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Analysis of the technical efficiency of maize producers in the Municipality of Bembèrèkè in the North of Benin

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In Benin, maize plays a key role, both in production systems and in commercial transactions and population feeding. Smallholders are facing a decline in productivity due, among other things, to difficulties in accessing agricultural inputs such as improved seeds and fertilizers (NPK and Urea). The project "Sustainable intensification of maize production among small producers in the departments of Alibori and Borgou in Benin" attempted to solve these problems in its intervention areas. The objective of this research is to analyze the technical efficiency of the maize producers of the Municipality of Bembèrèkè who benefited from the project's support. The sample of the study consists of the 95 farmers benefiting from the project interventions in the Municipality of Bembèrèkè. Data on quantities and prices of inputs used as well as quantities and labour costs were collected. We used the stochastic production frontier to calculate the beneficiaries' technical efficiency scores. The results of the analysis show that the average yield obtained on the experimental plot is 1422 kg/ha compared to 1005 kg/ha for the control plot. In addition, the average value of the technical efficiency scores of all the farms studied is 65.2%, varying from 8.8 to 100%. This means that the current production level can be further increased by an average of 34.8% using the same quantities of inputs. The technical efficiency obtained by producers on the experimental plots is higher than that obtained on the control plots. It is 68.5 and 62% respectively. The comparison test performed on the mean difference between the two groups shows that this difference is significant (probability = 0.004). This shows that the technological packages disseminated as part of the project activities have a clear impact on the technical efficiency of producers. The Government must then encourage farmers to make greater use of certified maize seed and specific fertilizers at subsidized prices.

Key words: Technical efficiency, stochastic production frontier, maize, project, Benin.

INTRODUCTION

In Benin, maize plays a key role, both in the production systems, in the local economy and in the diet of the population (Yo and Adanguidi, 2017). To date, it is the most widely consumed cereal, far ahead of rice and sorghum despite its low productivity (Houndétondji et al., 2014). It is the staple food of about 65% of the

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population, especially in the south of Benin. As a result, it is heavily involved in commercial transactions at the local, national and sub-regional levels. Maize production, which stood at 1,376,683 tonnes in 2016, 1,514,914 tonnes in 2017 and 1,543,973 tonnes in 2018, represented an increase of 1.92% between 2017 and 2018.

Given its importance, maize has been selected as one of the six key agricultural products in the Government's Action Programme for the period 2016-2021 (Government Action Programme, 2016). Maize is used in several forms (Toleba, 2017; Houssou et al., 2019): (a) in human food with consumption patterns varying from one region to another or from one social category to another (fresh or green product, dry shelled and cooked seeds, dry ground seeds in flour or semolina); (b) in animal feed; (c) It is also a raw material for the agro-industry (in the manufacture of beverages such as beer and improved infant and adult flours. Depending on the intensification gradient, four cropping systems can be distinguished (Yo and Adanguidi, 2017):

i) traditional maize cultivation led by smallholders without the use of exogenous inputs with a low productivity of around 0.8 ton per hectare;
ii) semi-intensive maize cultivation using mineral fertilizer and improved variety seeds for a yield of 1.5 ton per hectare to 3 tons per hectare;
iii) intensive maize cultivation, which involves large mechanized and fully fertilized farms with yields of up to 5 tons per hectare with hybrid varieties;
iv) and off-season crops grown mainly in the flood recession areas of the Ouémé Valley and on the banks of rivers and streams throughout the country.

The "traditional crop" system represents more than 60% of maize producers. And the low productivity of small farms is mainly due to: (i) the unavailability of specific inputs (improved seeds, NPK and Urea fertilizers), (ii) the low level of application of improved production techniques, (iii) the lack of adequate training and information, and (iv) the storage problems. In addition, the effects of climate change, which have become increasingly sensitive in recent years, through irregular rainfall and frequent droughts, are additional constraints to be taken into account.

In response to these difficulties, the Government of Benin, with the support of FAO, has developed the project "Sustainable intensification of maize production among small producers in the departments of Alibori and Borgou in Benin", implemented in three Municipalities, namely Bembèrèkè, Gogounou and Kandi.

To date, no real assessment has yet been made of the effects of this project on maize producers in the Municipality of Bembèrèkè. The objective of this research is to analyze the impact of the activities carried out under this project on the technical efficiency of the maize producers, and to determine whether these impacts are influenced by the gender, given the share of women participants in the project. To do this, after presenting the methodology of the study, we will compare maize yield levels and technical efficiency levels with or without the project support in relation to the gender of the farm managers. Some recommendations will be made at the end.

