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Technical efficiency of irrigated rice seed farmers in Koussin-Lélé, Benin Republic

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Seed is one of the key inputs for rice production. The quantity of rice seeds produced is largely below the demand expressed by rice producers in Benin. In recent years, several projects have been implemented to promote this activity. A one stage stochastic frontier production which incorporates a model for the technical inefficiency effects was applied on a whole population of 141 farmers identified in the irrigated site of Koussin-Lélé, Benin. The result showed that the technical efficiency ranged from 69% and 99% with the mean of 92%. The most efficient producers had the best yields, 5,096 kg/ha comparable to the experimental potential yields estimated at 4,800 to 5,000 kg/ha in a controlled peasant environment. Farmers who exercise the multiplication of rice seeds as their main activity educated producers and those who are often in contact with agricultural advisers are the most technically efficient. Therefore, the current institutional environment is favorable to rice seed farmers in the study area. The undertaken actions implemented in recent years must be continued and strengthened. The content of the extension should also be focused on appropriate techniques of fertilization and/or restoration of soil fertility to prevent the misuse of mineral fertilizers. Special attention should be given to the producers in the village, Lélé, to help them improve their technical efficiency.

Key words: Rice seed, technical efficiency, irrigated perimeter, Koussin-Lélé, Benin.

INTRODUCTION

Benin has a significant natural resource potential for rice production, with 322900 ha of irrigable land, including 117000 ha of floodplains and 205900 ha of lowland (MAEP, 2011). Thus, rice production is developed throughout Benin territory. Rice can be grown on five of the country's seven agricultural development poles. The lowlands and the valleys of the rivers constitute areas of rice production. However, rainfed rice can be practiced wherever rainfed crops of maize, cowpea and cassava are possible. Thus, rainfed upland rice, irrigated rice, strict rainfed rice and mangrove rice crops are distinguished (FAO, 1997). Rice cultivation is mainly practiced by smallholders. According to MAEP (2014), in terms of production volume, rice has emerged as the third cereal crop (9%) following maize (77%) and sorghum (11%). While national production in the 1980s

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was low and hardly exceeded 9000 tons of paddy rice per year, there has been some improvement in recent years. Indeed, since 1990, production is constantly increasing. According to MAEP (2014), it increased from 10940 tons of paddy rice in 1990 to 16498 tons in 1995, 48607 tons in 2000, 124975 tons in 2010 and 234145 tons in 2015, with an average annual growth rate of 12.4% over the past ten years. The national production of husked rice can therefore be estimated at 140000 tons in 2015. The total quantity of rice consumed each year is increasing. From 69,206 tons in 2003 to about 110,800 tons in 2010, to at least 275,000 tons in 2015, with an estimated annual consumption of 25 kg per capita (Gandonou et al., 2010). Thus, Benin remains structurally deficient in rice (ONASA, 2015) and the deficit can only be filled by imports which have increased from 96,500 tons in 2000 to 1,390,340 tons in 2013 (INSAE, 2014).

Several projects or programs have been implemented to promote rice production. Also, several technological packages such as improved varieties of rice have been developed and made available to producers. A framework or platform for dialogue between actors in the sector has been created. Two large rice mills are built in Malanville and Glazoué to ease the processing of paddy and putting consumable rice on the market. Access to fertilizers and to certified seeds to rice producers was subsidized. Indeed, the availability and accessibility of producers to quality seeds is the first of the eight strategic axes defined in the SNDR (MAEP, 2011).

In spite of the noted potentialities, rice production faces several constraints, such as difficulties in accessing specific inputs, lack of adequate credit for rice production, low level of professionalization, lack of materials and work equipment, and climate change. After the diagnostic analysis of the situation, the Government of Benin developed and adopted in November 2011, the National Rice Development Strategy (SNDR).

Production and productivity cannot be improved without timely access to quality seeds. They can contribute about 30 to 40% of crop productivity (Kpedzroku and Didjeira, 2008; Dembélé, 2011). From this point of view, it is necessary that particular attention be given to the production of seeds, especially since it is planned to increase rice production by at least 385,000 tons of white rice, that is, 600,000 tons of paddy by 2018. This objective will be achieved with the production and distribution of 8300 tons of rice quality seed (MAEP, 2011). But by 2014, only 2099 tons of seeds are produced on 1523 ha of land. In addition, there has been a downward trend in seed yields in recent years. The yields for 2011-2012, 2012-2013 and 2013-2014 are respectively 2.7, 2.4 and 1.4 tons/ha (Konnon et al., 2014). Efforts must therefore be made to achieve the objectives set.

