

Socio-economic characteristics of respondents

Analysis of Table 4 shows that approximately 86% of the respondents are men. The marital status of the respondents reveals that more than 94% of them are married and that only 5.16% are single. In terms of level of education, only 1.98% of those surveyed were able to reach university level, 20.95% reached secondary level, 36.36% reached primary level and 40.71% have no education. Over 88% of the pineapple producers surveyed are native to the area with high proportion at the level of large producers. Membership in an association being a determining factor in production in general, 63.24% of pineapple producers are members of an association. Since pineapple production is an integral part of agriculture, 90% of the pineapple producers surveyed have agriculture as their main activity with a level of contact with agricultural extension systems of 48.22%. On the religious level, most of the respondents are Christians. Nearly all respondents have a clear knowledge of the two types of pineapple varieties. With regard to the tracks used to transport the pineapple produced, more than 44% are suitable for motor vehicles compared with only 3.95% which are paved. In terms of subsidy, it should be noted that only 3.16% of the respondents declared having received it for the production of pineapple.

Overview of the variables used in the stochastic model

The description of the different variables used in the

Table 4. Socio-economic characteristics of the respondents.

Variable	Modality	Category of producer				All
		Small	Medium	Large	Industrial	
Sex	Female	12.07	13.33	14.81	6.67	13.44
	Male	87.93	86.67	85.19	93.33	86.56
Marital status	Married	100	95.56	91.79	100	94.84
	Single	0.00	4.44	8.21	0.00	5.16
Educational level (successful class)	University	1.72	4.44	1.48	0.00	1.98
	Middle school	25.86	17.78	20.74	13.33	20.95
	Primary	29.31	44.44	33.33	66.67	36.36
	None	43.10	33.33	44.44	20.00	40.71
Status in the area	Native	86.21	84.44	91.11	80.00	88.14
	Non-native	13.79	15.56	8.89	20.00	11.86
Membership in an association		75.86	75.56	51.11	86.67	63.24
Principal activity	Agriculture	94.83	95.56	85.61	93.33	90.00
	Trader	3.45	2.22	4.55	0.00	3.60
	Other	1.72	2.22	9.85	6.67	6.40
Contact with extension systems		60.34	60.00	37.04	66.67	48.22
Religion	Christian	84.44	77.78	89.66	66.67	83.40
	Islam	7.41	15.56	5.17	13.33	8.70
	Animist	7.41	6.67	3.45	0.00	5.93
	Other	0.74	0.00	1.72	20.00	1.98
Knowledge of variety	Smooth cayenne	1.48	0.00	0.00	0.00	0.79
	Sugarloaf	1.48	0.00	0.00	0.00	0.79
	Both	97.04	100.00	100.00	100.00	98.42
Accessibility of the village	Asphalt road	5.19	4.44	1.72	0.00	3.95
	Driveway	31.85	51.11	65.52	60.00	44.66
	Non-passable track	40.74	26.67	18.97	26.67	32.41
	Path	21.48	17.78	8.62	13.33	17.39
	Other	0.74	0.00	5.17	0.00	1.58
State subsidy		1.48	4.44	6.92	0.00	3.16

Source: Survey (2015).

stochastic econometric model is presented in Table 5. On reading this table, we note that more than 66,000 suckers of pineapple are used per hectare by producers. The point here is that large producers, in general, use more suckers per hectare than other categories of producers. The average quantity of fertilizer (NPK + urea) used per hectare for the production of pineapple in the production area is 807.50 kg, with 516.02 kg for industrial producers, 747.63 kg for large producers, 884.39 kg for medium producers and 839.98 kg for small producers. Pineapple production requires the use of pesticides. The results of this study show that on average, 1 L of pesticide is used per hectare by producers in the production area. The average value of the depreciation of materials is 105,030 FCFA. This value is higher at the level of small producers and is equal to 169,045 FCFA. In the production area, the average area sown is 1.87 ha against a larger area of 2.79 ha for large producers. The average production obtained is estimated at 29,692.69 kg/ha for all the varieties combined. This production is 10,124.76 kg/ha for the smooth cayenne variety and 41,897.09 kg/ha for the sugarloaf variety. It should be noted that industrial

Table 5. Characteristics of the cropping system practiced by pineapple producers.

