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Total Factor of Productivity (TFP) of the Northeast Benin rice producers: A case study of Malanville Municipality

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ABSTRACT

Rice producers' efficiency is widely assessed by using the Stochastic Frontier Analysis (SFA). But because of gaps between the output(s) implied by the regression line for a given level of input(s) and the real output(s) at the same level of input(s), the Frontier Analysis can provide misleading measures and this is a limit. This article aims at analyzing the economic efficiency levels of rice producers using a framework which does not impose any parametric function: the indexes of productivity (Total Factor of Productivity (TFP) for instance). To reach this objective, primary data were collected from hundred and twenty (120) rice producers in Malanville Municipality. From the data analysis, it comes out that the average indexes of productivity (TFP) are 1.32 (± 0.57) in wet season, 1.45 (± 0.78) in dry season, and 1.33 (± 0.55) for both seasons. On one hand, this indicates that rice producers are economically efficient. On the other hand the access to credit, the experience in rice farming and the rice farming system are the main factors determining the producers' efficiency level.

Keywords: Rice production, Indexes of productivity, Total Factor of Production, Economic efficiency, Malanville.

INTRODUCTION

Second cereal regarding the areas under cultivation and third one according to its production, rice is a staple food for more than half of world population (Hirsch, 1999; Dupaigre, 2005). In developing countries, around one billion of people living in rural areas work in rice farming systems and the post-harvest processes (Baris et al., 2005). This indicates the sensitivity of the sector, subject to several and various interventions from the public policies in both developed and developing countries.

In Benin, rice is one of the crops which can be grown up almost everywhere. It is cultivated at various levels or degrees in all departments of the country. In the production areas, most of the rice producers have small fields from four hundred (400) square meters to two (02) hectares. As a result, the local rice production is not enough to satisfy the local market demand all along the year. Moreover,

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for supplying the local market demand, the small rice producers have to face the competition resulting from imported and donated rice.

To reach the goals aiming to reduce food insecurity and diversify the productions - commodities - oriented toward exports or imports substitution, the beninese government has promoted the rice path. In this line, several projects have been implemented to enhance the performances of rice farming in Benin. The expected socioeconomic impacts of these investments – projects – are to make more competitive the local rice farming systems and, by the way, improve the rice producers' livelihoods. However, it is useful to remind that agricultural production in general and the rice one in particular take place in an environment where the resources are not unlimited. From this fact, rice production is expected to be more and more competitive and rice producers more and more efficient. Regarding the latest expectation, the rice producers' challenge is to be efficient in their production factors allocation and at the same time, to be able to carry out the maximum output from the limited inputs they have.

Previous studies on rice production efficiency in Benin revealed that rice producers are economically efficient (Adégbola et al., 2006; Chanou, 2006; Danhounsi, 2007, Yabi, 2009). But all these studies assessed the production efficiency using the Stochatistic Frontier Analysis (SFA). This framework requires the specification of a production function which describes the technical link between input(s) and output(s) within the production process (Cobb Douglas production function for example). But there are gaps between the output(s) suggested or implied by the regression line at a given level of input(s) and the real output(s) observed at the same level of input(s). Because of these gaps, the Frontier Analysis can provide misleading results and then, presents some limits.

To deal with this situation, the current survey analyzed the rice producers' efficiency using another methodological approach: the Index Number Technique calculation. According to Rija (2004), it is a simple and direct method which does not need any parametric production function and consequently, appears more flexible. It cannot recognize the mistakes due to randomization in data and is not subject to econometric pitfalls because not based on the econometrical estimation of parameters (Coelli, 1998).

MATERIALS AND METHODS

Survey zone

The Municipality of Malanville is located at the extreme North of Benin (Figure 1), in the Department of Alibori, between 11.5° and 12° latitude. Its relief is composed of plains and valleys. The climate is soudano-sahelian characterized by one dry season and one wet season. The average annual rainfall recorded the last five years is around 750 mm (Afrique Conseil, 2006).

Database

The research units were rice producers of the survey zone. To take into account the variability existing in term of rice farming systems, four (04) representative research sites were selected: the irrigated scheme and the villages of Bojécali, Monkassa, and Banitè. Hundred and twenty (120) rice producers randomly sampled were investigated based on individual questionnaire. Through this questionnaire, data on quantities and prices of inputs and outputs involved in the production process were collected. In addition, semi-structured interviews and focus groups were also used to check out the collected data.