Under these conditions, it is essential to assess the capacity of the rice seed production system in order to better produce through the implementation of all inputs of production. Indeed, the increase in production does not necessarily require an overall increase in productive resources, but may also stem from a change in the way in which existing resources are managed. As such, concerns about efficiency are one of the main subjects of the economy of production. At the microeconomic level, measuring farm efficiency does not only provide a better understanding of productivity analyzes, but also the effects of market regulation policies on farms. However, at the macroeconomic level, these same levels of individual efficiency are conditions for social or collective efficiency (Piot-Lepetit, 1996). Therefore, it is necessary to study the imperatives of efficient use of productive resources (Nishimizu and Page, 1982).

Prior to the implementation of the SNDR, several studies have been carried out on the consumption of rice in Benin and have yielded many useful results. After the implementation of the SNDR, few studies have been carried out on the technical efficiency of rice producers in Benin in general, and on rice seed producers in particular in which IR 841 perfumed rice is the most popular variety of Beninese consumers (Konnon et al., 2014).

Therefore, this article aims at investigating the technical efficiency and its determinants for rice seed farmers in the partially irrigated area of Koussin-Lélé in Covè, southern Benin.

METHODOLOGY

Population and data collection

The data used in this study were collected in the irrigated area of Koussin-Lélé in the district Covè in Benin. This perimeter covers an area of 106 ha divided into two blocks (villages) separated by 4 km: Koussin (54.7 ha) and Lélé (51.3 ha). So, it is possible to distinguish the farmers from each village (Koussin or Lélé). On this perimeter, there were 141 farmers; all of them belong to 11 groups: 5 groups of men and 1 women group in Lélé; 4 groups of men and 1 group of women in Koussin. All these groups are members of the Union of Groups of Rice Farmers of Koussin-Lélé (UGPR-KL). All producers in the area are seed farmers who produce only the IR 841 rice variety. All of them were surveyed and the production data collected relate to those of the first cycle of the 2014-2015 rice season. Data were collected primarily through structured questionnaire. These data were supplemented by documentation and observations made in the field.

Data analysis

Technical efficiency analysis

Discussions on the concept of efficiency in production date back to the work of Farrell (1957), which included those of Debreu (1951) and Koopmans (1951). According to Farrell (1957), technical efficiency is achieved when, for a given level of production, it is impossible to obtain a larger quantity produced with the same quantities of inputs. In other words, it is the capacity of the firm to situate itself on the frontier of production possibilities, called frontier production function (Kpenavoun et al., 2017). There are a variety of theoretical approaches developed to measure the technical efficiency of farmers.

Most of the studies, investigating the influence of factors which explain the differences in technical efficiencies of farmers use a two-stage approach. The first stage involves the estimation of a stochastic frontier production function and the prediction of farm-level technical inefficiency or technical efficiencies. In the second stage, these predicted technical inefficiency or technical efficiencies are related to farmer or farm specific factors using ordinary least square (OLS) regression. This approach appears to have been first used by Kalirajan (1981) and has since been used by a large number of agricultural economists. Kumbhakar et al. (1991), Reifschneider and Stevenson (1991) and Huang and Lui (1994) specify stochastic frontiers and models for the technical inefficiency effects and simultaneously estimated all the parameters involved, given appropriate distributional assumptions associated with cross-sectional data on the sample firms. Battese and Coelli (1995) proposes a model for technical inefficiency effects in a stochastic frontier production function for panel data.

This one-stage approach is less objectionable from a statistically point of view and is expected to lead to more efficient inference with respect to the parameters involved (Coelli and Battese, 1996). This is this one stage approach used in this study.