Variable		Category of producers				All
		Small	Medium	Large	Industrial	
Age		36.13±8.72	39.38±9.71	41.57±10.20	47.07±9.56	38.65±9.77
Quantity of suckers		72275±1867.55	42126±403.05	75665±2495.97	58125±823.51	66851±1828.80
Quantity of fertilizer (kg/ha)	Average	839.98±637	884.39±547.31	747.63±439.13	516.02±492.41	807.50±576.77
	Smooth cayenne	896.97±638.09	770.50±456.75	857.42±479.25	468.91±204.75	818.18±541.64
	Sugarloaf	824.57±643.78	985.74±613.29	702.60±426.57	569.85±714.50	813.14±607.24
Quantity of pesticide (L/ha)	Average	1.02±0.08	1.04±0.10	1.04±0.15	1.03±0.12	1.03±0.11
	Smooth cayenne	1.06±0.13	1.05±0.11	1.05±0.18	1.05±0.17	1.06±0.14
	Sugarloaf	1.00±0.04	1.04±0.10	1.02±0.12	1.00±0.00	1.01±0.07
Total area planted (ha)	Average	1±1.94	1.28±0.82	2.79±1.98	7.89±4.64	1.87±2.65
	Smooth cayenne	0.95±1.05	1.42±0.82	2.70±1.09	8.43±5.97	2.18±2.92
	Sugarloaf	1.04±2.21	1.19±0.85	2.72±2.05	7.29±2.81	1.67±2.46
Yield (kg/ha)	Average	51213.22±2492.31	6820.74±182.86	4587.59±164.07	1696.90±2385	29692.69±183529
	Smooth cayenne	22340.42±1026.88	272.00±3.57	665.63±15.47	675.48±1207	10124.76±685.07
	Sugarloaf	63407.55±2882.54	12571.84±237.82	7898.09±216.38	2864±29.31	41897.09±2254.94
Quantity of labor (H/d)	Average	13±11.63	10±5.62	5±3.83	3±6.06	10±9.83
	Smooth cayenne	15±14	9±4.71	5±2.84	5±8.16	10±10.92
	Sugarloaf	12±10.51	10±6.03	5±4.30	2±1.63	10±9.29
Household size		5±3.78	7±3.76	8±3.87	11±5.59	7±4.23
Total number of agricultural assets		5±4.38	5±4.72	5±3.74	10±8.22	5±4.73
Number of years of experience		8±4.91	11±10.73	13±6.41	16±5.59	10±7.12

Source: Survey (2015).

producers have an average of 10 men per day as agricultural workers in their different households, with an average of 10 for all categories of pineapple producers. The average number of years of experience in pineapple production is 10 for the producers surveyed. Industrial producers recorded a higher average of 16 years of experience in pineapple production.

Analysis of the efficiency levels of pineapple production

The results of the Cobb-Douglas type stochastic frontier production function are presented in Table 6. These results show that the model is globally significant at the 1% level. The parameter μ is not significant. The terms of technical efficiency follow a truncated normal distribution. Parameters σ_u^2 and σ_v^2 reflect the presence of ineffectiveness and random effect in the production of pineapple in Benin. The parameter λ is significantly different from zero at the 1% level. This parameter, which is the ratio between σ_u^2 and σ_v^2, is equal to 0.0003, and thus σ_u^2 represents 0.0003 times σ_v^2. This low level of inefficiency is largely due to the producer because σ_u^2 represents 97% of σ^2. Only 0.03% of the inefficiencies are due to environmental parameters that are not under the control of the producer. This is the case of temperature, humidity and dry spells.

The quantity of labor, the total area and the depreciation value of equipment have negative coefficients. As a result, the quantity of pineapple produced is negatively correlated with the quantity of labor, the area and the depreciation value of the material. A decrease in these factors would lead to a decrease in the amount of pineapple produced.