Analytical approach

According to Issaka (2002), efficiency in agriculture can be defined as the degree or the level at which farmers get the best result using available resources and given technologies. The concept efficiency relies on the measure of how farmers transform inputs into outputs per unit of land (Rija, 2004). Thus, it appears as an indicator of the producers' capacities to manage their resources (Yegbemey, 2010).

There are many techniques for measuring the producers' efficiency. The mains are: the mathematical programming (DEA), the statistical techniques (OLS and SFA) and the Index Number Techniques (INT). The OLS (Ordinary Least Square) identifies a line of best fit which represents the average of farmers (Hughes, 2001 quoted by Rija, 2004). The DEA and the SFA methods estimate frontier functions and measure the efficiency of farmers in relation to this estimated frontier. In contrary to these methods, the INT do not impose any parametric production function.

Several types of indexes have been developed and they differ essentially in their application (Rija, 2004). In this study, the "Indexes of Productivity" can be used since we want to measure and compare productivity between farms using different rice farming systems. Two (02) measures of productivity are possible: the Partial Factor of Productivity (PFP) and the Total Factor of Productivity (TFP) (Rija, 2004).

The PFP measures the contribution of each individual factor of production. This approach is flexible because it is possible to quantify the productivity of the major resources (labor, manure, chemical fertilizer, etc.) used in the production. For example, the land productivity ratio that is widely used in numerous studies measures the output per unit of land. In this case, the PFP is mathematically defined as:

$$PFP_{land} = \sum_i (Q_i \times P_i) / \sum_i A_i \qquad [1]$$

In this specification, Q_i stands for the quantity of i^{th} crop in the selling unit, P_i for the price of i^{th} crop, A_i the area under i^{th} crop, and n the total number of crops under consideration (Rija, 2004).

The main limitation of the partial productivity measure is that it measures the specific contributions of labor, capital or any other single production factor. Thus, it does not capture the joint effect of all possible inputs, which are used in the production process. Hence, it can provide a misleading indication of the overall productivity. To come over this problem, the TFP can be used. It measures how efficiently a farmer combines the inputs (take together as one) to produce one unit of output. Mathematically, the TFP is defined as:

$$TFP = \sum_i (OUTPUT_i \times PO_i) / \sum_j (INPUT_j \times PI_j) \qquad [2]$$

In this specification, $OUTPUT_i$ stands for the quantity of i^{th} crop in the selling unit, PO_i for the price of i^{th} crop, $INPUT_j$ for the quantity of j^{th} input in buying unit, and PI_j for the price of j^{th} input (Rija, 2004). In this case study, the paddy is the only one considered output. Thus, the TFP_p of p^{th} rice producer is:

$$TFP_p = OUTPUT_p \times PO / \sum_j (INPUT_{jp} \times PI_{jp}) \qquad [3]$$

Where $OUTPUT_p$ stands for the quantity of paddy harvested by the p^{th} rice producer, $INPUT_{jp}$ for the quantity of j^{th} input in buying unit used by the p^{th} rice producer, and PO for the average price of paddy.

Empirical modeling of the efficiency level

To analyze the factors which determine the rice producer's efficiency level a multiple linear regression model was used. It is a function representing the factors that correspond to a given economic efficiency level. The theoretical model which expresses this relation is:

$$TFP_i = F(Zm_i, e_i) \quad [4]$$

TFP_i stands for the producer's productivity index; Zm_i the socio-demographic factors that could explain the differences observed between the producers' efficiency; and e_i represent the error term. Considering j socio-demographic factors, the equation [4] becomes:

$$TFP_i = \alpha_0 + \sum_j (\delta_j Zm_{ij}) + e_i \quad [5]$$

Where α and δ are the parameters to be estimated.