The stochastic frontier production function, initially and independently proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), is the approach used in this study. It is the most suitable method for African farms characterized by a failure of agricultural markets. The formulation is as follows:

$$Y = f\left(X,\beta\right)e^{V_i - U_i} \text{ with } i = 1, 2, ... n \text{ (n = sample size)} \quad (1)$$

The variable Y_i denotes the output of the firm *i*; the variables *X* denote the quantities of each of the inputs used to produce Y_i; β is the vector of the parameters associated with *X* to be estimated. The error term is split into two parts V_i and U_i. The random term V_i is associated with random factors that are not under the farmer's control such as economic environment, climate, floods, devastating bird invasions, measurement errors and any other statistical by hypothesis, V_i is a symmetric error term which is assumed to be independently and identically distributed (iid) having normal distribution (0, σ_v^2) errors. U_i represents the random variable reflecting the technical inefficiency, in terms of production of the farm *i*, U_i is defined with an asymmetric distribution and assumed to be independent of V_i. U_i is the non-negative truncation (at zero) of the normal distribution with mean μ_i and variance σ_u^2.

Technical efficiency index (EFFICIENCY) of a rice seed farmer is defined as the ratio of the observed output to the frontier output which could be produced by a fully-efficient farmer, in which the inefficiency effect is zero. So, this technical efficiency is given by the following formula:

$$EFFICACITE_i = e^{-Ui} \quad (2)$$

where

$$\text{EFFICACITE}_i = \frac{f(X;\beta)e^{V_i - U_i}}{f(X;\beta)e^{V_i}} = \frac{Y_i}{f(X;\beta)e^{V_i}} \quad (3)$$

The interpretation of the results is based on the following mathematical expressions which are presented in terms of variance parameters:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2,\ \gamma = \sigma_u^2/\sigma^2,\ 0 \le \gamma \le 1 \text{ and } \lambda = \sigma_u/\sigma_v. \quad (4)$$

The variance ratio γ (Gamma) is an important indicator in the specification and validation of the model. It measures the part of the contribution of the error due to technical inefficiency (γ) or the random error (1-γ) in the total variability. The ratio of 0 indicates that there is no technical variation between farmers and that the total variation is due to random errors. In this case, it can be concluded that the stochastic frontier is not the correct specification of the model and that the estimation of the production function by the ordinary least squares method is sufficient to describe the technology. On the other hand, if γ = 1, it appears that the total variation observed between farmers is due to technical inefficiency. The deterministic frontier would then be preferable to the stochastic frontier. The parameter λ measures the ratio of the standard deviations of the error due to technical inefficiency and random error.

The Cobb-Douglas and the transcendental logarithmic (translog) are two of the most popular functional forms in the economics literature. The functional specification is tested using the log-likelihood ratio test. The result showed that the translog stochastic production frontier function can be reduced to a Cobb-Douglas stochastic production frontier. So, empirically, the stochastic frontier production function of Cobb-Douglas is the model used in this study to estimate the level of technical efficiency of the rice seed farmers in the irrigated perimeter of Koussin-Lélé. It is as follows:

$$LnProduction_i = \beta_0 + \beta_1 LnArea_i + \beta_2 LnSeed_i + \beta_3 LnFertilizer_i + \beta_4 LnHerbicide_i + \beta_5 LnInsecticide_i + \beta_6 LnLabor_i + \beta_7 LnCapital_i + \beta_8 \text{Site}_i + V_i - U_i \quad (5)$$

With *i* = 1, 2, …, n (n is the sample size; *Ln* is the neperian logarithm).

Table 1 defines the variables of this model. According to the producer's neoclassical theory, the positive sign is expected for all inputs of production.

The site of Koussin is better fitted and equipped than that of Lélé. This is why the SITE variable is introduced in the production function. This variable is not an input of production. It was introduced to help neutralize potential biases in the estimates in accordance with the approach suggested by Sherlund et al. (2002).

Technical inefficiency (efficiency) determinants analysis

The final specification for the inefficiency model is as follows:

$$\text{Inefficiency } (\mu_i) = a_0 + a_1\text{Sex}_i + a_2\text{Age}_i + a_3\text{Activity}_i + a_4\text{Primary}_i + a_5\text{Secondary}_i + a_6\text{Experience}_i + a_7\text{Contact}_i + a_8\text{Credit}_i + \varepsilon_i \quad (6)$$

Variables included in the inefficiency model are defined in Table 2. Variables such as level of education, number of years of experience, access to credit and access to technical advice (expressed here by the number of contacts with the agricultural adviser) capture the seed farmer's abilities to access technical knowledge and possibly apply them or seize economic opportunities.