DATA AND METHODOLOGY

Study areas and data collection

This study was carried out in the Municipality of Bembèrèkè in the department of Borgou in northern Benin. In this Municipality, 95 households are supported by the project. We selected all of them for the field surveys. As part of the project activities, each beneficiary received 10 kg of certified maize seed, NPK fertilizer (100 kg) and Urea (50 kg). Their capacities have also been strengthened on the best maize production practices developed by the National Institute of Agricultural Research of Benin. Each beneficiary has an experimental plot of 0.5 ha on which the inputs made available by the project and the best practice are used, and a control plot of 0.5 ha on which the farmer also used his traditional practice (local seed, no chemical fertilizer). Data on the quantities and costs of inputs used, including maize seed, chemical fertilizers (NPK and Urea), organic fertilizer, herbicide and labour (for soil preparation, seeding, weeding, fertilizer and herbicide application and harvesting) were collected during the 2017 crop year. Some socio-demographic characteristics of the beneficiaries (age, sex, household size) were also collected.

Model specification

There are two families of methods used to estimate technical efficiency:

i) The parametric methods that have the advantage of taking into account hazards other than inefficiency (stochastic frontiers). The disadvantages of these methods include the obligation to represent the technology by a particular parametric form; moreover, it is not possible to separate the various components of inefficiency for multi-product technologies (Chaffai, 1997).
ii) The non-parametric methods that offer the possibility of decomposing the various types of inefficiency (technical, allocative and scale). The technology here is not represented by a functional relationship; the disadvantage here is that inefficiency measures can be affected by measurement errors and/or variable forgetting (Chaffai, 1997).

In this study, we used the stochastic production frontier (SFA) method developed simultaneously by Aigner et al. (1977), Battese and Corra (1977) and Meeusen and van den Broeck (1977) to calculate technical efficiencies.

The original specification involved a production function specified for cross-sectional data that had an error term that included two components, one to account for random effects and the other to account for the effect of technical inefficiency. This model can be expressed as follows (Coelli, 1996):

$$P_i = Y_i\beta + (W_i - Z_i) \quad \text{where} \quad i = 1, 2, \ldots, N \qquad (1)$$

where P_i is the production of the i^{th} farm; Y_i is a k×1 vector of the inputs of the i^{th} farm; β is a vector of unknown parameters; W_i are random variables that are supposed to be iid. N (0, σ_W^2) and

Table 1. Variables used to estimate the production function and expected signs.

Variable	Meaning of variable	Expected signs (+/-)
Y_{eng}	Quantity of NPK and Urea fertilizer used (kg)	+
Y_{org}	Quantity of organic materials used (Bag of 50 kg)	+
Y_{her}	Quantity of herbicides used (L)	+
Y_{mo}	Quantity of labour used (Man-Day)	+
P_{rec}	Quantity of maize harvested during the season (kg)	+

independent of Z_i, which are non-negative random variables that are assumed to explain the technical inefficiency of production and are often assumed to be iid [N (0, σ_Z^2)].

The measurement of technical efficiency (TE) in relation to the production frontier (1) is defined as follows:

$$TE_i = E(P_i^*|Z_i, Y_i)/E(P_i^*|Z_i = 0, Y_i)$$

where P_i is the output of the i^{th} farm, which will be equal to Z_i when the dependent variable is in original units and will be equal to exp(Z_i) when the dependent variable is in logarithm.

In the case of a production frontier, TE_i will have a value between zero and one. The Cobb-Douglas production frontier is as follows:

$$Ln(Z_i) = \beta_0 + \sum_{i=1}^{k} \beta_i \ln(Y_i) + (W_i - Z_i) \quad (2)$$

where Z_i, is the output of the producer i, β_0 the constant expressing the value of productivity which is not influenced by the production factors, β_i the elasticity of production with respect to each factor, W_i the purely random variable out of control, Z_i the technical inefficiency of the producer i. Y_i represents the factors of production. The expected signs of the different variables of the model are presented below (Table 1).