After estimating the production function, the technical efficiency indices were generated. The results of the descriptive statistics presented in Table 7 show that in the Atlantic department, the average technical efficiency index is the same, 96.91% for the municipalities of Allada and Zê. However, we can see that the average technical efficiency of the municipalities of Toffo and Tori is higher than the average technical efficiency of producers in the municipality of Abomey-Calavi. This performance, generally observed among pineapple producers in the

Table 6. Cobb-Douglas type production function.

Variable	Coefficient value	Standard error
Constant	23.424***	7.419
Quantity of suckers	0.613	0.128
Amount of fertilizer	0.281	0.268
Amount of pesticide	1.478	1.937
Amount of labor	−0.660**	0.321
Area	−2.744***	0.664
Amortization of capital	−2.384***	0.590
μ	0.049	10.480
σ_u^2	0.003	0.393
σ_v^2	9.816	0.879
σ^2	9.819	0.932
λ	0.0003	0.040
Log likelihood	−647.926	-
Wald chi-square	50.65***	-
Sample size	253	-

*** = 1%, ** = 5% and * = 10% are the levels of significance.
Source: Survey (2015).

Table 7. Statistical description of technical efficiency indices by municipality.

Variable	Municipality					Southern Benin
	Abomey-Calavi	Allada	Toffo	Tori	Zê	
Observations	40	41	41	39	92	253
Average	96.89	96.91	96.92	96.93	96.91	96.91
Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00
Minimum	96.87	96.87	96.87	96.87	96.87	96.87
Maximum	96.94	96.95	96.95	96.96	96.96	96.96

Source: Survey (2015).

Table 8. Statistical description of technical efficiency indices by category of producers.

Variable	Category of producers				Southern Benin
	Small	Medium	Large	Industrial	
Observations	135	45	58	15	253
Average	96.91	96.91	96.91	96.93	96.91
Standard deviation	0.00	0.00	0.00	0.00	0.00
Minimum	96.87	96.88	96.87	96.89	96.87
Maximum	96.96	95.95	96.95	96.95	96.96

Source: Survey (2015).

Atlantic department, is due to their dedication to the business.

Indeed, the different levels of technical efficiency of pineapple producers are easily explained by the different constraints they face in their activity.

Determining of the level of efficiency of pineapple production

Table 9 presents the result of the factors that determine the different levels of technical efficiency of pineapple

Table 9. Factors determining technical efficiency.

Variable	Technical efficiency	
	Observed coefficient	Bootstrap standard deviation
Constant	0.9691578***	0.0000414
Industrial producer	0.000186***	0.0000524
Known variety: smooth cayenne	0.000305***	0.0000367
Farmer as main activity	0.0000312	0.0000381
Municipality of Allada	−0.0001735***	0.0000292
Municipality of Zê	−0.000213***	0.0000299
Municipality of Abomey-Calavi	−0.0003145***	0.0000326
Cultivated variety: smooth cayenne	0.0000281	0.0000334
State subsidy	−0.0000847**	0.0000379
Accessibility of the village: paved road	−0.0001099***	0.0000272
Religion	0.0000839**	0.0000325
σ	0.000176***	0.000011
Likelihood ratio chi-square	7156.82	-
Prob > chi-square	0.0000	-
Log likelihood	1789.2548	-

*** = 1%, ** = 5%, * = 10%
Source: Survey (2015).

producers in the Atlantic department. The model is globally significant at the 1% level. The status of industrial producer, knowledge of the smooth cayenne variety, membership of the municipalities of Allada, Zê and Abomey-Calavi, state subsidy, and access to a paved road are the factors which determine the technical efficiency of pineapple production.

The status of industrial producer is significant at the 1% level and has a positive effect on technical efficiency. Therefore, industrial producers are more efficient than other categories of producers. This result confirms those presented in Table 8. This could be explained by the fact that most industrial producers (93.33%) have agriculture as their main activity. Industrial producers dedicate themselves more to their work than the other small, medium and large producers. This category of producers pays other activities by the task in order to devote more time to pineapple production.