The choices made by farmers are not only related to their capacities. Seed-farmers may seek to differentiate themselves because of its preferences and this behavior can be explained by factors such as age, gender, the fact of exercising production as a main activity.

On the other hand, all farmers are members of a group. Women are systematically members of women's groups and men are systematically members of men’s groups. Thus, at the same time, the variable "sex" captures the status of the farm. The parameters of the stochastic frontier production function are estimated simultaneously with those involved in the inefficiency model for the method of maximum likelihood. Therefore, it is interesting to test three null hypotheses that:

1. The inefficiency effects are not present;

Table 1. Description of the variables of the frontier production function.

Variables	Description
Quantitative variables	
Production	Total harvested rice production (kg)
Area	Cultivated land area to produce rice seed (ha)
Seed	Quantity of basic seeds used (kg)
Fertilizer	Quantity of mineral fertilizers (NPK and Urea) used (kg)
Herbicide	Quantity of herbicide used (l)
Insecticide	Quantity of insecticide used (l)
Labor	Quantity of labor (man-day) which takes into account all types of labor used.
Capital	Total value of depreciation of equipment used in rice seed production (fcfa)
Variable qualitative	
Site	Dummy variable which the value 1 if the seed farmer belongs to Koussin site.

1 euro = 656 fcfa

Table 2. Description of the variables of the multiple linear regression model

Variables	Description	Type of variables
Dependent variable		
Efficiency	Technical efficiency indices of the seed-farmer	Quantitative
Explanatory variables		
Sex	Sex of the seed-farmer	Dummy: 1 if the seed-farmer is male
Age	Age of the seed-farmer	Quantitative
Activity	Main activity	Dummy: 1 if the seed-farmer's main activity is seed production
Primary*	Primary instruction level	Dummy: 1 if the seed-farmer has only primary school instruction level
Secondary	Secondary school instruction level	Dummy: 1 if the seed-farmer has only secondary school instruction level
Experience	Years of experience of rice production	Quantitative
Contact	Number of contacts with the agricultural adviser	Quantitative
Credit	Credit access	Dummy: 1 if the seed-farmer had access to credit over the studied cropping's season cycle

*The modality "uneducated or literate farmer" is the reference of the variable level of education.

2. The inefficiency effects are not stochastic;
3. All the coefficients of the variables in the model for the inefficiency effects are zero.

As the dependent variable of the inefficiency model in Equation 6 is defined in terms of technical inefficiency, a farm-specific variable associated with the negative (positive) coefficient will have a positive (negative) impact on technical efficiency.

RESULTS AND DISCUSSION

Technical efficiency analysis of rice seed-farmers

Table 3 presents characteristics of the variables of frontier production function. This table also shows the quantities of production inputs per unit area of cultivated land. Access to land on the perimeter is subject to membership in the Union of Rice Farmers' Groups of Koussin-Lélé (UGPR-KL). All producers are members of this organization and all of them have access to land by borrowing. The average area planted for rice seed production is 0.82 ha for men and 0.30 ha for women, or on average, 0.75 ha per farmer. The areas of cultivated land varied between 0.24 and 2.55 ha. All 106 ha of managed land are fully exploited.

Managed land is currently a scarce resource on the perimeter. The average amount of mineral fertilizer applied by farmers is 557 kg/ha, well above the

Table 3. Descriptive statistics of the production system

Quantitative variables	Mean	Std. Dev.
Production (kg)	3 684	1 575
Area (ha)	0.75	0.35
Seed (kg)	35	16
Fertilizer (kg)	408	180
Herbicide (l)	1.1	0.7
Insecticide (l)	0.4	0.2
Labor (man-day)	105	53
Capital (fcfa)	39 500	25 900
Partial productivity		
Seed (kg/ha)	47	5
Fertilizer (kg/ha)	557	85
Herbicide (l/ha)	1.3	0.3
Insecticide (l/ha)	0.5	0.2
Labor (man-day/ha)	135	10
Capital (fcfa/ha)	55 140	30 600
Qualitative variable	**Frequency**	**Proportion (%)**
Site 1 if the farmer is on the village Koussin)*	72	51