Exogenous variables

Sex, age, level of education, experience in agriculture, contact with extension, and access to credit are exogenous variables commonly used to describe farmers. In the survey zone, there are six (06) predominant types of rice farming systems. These systems were named S1, S2, S3, S4, S5 and S6. Each type of system was used as dummy variable. Because of the model specification, only five (05) systems were introduced in the model. Then, the results were interpreted with regard to the non-introduced system (S1). Table 1 shows the explanatory variables introduced in the model. With such specifications, the equation [5] becomes:

$$TFP_i = \alpha_0 + \delta_1 SEX_i + \delta_2 AGE_i + \delta_3 EDU_i + \delta_4 EXP_i + \delta_5 EXN_i + \delta_6 CRE_i + \delta_7 S2_i + \delta_8 S3_i + \delta_9 S4_i + \delta_{10} S5_i + \delta_{11} S6_i + e_i \quad [6]$$

The parameters α and δ were estimated using a multiple linear regression model. From the signs of these parameters and their levels of significance, the factors affecting the rice producers' efficiency levels were deducted.

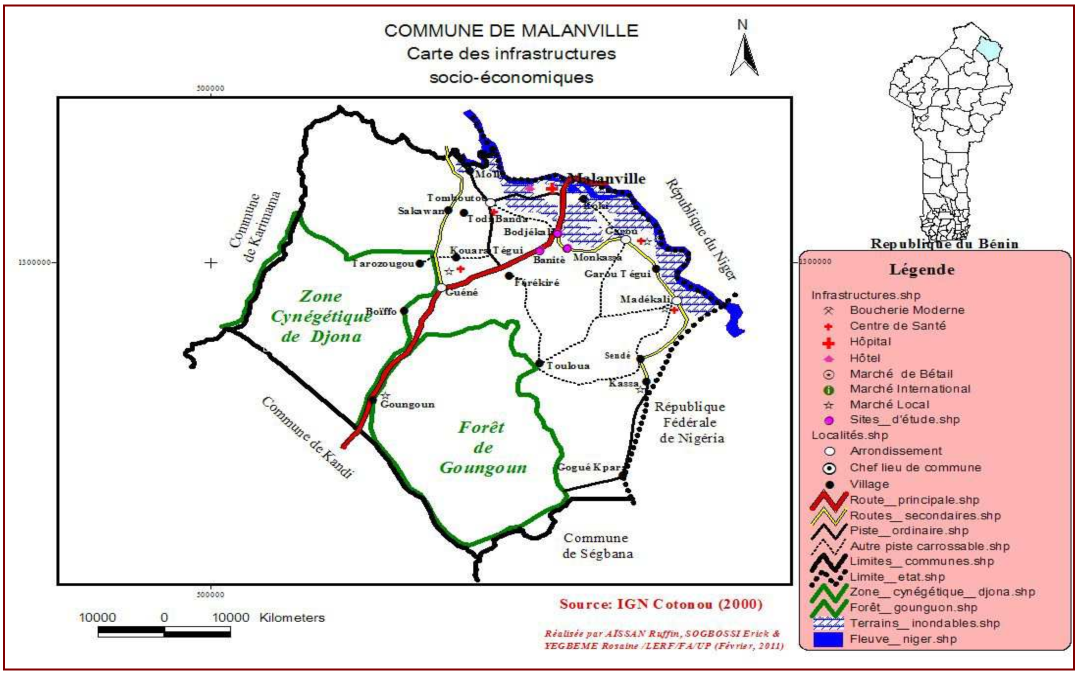


Figure 1: Map of the survey zone.

Table 1: Explanatory variables introduced in the regression model.

Variables	Codes	Modalities	Expected Signs
Sex	SEX	Man = 0 ; Woman = 1	-
Age	AGE	< 43 years = 0 ; ≥ 43 years = 1	+
Level of education	EDU	Not educated = 0 ; Educated = 1	+
Experience in rice production	EXP	< 6 years = 0 ; ≥ 6 years = 1	
Contact with extension	ENX	No = 0 ; Yes = 1	+
Access to credit	CRE	No = 0 ; Yes = 1	+
Rice farming system	S2	No = 0 ; Yes = 1	+
	S3	No = 0 ; Yes = 1	+
	S4	No = 0 ; Yes = 1	+
	S5	No = 0 ; Yes = 1	+
	S6	No = 0 ; Yes = 1	+

Source: Authors' specifications

RESULTS

Rice producers' Characteristics

The main variables which describe the sampled rice producers are summarized in Table 2. It comes out that the rice production in the survey zone is mainly done by men. Most of rice producers are household heads and then, decision makers. Indeed, the household head is responsible of how the household's resources (land, labor, capital, etc.) will be allocated for achieving a given level of production able to feed his dependents either by auto-consumption or selling. The education level is low. Only 30% of producers received a formal education. Most of the producers are in touch with an extension service. In spite of the "small credits" farmers can get from their organization or cooperative, the access to credit is low. The main reasons are: the high interest rate, the tricky access conditions, the small size of rice fields, etc.