The coefficient of the variable of knowledge of the smooth cayenne variety is positive and is significant at the 1% level. This means that knowledge of the smooth cayenne variety significantly influences the technical efficiency of the producer in their activity as a producer. Generally, pineapple producers use both varieties, smooth cayenne and sugarloaf. Due to its higher weight compared to the sugarloaf variety, the smooth cayenne variety is appreciated by producers. This is the reason why they plant it in the minority of the area and that positively and significantly influences their technical efficiency.

The negative sign observed in the coefficient of the variable of the municipalities of Allada, Zê and Abomey-Calavi confirms the analysis made in Table 7. The pineapple producers in these municipalities are slightly less technically efficient than those in the municipalities of Toffo and Tori-Bossito. This could be explained by the different agroecological conditions which benefit the 52% of the producers surveyed in these two municipalities.

The coefficient on the government subsidy variable is negative and significant at the 5% level. This observed sign is unexpected. But this could be explained since the subsidies are for the most part such as not to be made on time. In principle, pineapple producers need state subsidies in a specific period, that of the establishment of suckers.

The sign observed for the access road variable of asphalted nature in terms of accessibility is negative, and the coefficient of this variable is significant at the 1% level. In reality, the quality of the access road to the producers' field is able to positively influence the technical efficiency of the pineapple producer. The negative sign observed in this variable shows that if the producer has their pineapple field on or near a paved road, they are less likely to be technically efficient. Therefore, the carriageways are more suitable for the production of pineapple in the different study areas.

The sign observed for the religion variable is negative. This variable is significant at the 1% threshold. This result shows that producers belonging to one religion are technically more efficient than those belonging to other religions. This study showed that there is a close relationship between religion and agriculture. From the economic point of view, this significance of the religion variable allows us to underline that religious belief and faith could constitute an advantage in production, by motivating believers to make more efforts to work and, thus, to improve their efficiency in production.

Figure 3 shows the priority constraints that pineapple producers face in production and the marketing process of their product. It thus appears that financial difficulties (30% of the producers), the problem of market flow (24% of the producers) and the problem of manpower (21% of the producers) are the major constraints raised by the producers. To a lesser extent, the land issues and access to fertilizers were also raised.

Financial issues

Everyone is aware of the importance of financial capital in farm activities. This constraint deals with the unavailability or insufficiency of financial means by the producer as well as the lack of access to credit. This negatively influences yields. The different policies in the agricultural sector will have to put a particular emphasis on the financing of agriculture through micro credits. This will help producers to easily cope with the various burdens in this sector of the pineapple industry.

Labor issues

The labor issues are crucial in the study area and arise at two levels: physical accessibility and financial accessibility. The physical inaccessibility is explained by the fact that the producer, despite having the financial resources to pay the wage labor, is in a situation of dissatisfaction. This situation is becoming more and more recurrent with the massive displacement of young people from the countryside to the cities. As for financial inaccessibility, the producer has the workforce at their disposal but is unable to hire due to lack of financial means. To facilitate access to labor for producers, politicians should think about mechanizing production of pineapple by providing agricultural machinery to said producers in the form of subsidies but on time.

Export market issues

In the study area, producers operate on Jean-Baptiste Say's law of outlets: supply creates its own demand. In other words, the latter produce without a prior market but with the hope that their offer will create an outlet. Unfortunately, this law is limited as demonstrated by John Maynard Keynes through the possibility of general overproduction. Pineapple producers do not have a market in advance that counts on the sale of their product. They are sometimes forced to sell off to avoid damage. This negatively affects the profit margin. As a result, export channels are not available to everyone. Only large producers and industrial producers have for the most part the ease of exporting their products to foreign countries. Different policies will have to think of an innovation platform bringing together producers and traders of pineapple in order to create a network that can facilitate sales for small and medium producers.