*On the site there are two villages: Koussin and Lélé.

recommended mineral fertilizer value of 275 kg/ha (Yabi, 2013). More than two-thirds of farmers (71%) applied a mineral fertilizer dose of more than 300 kg/ha. This overdose could be explained by the gradual decline in soil fertility and could have many environmental consequences. Similarly, the average quantity of seed applied is 47 kg/ha with a low standard deviation of 5 kg/ha. Practically, all farmers (99%) used a higher seed density than recommended (40 kg/ha) according to the agricultural advisors in the study area. All farmers use herbicides and insecticides. The applied doses are 1.3 and 0.5 l/ha, respectively with low standard deviations.

On the rice area, three types of labor were used. These included family labor, hired labor and mutual assistance. On average, the hired labor force, family labor and mutual assistance represented respectively 64, 30 and 6% of the total workforce employed. All farmers used external labor. Occasional labor is paid for on a piece-by-piece basis and the cost varies depending on the hardness of cultivation and the availability of specialized farmers. The average price is 1 430 fcfa per man-day. The average production is 3 684 kg with an average yield of 4 955 kg/ha which is significantly higher than that of 2 178 kg/ha found by Arouna and Diagne (2013). The potential yield of this rice variety is estimated at 5 tons/ha. The obtained results show that the farmers have succeeded in reaching and even exceeding this potential yield. This means that rice seed-farmers of the Koussin-Lélé area must be technically efficient.

Table 4 presents the results of the one stage Cobb-Douglas-type stochastic frontier production function involving a model for technical inefficiency effects. Preliminary tests showed that the area is highly correlated with each of the other inputs of production. Therefore, it was ultimately excluded from the model. This model is globally significant at the level of 1%. The coefficients of the inputs of production are positive as expected but only the inputs of production labor and mineral fertilizers are significant. Coefficients of inputs such as seeds, insecticides and herbicides are positive as expected but not significant at 10%. This does not mean that the use of these factors has no influence on rice production. In practice, all producers (99%) use a seed dose higher than recommended (40 kg/ha). So an increase in the dose of seeds, all other things being equal, could not improve production.

Similarly, the low variability in the amounts of herbicides and insecticides per ha adopted by producers could explain the estimation results obtained. Moreover, the results showed that the farmers of the Koussin block obtain a larger production than those of the Lélé block, all things being equal. As a result, they obtained an average yield of 5 069 kg/ha when compared with 4 836 kg/ha for the others.

The null hypothesis that the inefficiency effects are not present is rejected at the level 1% $Chi^2 = 65.60$ and Prob > Chi^2 = 0.000. Also, the null hypothesis that the inefficiency effects are not stochastic is rejected at the level 1% (Prob > |Z|.= 0,000). As a result, a part of the seed-farmers inefficiency is due to technical errors. The parameter γ which makes it possible to measure the contribution of the error due to technical inefficiency (γ) in

Table 4. Results of the one stage Cobb-Douglas-type stochastic frontier production function involving a model for technical inefficiency effects.

Variable	Coefficient	Std. Error	Z	P > | Z |
Stochastic frontier production function				
Constant	3.075***	0.3555	8.65	0.000
Seed	0.051	0.056	0.91	0.364
Fertilizer	0.575***	0.053	10.80	0.000
Herbicide	0.011	0.034	0.32	0.750
Insecticide	0.005	0.014	0.36	0.716
Labor	0.288***	0.083	3.49	0.000
Capital	0.023	0.034	0.67	0.503
Site (=1 If Farmer From Koussin Site)	0.022*	0.011	1.99	0.047
Inefficiency model				
Constant	0.738***	0.218	3.38	0.001
Sex	-0.021	0.034	-0.63	0.531
Age	-0.011	0.008	-1.29	0.196
Age^2	0.000	0.000	1.49	0.137
Activity	-0.105**	0.037	-2.85	0.004
Primary	-0.076*	0.0439	-1.93	0.053
Secondary	-0.115**	0.051	-2.26	0.024
Experience	-0.003	0.004	-0.74	0.459
Contact	-0.078**	0.038	-2.06	0.040
Credit	-0.046	0.043	-1.05	0.292
N (Sample Size)		141		
Log Maximum Likelihood Function		193.07		
Prob > Chi^2		0.0000		
σ_u		0.05***		0.000
σ_v		0.045		
σ_u^2		0.003		
σ_v^2		0.002		
σ^2		0.005		
γ (gamma) = σ_u^2/σ^2		0.64		
λ (lambda) = σ_u/σ_v		1.11		
Technical Efficiency		0.92		