Women producing rice are older than men. In the survey zone, women are generally considered like housewife and labor reproductive. Most of the times, women have access to land when they reach certain status in the society (for instance widow). With an average experience in rice production around 10 years, the sampled rice producers are assumed to have a good knowledge of rice farming and subsequently are expected to be efficient in their resources allocation.

The average size of households is about 11 persons including the household head. All the household's members are not involved in rice production because they are too young to work, are unable or are busy with other activities. On average, 5.13 persons per household are involved in rice production. This leads to a dependence rate (1.45 ± 1.98) between the ones involved in the production and the non-involved. Theoretically, this means that one (01) member involved in rice production should feed from his work 1.45 non-involved members.

Rice production systems

Six (06) different types of rice farming systems were identified as predominant in the survey zone. All the systems use fertilizers. The main factors or criteria which give the best discrimination of rice farming systems are: the water management capacity, the period of production, the sowing mode, and the pesticides use. Table 3 presents each system with its characteristics. It is obvious that different rice farming systems mean different levels of yield or production. Arithmetically, the system S6 followed by S5 give the highest outputs per hectare.

Indexes of productivity

From the quantities and prices of inputs and outputs involved in rice production, the producers' TFP were computed. Figure 2 shows the distribution of the producers' indexes of productivity according to production periods. Whatever the period of production under consideration, the most represented TFP classes are [1-1.5[and [1.5-2 [. As a result, most of the rice producers have their index of productivity between 1 and 2, letting us assume that they are economically efficient. Observations in the TFP classes under unit (classes [0-0.5[and [0.5-1[for instance) indicate the presence of inefficient rice producers.

To find them out, we analyze the indexes of productivity with regard to the rice production systems. Figure 3 shows the average indexes of productivity according to the rice farming systems following the periods of production. Considering all the rice farming systems, the average productivity indexes are higher than unit whatever the period of production. Thus, the producers are economically efficient (TFP> 1) at the mean. It comes also out that rice producers are more efficient in dry season (TFP = 1.46 on average) than in wet season (TFP = 1.32 on average). This general picture hides differences from one farming system to the other.

In wet season the average indexes of productivity are statistically different according to the rice farming systems (F = 6.731; ddl1 = 5; ddl2 = 114; p = 0.000). The average index of productivity of the rice farming system S1 is, at 1% level, statistically lower than the remaining average indexes. Then, with the pluvial rice production system, producers are not economically efficient. This low performance can be explained by the producers' objective of production. In S1, producers mainly grow up rice for auto-consumption and not for market. They do not use any pesticides and are not looking for any profit.

In dry season, only the systems S4, S5, and S6 produce rice. Like in wet season, the average indexes of productivity are statistically different according to the rice farming systems (F = 11.403; ddl1 = 2; ddl2 = 44; p = 0.000). The average index of productivity of the rice farming system S4 is, at 1% level, statistically lower than the remaining average indexes. Here, this inefficiency could be explained by the rice production technique (without pesticides and low water management capacity).

For both periods of production (Wet season and dry season together), the producers' average indexes of productivity are statistically different from one rice farming system to the other (F = 8.738; ddl1 = 5; ddl2 = 114; p = 0.000). At 1% level, the average productivity index of the rice farming system S1 is statistically lower than the remaining average indexes like in wet season.

In sum, the rice farming systems S2, S3, S4, S5 and S6 allow their producers to be statistically more efficient than the ones producing with a system S1 in wet season. In dry season, the rice farming systems S5 and S6 allow their producers to be statistically more efficient than the ones producing with a system S4 (S1, S2 and S3 do not produce in dry season). The rice farming systems S5 and S6 are more effective in dry season than in wet season. The system S4 records the inverse phenomenon because of its low water management capacity in dry season.