DISCUSSION

This number of suckers used by large producers greatly exceeds the recommended standard which is between 45,000 and 55,000 suckers per hectare (PADA, 2013). This study showed that more than 83% of the producers surveyed are Christians. This result is in line with the study done by Jaouadi (2014) which says several studies have proven the role of the Protestant religion for example in positively influencing the economic performance of producers. The study done by Jaouadi (2014) says enough.

Due to lack of financial means or credit, producers are unable to bear the costs that should lead to good production. These charges are related to the purchase of fertilizers, suckers and payment of wage labor. The educational level results confirm the work of Sossa et al. (2014) who concluded that pineapple producers in southern Benin are mostly illiterate. The level of production (yield) obtained in this study is far below the yields indicated in the literature in Benin. In general, these are yields estimated from the number of suckers used by producers or the yield obtained from data collected from wealthy producers. The difference observed in the results of this study follows the logic of Kpènavoun et al. (2017). According to them, it would be useful to set up a more reliable monitoring system for producers, from soil preparation to counting flowering plants, to better assess and understand yields. The amount of labor used is on average 12 men per day with a high average of 16 men per day at the level of small producers.

Furthermore, the level of technical efficiency of pineapple producers in Benin can be compared to that estimated in other countries of the sub-region (Figure 2). With the frontier production function estimation method, Akhilomen et al. (2015) estimated the average level of technical efficiency of pineapple producers in Edo State in Nigeria to be 70%. The Data Envelopment Analysis (DEA) method was used by Lubis et al. (2014) to estimate the level of technical efficiency of pineapple producers in a province of Indonesia at 70%. Koech et al. (2013), in a study of pineapple producers in the Bureti district of Kenya, showed that these producers had an average technical efficiency score of 69%. Note that there are also studies that show higher levels of effectiveness. For example, according to Trujillo and Iglesias (2014), the technical efficiency is 76% for Colombian pineapple producers. Mohd Idris et al. (2013),