In parentheses are reported the Student t values or the Z values. ***, ** and *: significant values at 1, 5 and 10%, respectively.

the total variability of the output is estimated at 64%. As a result, technical inefficiency is mainly due to errors in the management of available resources. However, on average, seed-farmers have a technical efficiency index of 92%. This level of mean technical efficiency implies that shrimp farmers are operating only 8% below the production frontier, given the level of technology. This result also indicates that the rice seed-farmers in the study area in Benin, on average, can increase the output only by 7% [1 − (92/99)] through improvements in technical efficiency. Otherwise, on the average, If the technical errors could be corrected, with the same resources, the production per rice seed cycle would increase from 3 684 (7 368 kg per year) to 3 942 kg per cycle (7 884 kg per year).

Figure 1 shows the distribution of the estimated technical efficiency indices. These efficiency indices varied between 69 and 99%. The gap between the minimum and the maximum scores is not very large. Unfortunately, no single farm appears as fully technically efficient. The proportion of seed-farmers with an efficiency index greater than or equal to the average is 62%, or close to two-third of the seed-farmers population.

Figure 2 shows a positive correlation between the level of technical efficiency and rice seed yield. The most efficient farmers have the best yields (5 096 kg/ha) comparable to the experimental potential yields. Indeed, a study carried out in controlled farms shows that the average yield of IR 841 rice is 4 800 to 5 000 kg of paddy per hectare (Yabi, 2013; Konnon et al., 2014). The most efficient farmers

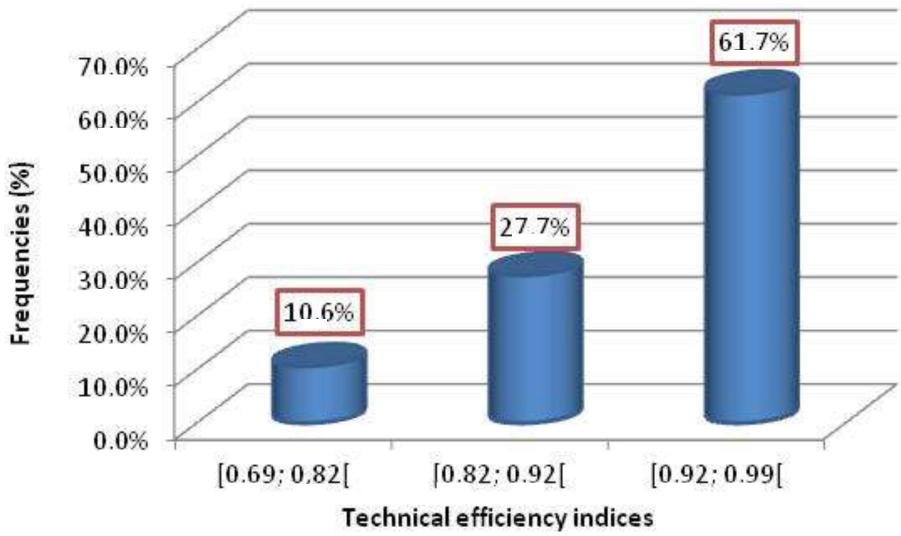

Figure 1. Distribution of technical efficiency scores for Koussin-Lélé seed-farmers.