Whatever the production period under consideration, the rice producers using the system S6 have the higher indexes of productivity. Thus, they are the most efficient. The inefficiency observed within the systems S1 (in wet season) and S4 (in dry season) is quite due to their technology of production.

Determinants of the productivity indexes

To find out the main factors affecting the producers' indexes of productivity a multiple linear regression model was run (Table 4). Globally, the model is significant at 1% level. 36% of the productivity indexes variations are explained by variations of variables – factors – introduced in the model. The remaining 64% of non-explained variations are attributable to factors difficult to measure and not introduced in the model. It is about factors such as: the level of soils fertility, climate conditions and climate changes that can occur from a season to the other, etc. On one hand, experience in rice production, access to credit, and rice farming systems S2, S3, S4, S5, and C6 have positive and significant impacts on the producers' indexes of productivity. On the other hand, sex, age, education level, and contact with an extension service do not determine the productivity index levels.

The experience in rice farming has a positive and significant effect at 1% level. Indeed, a long experience in a given activity is assumed to give a certain level of knowledge or capacity that makes able to optimize the results. In this survey, the more the producer has rice production experiences, the more he masters the production process (technical itineraries), and by the way, is able to efficiently allocate his resources (water, land, labor, etc.). The access to credit has a positive and significant effect at 10% level. This finding is quite interesting because it calls to improve the producers' financing capacities. Enhancing rice producers' financing capacities is a way to make them able to increase their rice fields and furthermore, the local rice production. The rice farming systems have positive and significant effects at 5% level for S4 and 1% level for S2, S3, S5, and S6. With regard to the rice farming system S1, these effects mean that the more the rice plots are irrigated with water mastery and pesticides are used or not, the more producers are efficient.

Sex, age, education level, and contact with an extension service do not have significant impacts on the productivity indexes. The effect of sex is not significant because most of the rice producers in the survey area are men. Age does not mean the producer capacity to master the technical itinerary and then the resources allocation. Finally, the non-significant effect of the contact with extension service might be due to the fact that most of the rice producers are in touch with an extension service.

DISCUSSION

Women represent 51% of the survey zone's population (Afrique Conseil, 2006) but few of them are involved in rice farming as responsible of the production process. As stated by several studies in the northern region of Benin (e.g. Yegbemey, 2010; Paraïso et al., 2011; Paraïso et al., 2012), agriculture in the study zone is mainly performed by men. Women difficulty to have access to land is one of the relevant explanations. In the survey zone, the level education remains low (30%). This rate is even lower than the local and departmental averages equal to 40% and 46% (DDEPS, 2004) respectively.

The dependence rate (1.45 ± 1.98) between involved in the rice production and non-involved is close to the one found out by Mongbo and Floquet (1998) in Benin that is 1.5 consumers by household's worker. This confirms rice importance in Benin. However, the highest average yield recorded by the system S6 (5259.97 ± 3195.08 Kg/ha) is still low with regards to rice yields in Asia's countries. For instance, China achieved around 6,000 Kg/ha in 1990 (Roubaud, 1996) and Indonesia 4,500 Kg/ha (Roubaud, 1996). From this, rice technologies and rice production performance need to be improved.

The main findings of this survey show that rice producers are economically efficient. This result confirms the ones found out using the Stochastic Frontier Analysis.

Table 2: Rice producers' characteristics.

Qualitative variables	**Frequencies**	**Percentages**
Sex	--	--
Man	106	88.3
Woman	14	11.7
Status in the household	--	--
Household head	93	77.5
Spouse	17	14.2
Dependant	10	08.3
Educated rice producers	36	30
Contact with extension service	102	85
Access to credit	17	15.8
Quantitative variables	**Means**	**Standard deviations**
Age	43.06	10.48
Man	37.43	07.88
Woman	43.80	10.59
Experience in rice production	09.48	07.67
Household Size	10.47	04.99
Household's members involved in rice farming	05.13	03.75