RESULTS AND DISCUSSION

Description of the model variables

Table 2 presents the descriptive statistics of the variables used in the analyses. The analysis of this table shows that men represent 63% of the project beneficiaries compared to 37% for women. The surveyed farms benefited from the experimental plot of NPK fertilizer and Urea. The quantity of chemical fertilizer offered under the project is lower than the doses recommended by the extension services, which is 200 kg/ha (150 kg of NPK and 50 kg of Urea) (Balogoun et al., 2013). This gap is justified by the logic of the project, which choses a limited chemical fertilizer application approach with quality seeds and the best practice and sustainable land management approach to better impact yields. The data in the table also show that chemical fertilizer is also used on control plots that are intended to replicate normal farming practice. This is proof that producers are aware of the level of soil degradation. It was also found that crop residues were used as fertilizer on the plots, but on a variable scale between control and experimental plots. In addition, herbicide is systematically used by producers to address the problem of agricultural labour shortages. The average yield of maize is 1213 kg/ha. However, the table also shows a minimum yield of 168 kg/ha (reflecting the extreme degradation of some crop plots in the study area and the minimum that has been achieved with the local seed without chemical fertilizer) and 2250 kg/ha (the maximum that has been achieved through the project activities). There was also a slight difference in performance between men and women.

Comparison of maize yield levels between the experimental and control plots

Table 3 shows the maize yield levels obtained on the experimental and control plots. The average yield obtained on the experimental plot is 1422 kg/ha compared to 1005 kg/ha for the control plot. However, the comparison test carried out on the difference in the mean between the two groups shows that this difference is significant (probability = 0.000). This is therefore proof that the use of certified seeds of maize, NPK fertilizer and urea, as well as the respect of the best practice, have a significant impact on the yields obtained on the experimental plots.

Estimation results of the production function model

As stated earlier in the methodology, we used the Stochastic Production Frontier (SPF) as a model instead of the Data Envelopment Analysis (DEA). The advantage of the SPF over the DEA is that it makes it possible to explain the deviations observed between the random production frontier and the production actually observed through the technical inefficiency of the farm and random factors (climatic factors, omission of certain explanatory variables, etc.).

Table 4 presents the results from the estimation of the Cobb-Douglas stochastic production frontier model. Analysis of these results shows that the model is globally

Table 2. Descriptive statistics of the variables used.

Beneficiaries	Variable	Obs	Average	Standard deviation	Minimum	Maximum
Male producers	Y_{eng}	120	128.875	34.855	50	150
	Y_{org}	120	2.398	5.019	0	20
	Y_{her}	120	2.642	1.208	1	6
	Y_{mo}	120	19.133	10.926	8	56
	P_{rec}	120	1229.083	356.707	168	2250
Women producers	Y_{eng}	70	127.429	36.700	50	150
	Y_{org}	70	2.364	4.856	0	20
	Y_{her}	70	2.686	1.246	1	6
	Y_{mo}	70	19.057	9.820	8	48
	P_{rec}	70	1186.971	370.160	250	2000
Male and women producers	Y_{eng}	190	128.342	35.456	50	150
	Y_{org}	190	2.386	4.947	0	20
	Y_{her}	190	2.659	1.219	1	6
	Y_{mo}	190	19.105	10.506	8	56
	P_{rec}	190	1213.568	361.319	168	2250

Table 3. Comparison of maize production levels with and without the project (in kg/ha).

Group	Obs	Mean	Standard Error	Standard deviation	[95% Conf. Interval]	
Control plot	95	1005.179	23.131	225.449	959.253	1051.105
Experimental plot	95	1421.958	36.112	351.978	1350.256	1493.659
Difference		-416.779	42.885		-501.376	-332.182
t-Test	t = -9.7186			Probability = 0.0000		

Table 4. Estimation of the producer stochastic production frontier parameters.

LnP_{rec}	Coefficient	Standard Error	z	P>|z|	[95% Conf. Interval]	
LnY_{eng}	0.464	3.20e-06	1.4e+05	0.000	0.464	0.464
LnY_{org}	0.022	4.55e-07	4.8e+04	0.000	0.022	0.022
LnY_{her}	0.158	5.87e-06	2.7e+04	0.000	0.158	0.158
LnY_{mo}	0.042	2.76e-06	1.5e+04	0.000	0.042	0.042
Constante	5.062	0.000	2.7e+05	0.000	5.062	5.062
$Ln\sigma_W^2$	-38.542	402.398	-0.100	0.924	-827.228	750.143
$Ln\sigma_Z^2$	-1.090	0.103	-10.63	0.000	-1.291	-0.889
σ_W	4.27e-09	8.60e-07			2.3e-180	7.8e+162
σ_Z	0.580	0.030			0.524	0.641
σ^2	0.336	0.034			0.268	0.404
λ	1.36e+08	0.030			1.36e+08	1.36e+08

Number of observations = 190; Log likelihood = -34.322; Wald Chi^2 (4) = 6.51e+10; Prob > Chi^2 = 0.000.

significant at 1% significance level (Probability = 0.000). The constant predicted by the model is also statistically significant at 1% significance level. The Cobb-Douglas stochastic production frontier model also reveals that all production factors have positive and significant effects at 1%.