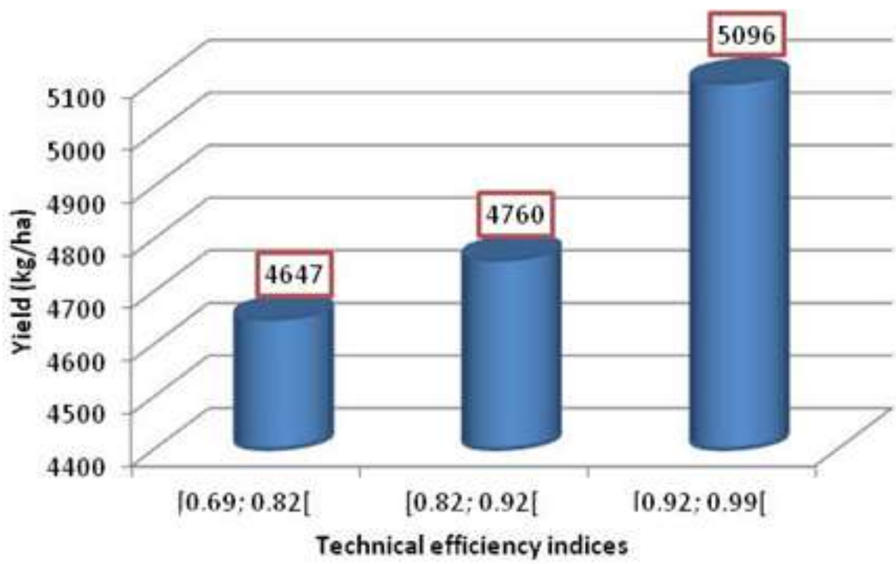

Figure 2. Evolution of rice yields (kg/ha) according to technical efficiency indices.

made small technical errors.

The results obtained on the technical efficiency levels are comparable to those obtained by Singbo (2007) in his study on the measurement of the efficiency of lowland exploitation systems in the central region of Benin. According to the results of this study, technical efficiency indices for rice farmers varied between 58.7 and 99.9% with an average of 88.9% for the rice monoculture system in the lowlands. Tijan (2006) also obtained a technical efficiency level of 87% in Nigeria ranging from 29 to 98%. On the other hand, the level of efficiency of the rice seed-farmers of the irrigated perimeter of Koussin-Lélé is higher than that obtained by Amoussouhoui et al. (2012) for seed-farmers in southern Benin. Their level of technical efficiency was estimated at 72%. Similarly, recent study by Oumourou et al. (2016) showed that rice farmers in south-western Niger have a technical efficiency level of 48%. The high level of technical efficiency in this study could be explained by several factors presented and discussed in the next section.

Technical inefficiency (efficiency) determinants analysis

The descriptive statistics of the variables included in the model for technical inefficiency effects are presented in Table 5. The average age of farmers is 41 years. These

Table 5. Descriptive statistics of the variables of the multiple linear regression model.

Quantitative variables	Mean	Std. Dev.
Age	41.08	9.42
Experience	17.59	7.61
Contact	2.49	0.50
Qualitative variables	**Frequency**	**Proportion (%)**
Sex (1 if the farmer is a man)	123	87.2
Primary	33	23.4
Secondary	33	23.4
Activity	131	92.9
Credit	136	96.5

Source: Survey data, Koussin-Lélé, 2016

farmers have on average 17 years of experience in rice production. The analysis in Table 5 shows that only 13% of women led rice farms on the irrigated perimeter. Less than half of the seed-farmers (47%) have at least primary level of education. Majority of the rice farmers consider seed production as their main activity. All farmers have access to agricultural advice facilitated by their membership of farmer organizations. They were visited on average two to three times for a six-month production cycle. They were also monitored by the department in charge of the Quality and Packaging Promotion (DPQC). Each seed supplier must therefore respect the recommended technical route in order to have the certification of the rice produced. Almost all farmers (97%) have access to credit. For the 2014-2015 season, it was the ALIDé microfinance structure that granted farmers some season's credits at an interest rate of 9.5% for a period of six months. These credits should be recovered automatically from sales revenue. Certified seeds are bought by National Society for Agricultural Promotion (SONAPRA) from farmers. The described environment below is favorable for better seed production.

The null hypothesis that all the coefficients of the variables in the model for the inefficiency effects are zero is rejected at the level 1% (Chi^2 = 20.84 and Prob > Chi^2 = 0.0076). The estimates for the parameters in inefficiency model presented in Table 4 showed that there is a positive and significant relationship between the nature of the main activity, the level of education and access to agricultural advice. The technical efficiency indices of those engaged in seed production as a main activity exceeds that of others by 10.5%. This result is comparable to that obtained by Amoussouhoui et al. (2012).