Source: Authors' calculations

Table 3: Rice production systems

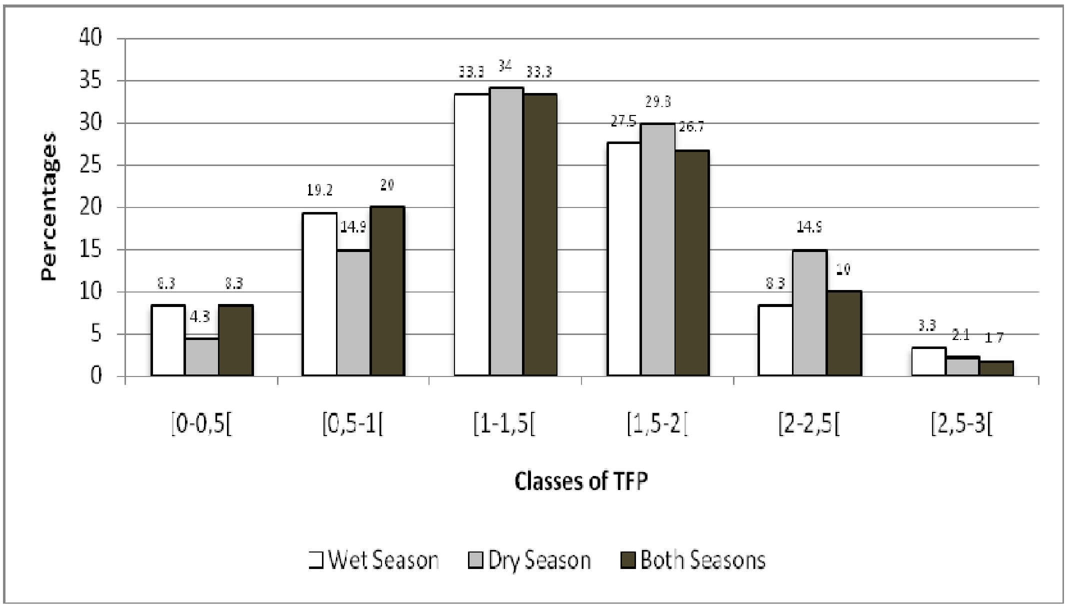
<table>
<tr><th rowspan="2">Systems</th><th colspan="4">Discriminate criteria</th><th rowspan="2">Average yield[c]</th><th rowspan="2">Percentage of farmers</th></tr>
<tr><th>Water management</th><th>Period of production[a]</th><th>Sowing with rope</th><th>Pesticides[b]</th></tr>
<tr><td>S1</td><td>Pluvial</td><td rowspan="3">WS</td><td rowspan="2">No</td><td rowspan="2">No</td><td>1277.75 (±733.43)</td><td>10</td></tr>
<tr><td>S2</td><td rowspan="3">Irrigated + partial water mastery</td><td>3321.17 (±1419.92)</td><td>46.88</td></tr>
<tr><td>S3</td><td>Yes</td><td>Yes</td><td>3208.80 (±512.33)</td><td>04.16</td></tr>
<tr><td>S4</td><td rowspan="3">WS + DS</td><td>No</td><td>No</td><td>3166.63 (±1789.28)</td><td>09.16</td></tr>
<tr><td>S5</td><td rowspan="2">Irrigated + total water mastery</td><td rowspan="2">Yes</td><td>No</td><td>5156.78 (±2738.50)</td><td>15.83</td></tr>
<tr><td>S6</td><td>Yes</td><td>5259.97 (±3195.08)</td><td>13.97</td></tr>
</table>

Note: [a]: WS = Wet season; WS + DS = dry season; [b]: Herbicides and/or insecticides;
[c]: Values in Kg/ha
Source: Authors' summary and calculations

Table 4: Factors determining the efficiency levels.