Table 5. Comparison of technical efficiency levels with and without the project.

Group	Obs	Mean	Standard Error	Standard deviation	[95% Conf. Interval]	
Control plot	95	0.619	0.017	0.168	0.585	0.653
Experimental plot	95	0.685	0.018	0.172	0.650	0.720
Difference		0.066	0.025		-0.115	-0.017
t Test	t = - 2.6785			Probability = 0.004		

The results in the table also make it possible to analyze the sources of inefficiency, which are of two types: technical inefficiency related to random shocks and inefficiency from the producer.

The coefficient of the parameter is significantly different from zero at 1% significance level. This means that part of the producers' inefficiency is due to technical errors.

Since the coefficient of the parameter is not significant, this will mean that non-controllable random factors do not significantly influence the efficiency of producers.

The Lambda value (λ), measuring the relative variability of the two sources of inefficiencies (σ_z/σ_w), is equal to 1.36e+08; this means that the productive inefficiency explains essentially the differences at the border in the production systems.

Furthermore, the results of the test of the ratio of $\sigma_z = 0$, stipulating the non-inefficiency of productive origin, show the presence of inefficiency in the production systems (Probability = 0.0000).

Comparison of technical efficiency levels with or without the project

The average value of the technical efficiency scores of all the farms studied is 65.2%, varying from 8.8 to 100%. This means that the current production level can be further increased by an average of 34.8% using the same quantities of inputs.

The average technical efficiency score found in this study (65.2%) is almost similar to that found by Aminou (2018), which is in the order of 65.4%. It is smaller than what has been found by other authors who have worked on maize in Benin: Toleba et al. (2016) have obtained an average technical efficiency score of 80% and Amegnaglo (2018) has found 75%.

The low technical efficiency score obtained by the beneficiaries of this study is due to the fact that they applied the new measures recommended by the project on already poor soils.

The finding of this study is not, however, a peculiarity of Benin. Studies carried out elsewhere on the technical efficiency of maize producers using the stochastic production frontier have given a lower average efficiency score than the 65% found in Benin:

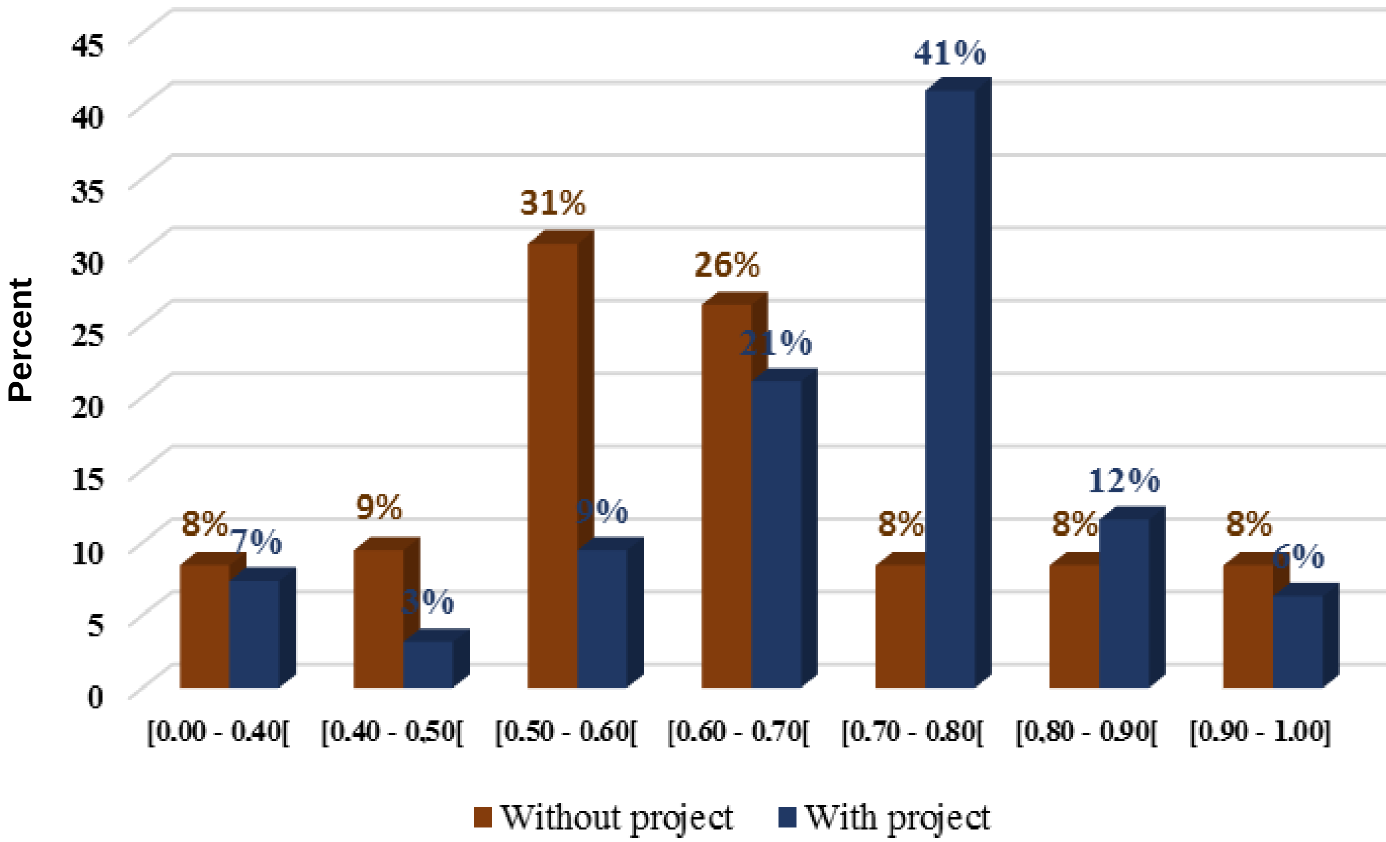
i) Olarinde (2011) studied 300 maize producers in Oyo and Kebbi States in Nigeria using the Translog production border. He found that producers are not technically efficient, with an average technical efficiency score of 55.88% (Oyo State) and 57.58% (Kebbi State).
ii) Chiona et al. (2014) in a study conducted in Central Zambia found an average technical efficiency score of 50% with a minimum of 2% and a maximum of 84%.
iii) Ng'ombe and Kalinda (2015) in another study also conducted in Zambia where farms adopted minimum tillage technology found average technical efficiency score of 60% (Half-normal distribution) and 71.7% (exponential model) respectively. The minimum score obtained is 9.3 and 8.5% respectively. The maximum score is 89.3% (Half-normal distribution) and 90.9% (exponential model).
iv) Bidzakin et al. (2014) in a study conducted in Ghana found an average technical efficiency score of 61% with a minimum of 11% and a maximum of 100%.
v) Kitila and Alemu (2014) in a study conducted in Ethiopia found an average efficacy score of 66% with a minimum of 6% and a maximum of 92%.

Comparison of results in Table 5 shows that the technical efficiency obtained by producers on the experimental plots is higher than that obtained on the control plots. It is 68.5 and 62% respectively. The comparison test performed on the mean difference between the two groups shows that this difference is significant (probability = 0.004). This shows that the best practice disseminated as part of the project activities have a clear impact on the technical efficiency score of the producers.

Graph 1 shows the distribution of efficiency with and without the project. The analysis shows that:

i) 48% of producers obtained a technical efficiency score of less than 60% on the control plots compared to 20% on the experimental plots.
ii) 59% of producers obtained a technical efficiency score varying between 70 and 100% on the experimental plots compared to 25% on the control plots.

This confirms once again the positive impact of the best practices teached by the project. This result confirms the observations made by Achigan-Dako et al. (2014) who already pointed out that the unavailability of quality seeds in Benin is one of the main constraints to the sustainable intensification of agricultural production. The same authors also stated that seeds are an important factor of production whose control determines the yield of the crop.



Graph 1. Distribution of efficiency scores with and without the project.

Table 6. Comparison of technical efficiency levels between men and women.