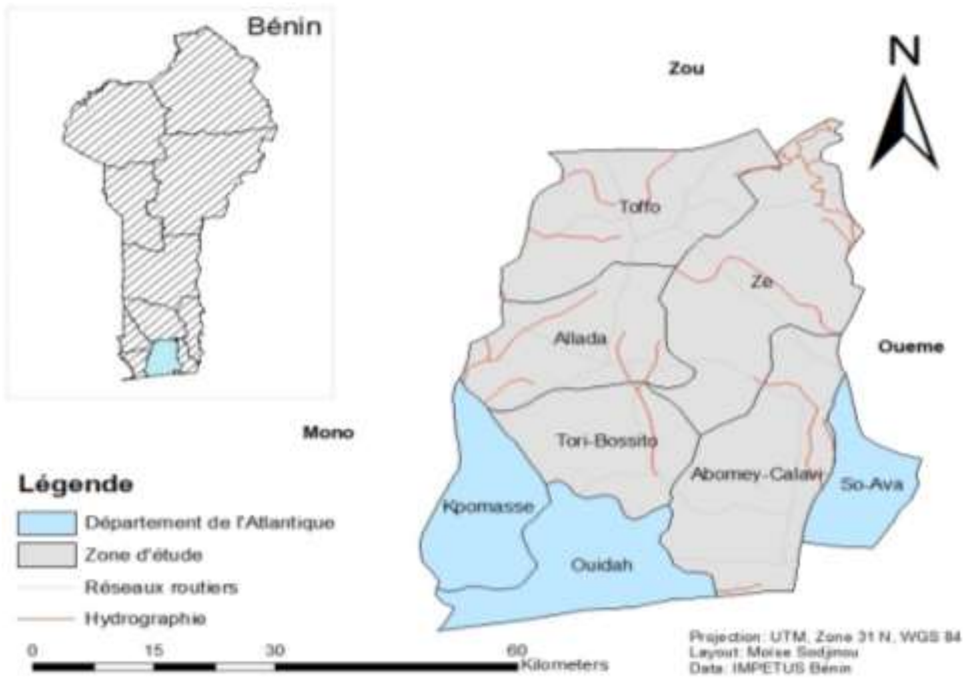

Figure 2. Map of the study area.
Source: Authors

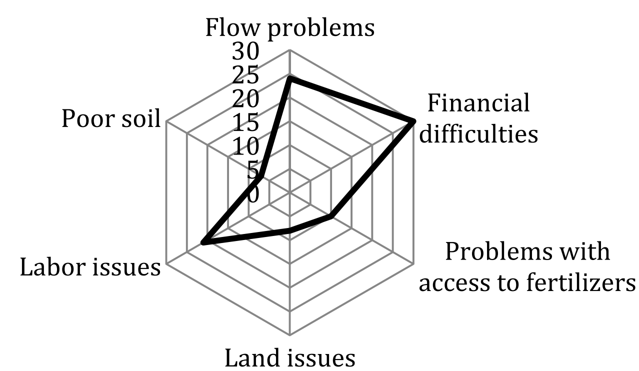

Figure 3. Constraints related to pineapple production
Source: Authors

using the DEA method, also estimated an average level of efficiency of 89% for pineapple producers in Malaysia. The average technical efficiency of producers in the Kurunegala district of Sri Lanka is 85% according to Amarasuriya et al. (2010). The technical efficiency levels of pineapple producers in Nigeria's Osun State range from 69 to 98%, with an average of 93% (Adegbite and Adeoye, 2015). Also, according to Olubunmi et al. (2018), revealed that pineapple farmers had an average efficiency score of 60%, an indication that all pineapple farms in the study area were operating inefficiently.

The results in this study disagree with that conducted by Singbo et al. (2014) in Benin which showed that pineapple producers are less efficient than those who cultivate rice, the latter having a technical efficiency level estimated at 86%. This study showed a higher level of technical efficiency than those of previous studies. Analysis of the technical efficiency indices made at the level of the different categories of pineapple producers shows that it is the industrial producers who have a higher level of efficiency than the average. The other categories of producer remained equal to the average. Knowledge of a technology is a motivating source of its use. Thus, a producer who knows a variety is able to adopt it or not. Also, knowledge of the variety promotes the efficiency of the producer. This result is in line with the result of Ntsama Etoundi and Kamgnia Dia (2008) which proved that knowledge of the improved variety of corn has an impact on corn yield. This study showed that the subsidy can help pineapple growers to move forward and be more efficient. Financing or subsidizing agricultural activities is a relief for producers in general. The results of this study are consistent with the study made by Lhuillery et al. (2013). According to them, public funding in terms of subsidies or tax credits is a tool that can increase the profitability of R&D projects by lowering the cost for companies and thus encouraging them to increase their private research spending. In terms of transport, rural roads play an important role in the transport of crops to export markets (Iwuchukwu et al., 2017). This study has shown that the quality of the rural road contributes to the efficiency of pineapple producers. This result is in line with the study by Riverson et al. (2000) which demonstrated that the good quality of rural roads favors the development of the agricultural sector by allowing producers to be less concerned about transporting their production.

Conclusion

The objective of this paper was to analyze the determinants of the technical efficiency level of pineapple producers in the face of new directions in agricultural production in Benin. The results show that the average technical efficiency index is 96.91%. Several factors are behind these observed levels of efficiency. These include, among others, the status of industrial producer, knowledge of the smooth cayenne variety, production municipalities such as Allada, Zê and Abomey-Calavi, state subsidy, access road of bituminous nature and Christian religion. The status of industrial producer and knowledge of the smooth cayenne variety have a positive influence on technical efficiency. On the other hand, being from the municipalities of Allada, Zê and Abomey-Calavi, the state subsidy, the tarmac access road and the Christian religion negatively influence the technical efficiency of pineapple producers. On the basis of the various results obtained, the following suggestions are made with the aim of improving not only the level of technical efficiency but also resolving the various constraints facing pineapple producers in southern Benin: organize periodic capacity building training; and technically and financially assist producers in order to hope for quality production that meets local and international demand.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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