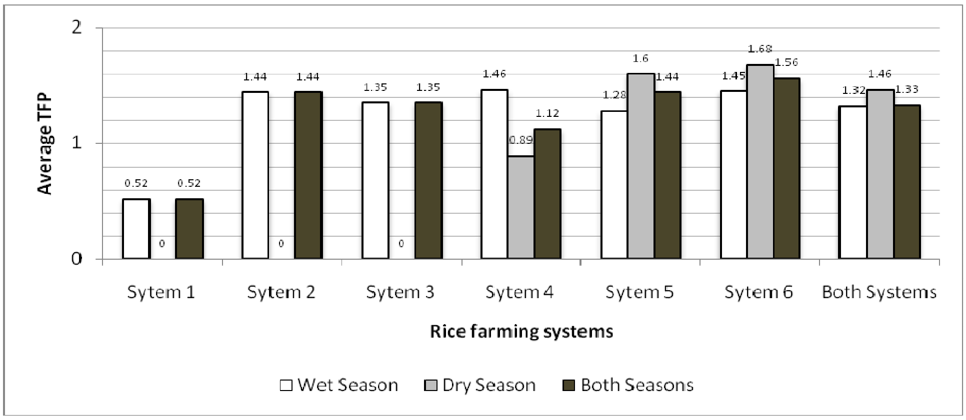
Parameters	Coefficients	Standard deviation	t-values	Signification
(Constant)	0.541***	0.208	2.607	0.010
Sex	-0.091	0.150	-0.608	0.544
Age	-0.074	0.097	-0.764	0.447
Level of education	0.147	0.101	1.461	0.147
Experience in production	0.384***	0.123	3.131	0.002
Contact with extension	-0.100	0.121	-0.822	0.413
Access to credit	0.175*	0.102	1.718	0.089
Farming System S2	0.837***	0.172	4.869	0.000
Farming System S3	0.898***	0.264	3.402	0.001
Farming System S4	0.502**	0.222	2.254	0.026
Farming System S5	0.610***	0.224	2.723	0.008
Farming System S6	0.713***	0.230	3.094	0.003
F= 4.518*** ; ddl1= 11 ; ddl2= 108 ; R2= 0.356; p = 0.000				

Note *, **, *** indicate significant at 10%, 5%, 1% level respectively
Source: Authors' estimations



Source: Authors' calculations.

Figure 2: Distribution of the productivity indexes.



Source: Authors' calculations.

Figure 3: Average TFP according to the rice farming systems and the production periods.

Indeed, using the Frontier Analysis, Chanou (2006) in Gogounou Municipality, Danhounsi (2007) in Malanville Municipality, Adégbola et al. (2006) in Central and Northeast Benin, and Yabi (2009) in Gogounou Municipality reported that rice producers are economically efficient. Beyond the previous conclusions, it comes out that rice producers are economically efficient in wet season, in dry season and for a complete campaign (wet season + dry season).

The experience in rice production and the access to credit as factors determining the producer's efficiency level confirm the results of Chanou (2006). But according to Chanou (2006), sex, education level, adherence to a rice producer organization and contact with an extension service determine also the efficiency level.

In Benin, the access to credit appears as an important factor to increase the producers' financing capacity. In Ivory Coast, Kouakou (2001) revealed that the farmers who do not have access to credit do not reach the same economic efficiency like the ones having access. According to the same author, the producers having access to credit are closer to the frontier production function and then more efficient. Because the economic efficiency is a result of the allocative efficiency and the technical efficiency, any difference in the economic efficiency is a result of a difference in one or both efficiencies (Allocative and technical). Kouakou (2001) showed that producers having access or not to credit have a same allocative efficiency. Therefore, the difference he found out in the economic efficiency is due to a difference in the technical efficiency. Giving so, enhancing the producers' financing capacities might make them able to improve their technique of production. Then, they can easily move toward more and more efficient rice farming systems like the ones S5 and S6.

According to Danhounsi (2007) the factors that determine the producer efficiency are: sex and age, experience in rice production, technical itinerary and irrigation level. With regards to the current survey, the experience in rice production is still an important determinant. As well, the technical itinerary and the irrigation level defined like rice farming systems are also important determining factors of producers' efficiency. Sex and age are mixed factors which can be widely influenced by the sampling.

Conclusion

This survey used the productivity indexes approach to assess the rice producers' economic efficiency. The average indexes of productivity indicate that rice producers are economically efficient. The efficiency levels vary from a given rice farming system to the others. In the current form of the rice production in Malanville Municipality, experience in rice production or farming, access to credit and type of rice farming systems are the main factors determining the producers' efficiency levels. To increase the levels of efficiency, the rice policy makers should focus on how to improve the techniques of production and specifically the water management capacity which is a key issue in rice farming. The farming systems S5 and S6 that record the highest indexes of productivity are proofs for that.

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