Group	Obs	Mean	Standard Error	Standard deviation	[95% conf. interval]	
Control plot	70	0.640	0.021	0.176	0.598	0.682
Experimental plot	120	0.659	0.016	0.171	0.628	0.690
Difference		-0.019	0.026		-0.070	0.032
t Test	t = - 0.732			Probability = 0.232		

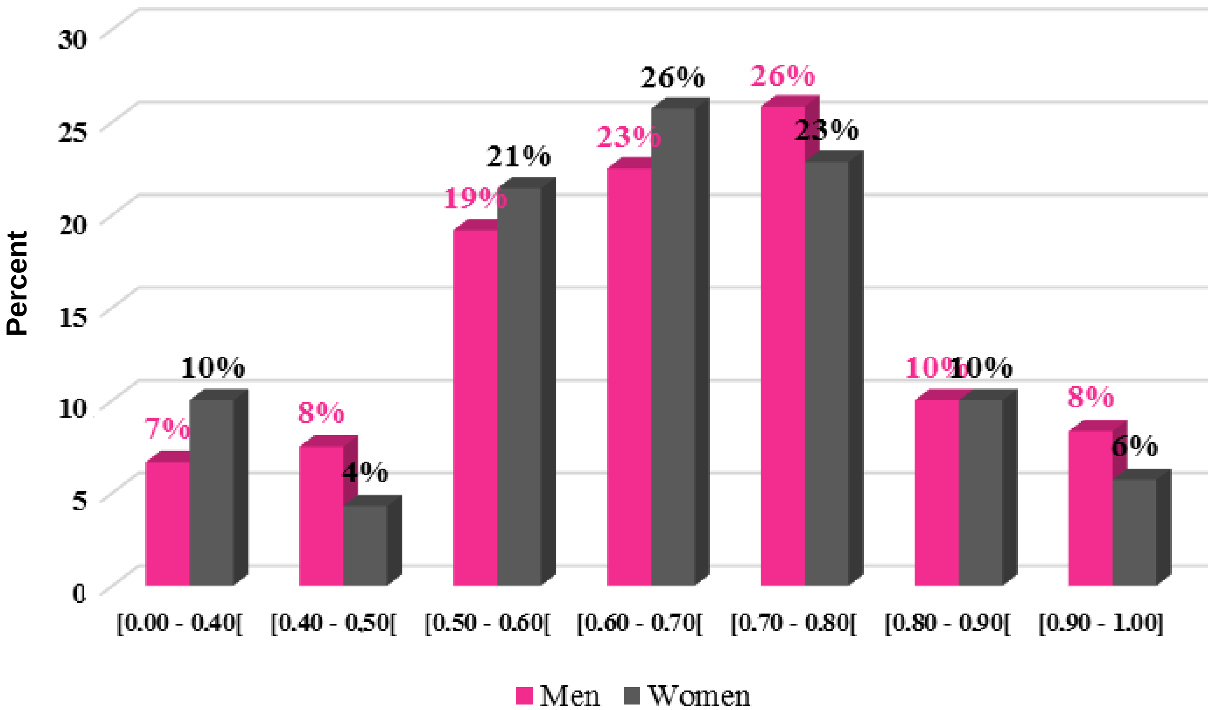
Comparison of technical efficiency levels between men and women producers

We have examined here whether the producer sex has some impact on his level of technical efficiency. The results in Table 6 show that the technical efficiency obtained by men producer is 66% for all plots combined compared to 64% for women producer. In addition, the comparison test carried out on the difference in the mean between men and women producer shows that this difference is not significant (probability = 0.2325).

This result has been confirmed in Graph 2, which shows the distribution of efficiency scores between men and women producers with and without the project. It is easy to see that:

i) 36% of women producers obtained a technical efficiency score of less than 60% compared to 33% of men.
ii) 44% of men producers obtained a technical efficiency score between 70 and 100% compared to 39% of women producers.

This means that the sex of the maize producer has no impact on the level of technical efficiency, unlike the results of the work of Toleba et al. (2016), Amegnaglo (2018) and Aminou (2018), who identified the producer's gender as a determinant of technical efficiency. This would certainly be due to the fact that all project beneficiaries (male and female) had access to the same technology package and inputs (certified maize seed,



Graph 2. Distribution of effectiveness scores among men and women.

NPK and urea fertilizer).

CONCLUSIONS AND RECOMMENDATIONS

The results of our research clearly show the predominant role of the quality of agricultural inputs in improving maize yield in Benin. Certified maize seeds used on the experimental plots combined with a limited supply of chemical fertilizers (NPK and urea) have boosted yields on relatively poor soils. The central government must then encourage the emergence of local private actors specialized in the supply of quality certified maize seeds throughout the national territory. The State must also continue to make specific fertilizers available for maize at subsidized prices in order to facilitate poor people's access to these inputs.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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