The results showed that the technical efficiency of farmers improves (technical inefficiency reduced) when the seed-farmer has at least the primary level of education. It exceeds that of other uneducated farmers by at least 7.6%. In the field, technical data sheets on technical recommendations and notices on the efficient use of phytosanitary products are produced in French. The educated farmers are therefore the most favored and are able to better understand the information conveyed. This result is consistent with that obtained by Wang (2010) in northern China. On the other hand, the level of education has no effect on the technical efficiency of rice farmers in Niger (Oumarou et al., 2016) and Côte d'Ivoire (Ekou, 2010). However, according to Ekou (2010), this result could be related to the low weight of educated farmers who constituted only 20% of the sample studied.

In addition, the extension system introduced reduced the level of productive inefficiency on the irrigated perimeter. The efforts of the agricultural advisors made available to farmers have been useful and should be encouraged. In Côte d'Ivoire, Ekou (2010) found that agricultural advisers are overloaded and their actions are null on technical efficiency.

The coefficients of the variables "Age" and "Age2" are not significant but the signs of these factors indicate that there are certainly many technical efficiency farmers among younger and older ones. The credit coefficient has the expected sign but was not significant. This does not mean that credit is not useful. The result obtained can be explained by the fact that almost all farmers have access to credits and the average amount obtained in 2014-2015 is 430 426 fcfa per farmer.

Conclusion

This research evaluated the technical efficiency of rice seed multipliers in the Koussin-Lélé irrigated area of the district of Covè, Benin. It used a stochastic frontier production function which incorporates a model for the technical inefficiency effects. The results obtained from all 141 rice seed-farmers show that all producers access land by borrowing. The average area planted for rice seed production is 0.82 ha for men and 0.30 ha for women, or in average, 0.75 ha per farmer. The area of land sown varied between 0.24 and 2.55 ha. All 106 ha of managed land are fully exploited. All producers are members of the Union of Rice Producers' Associations of Koussin-Lélé (UGPR-KL). They all produced a single variety of rice, the improved rice IR 841. Men constituted 83% of the seed-farmers population. All producers have access to agricultural advice facilitated by their membership of farmer organizations. Almost all producers (97%) have access to credit. Basic seeds are made available to farmers and the production is systematically sold to the public body responsible for rice promotion. On the other hand, there is a trend towards greater use of chemical fertilizers by farmers in order to improve their yields.

The results of the estimates of the frontier production function show that the mean technical efficiency of the seed producers in the study area in Benin is 92% ranging from 69 and 99%. The gap between the minimum score and the maximum score is not very large. The proportion of seed growers with an efficiency index greater than or equal to the average is 62%, which is close to two-third of the seed farmers population. The most efficient farmers have the best yields, 5 096 kg/ha comparable to the experimental potential yields of IR 841 rice estimated at 4 800 to 5 000 kg of paddy per hectare in controlled farmer environment.

On average, the rice seed farmers, can increase the output only by 7% [1 − (92/99)] through improvements in technical efficiency. Otherwise, on the average, If the technical errors could be corrected, with the same resources, the production per rice seed cycle would increase from 3 684 (7 368 kg per year) to 3 942 kg per cycle (7 884 kg per year).

Moreover, the results show that the farmers of the Koussin site are more efficient than those of the Lélé site. They achieved an average yield of 5 069 kg/ha against 4 836 kg/ha for Lélé site. Finally, farmers who exercise multiplication of rice seeds as their main activity, educated producers and those who are often in contact with agricultural advisers are the most technically efficient.

It can therefore be concluded that the current institutional environment is favorable to rice seed farmers in the Koussin-Lélé irrigated perimeter. The undertaken actions implemented in recent years must be continued and strengthened. The content of extension should also be guided by appropriate techniques of fertilization and/or restoration of soil fertility to avoid the misuse of mineral fertilizers. Policies to stabilize the selling prices of rice seeds must also be pursued in order to guarantee farmers some assurance in the market demand of their production.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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