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Research Article

Technical Efficiency of Rice Producers in Mali: A Comparative Analysis of the Office Niger Zone and the Baguinéda Irrigated Perimeter Office

Beidari Traoré*

University of Ségou, University Institute of Professional Training, Ségou, Mali

Abstract

As in most sub-Saharan African countries, agriculture is the dominant economic sector in Mali, and the potential for rice production is also high but remains largely untapped. Although achieving potential production depends on many variables, farmers in the two production areas studied are generally below the global efficiency score. The objective of this comparative study is to evaluate the productive performance of rice farmers in the Office du Niger zone compared to those in the Baguinéda Irrigated Perimeter Office. To do this, using program 4.1, we used the maximum likelihood method to estimate both the production function and the inefficiency function. The analysis of production frontiers shows that the variables Area, Seed, Fertilizer, and Herbicide have a significant effect on the level of production. As for the analysis of rice farmers' technical efficiencies, it appears that farmers in the Office du Niger and those in the Baguinéda Irrigated Perimeter Office operate at 0.79 and 0.72 of their productive capacity, respectively. Furthermore, the analysis of determinants shows that membership in a farmers' organization, ownership of equipment, main activity, technical support, and marital status are major factors in improving the efficiency of these rice farmers. There is therefore potential for increasing production without any additional inputs. The authorities responsible for rice development should therefore place particular emphasis on supplying farmers with agricultural equipment and materials, encouraging the creation of farmers' organizations, and intensifying rice production.

Keywords

Technical Efficienty, Rice Producers, Office Niger, Baguinéda

1. Introduction

In Mali, as in many other sub-Saharan African countries, agriculture is the dominant sector of the economy. It generates 41% of Gross domestic product (GDP) and is the main source of income and employment for over 80% of the working population [1]. With a population growth rate of 3.6%[1], the challenges facing agriculture are becoming ever. In Mali, as in many developing countries, the quest for food security is becoming a major concern for the authorities.

Dominated by rice cultivation in general, agricultural production in Mali is characterized by small-scale, low-productivity farms, essentially intended self-consumption. Rice alone generates around 5% of the country's GDP, but

1 Growth and Poverty Reduction Strategy Paper, 2016

*Corresponding author: beidaritraore2@gmail.com (Beidari Traoré)

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the average rice yield is still 3.16 t/ha [2] However, from Mali's independence to the present day, some sixty years ago, successive governments have made the development of the agricultural sector central to their development strategy in general, and the rice sector in, with the aim improving productivity, food self- sufficiency in rice, competing with food imports and promoting exports. The Malian government has implemented a number of plans and programs with the common aim improving productivity, including the Intensive Rice-growing System's total water control program implemented in 2007, the Rice Initiative in 2008 response to widespread cereal crisis, and an investment of 15.8 billion CFA francs in 2013 in hydro-agricultural land development by the European Union, as part of its cooperation with Mali, the granting of 1,000 tractors across the country to producers in the same year, and so on.

This being the case, rice growing was expected to play a number of important roles. In addition to being an effective means of combating the country's food insecurity, it was also expected to generate financial resources to improve the living conditions of all those involved in the sector. At the same time, the rice-growing industry was also expected to provide manpower to other sectors of activity to reduce poverty in rural areas and free up financial resources for the state budget in general.

However, despite the growing increase in rice production, estimated at 2.3 million tones2, Mali still relies imports to cover its rice needs. Rice alone accounts for 30% of total cereal consumption. In 2013, this consumption was estimated at 81.61 kg/head/year3 and 45% of the rice sold on the national market comes from imports. These imports are due to the high demand for rice in urban areas, intense urbanization at a rate of 37.5%4 and a change in the eating habits of city dwellers induced by population growth. These phenomena have contributed significantly to the increase in rice consumption as a household staple.

Furthermore, in the face of the new challenge of combating poverty in general, and in rural areas in particular, what are the main constraints to be overcome in order to improve the income of these rice growers improving productivity? The answer to this question requires on the one hand, an analysis of the real efforts made by rice growers through an assessment of their level of technical efficiency, and on the other, an analysis of the factors explaining this level of efficiency. Studies have certainly been carried out to determine the level technical efficiency of African farmers in general, and Malian farmers in particular. However, we feel that no studies have been carried out to assess the technical efficiency of Malian rice growers, particularly those in the Office Niger (ON) zone, compared with those in the Baguinéda Irrigated Perimeter Office (OPIB). Thus, the present study, whose general objective is to carry out a comparative analysis of the productive performance of rice farmers in the two zones, aims to fill this gap. Specifically, it will: i) determine the average technical efficiency score of rice farmers in the two production zones in Mali, and ii) analyze the factors explaining these levels of technical efficiency.

In this article, the second part presents a review of the literature. The methodology data collection and analysis are outlined in the third part; the fourth and fifth parts present the results and discussion respectively. Finally, the conclusion offers some recommendations.

2. Literature Review

In this section, we first present empirical work on technical efficiency of farms, followed by the theoretical framework of this concept.

2.1. Empirical Work Efficiency

In agriculture very few efficiency use the Data Envelopment Analysis (DEA) method. [3-5]. Most of the literature focuses on the Stochastic Frontier Analysis (SFA) method. Studies by [6-8]; etc. use this method.

Using the stochastic frontier in a district-specific input technical efficiency study in India [9] with a Cobb-Douglas type production function found that improved health is associated with a significant increase in technical efficiency. Similar results were obtained by [10] who found that differences in farmers' health explained the variance in agricultural production efficiency in Norway. Furthermore, in a comparative study between poor and non-poor farms [11] showed that the elasticity of land production is significantly higher on rich farms compared to farms owned by poor farmers. Furthermore, the average cost of the existence of technical inefficiencies was around 43% in terms of lost production, with large variations between farms ranging from 17 to 62%. He also concluded that the least efficient group not only operated below the frontier, but also at the lower end of the production frontier. Therefore, increasing access to inputs would be likely increase productivity and reduce poverty. [12] studied the relationship between agricultural productivity and household food security in Brazilian metropolitan regions, in taking into account other individual factors. He found that productivity gains were associated with greater household food security, in small proportions due to the strong influence of particular characteristics such as education and income.

With a view to identifying the determinants of technical efficiency [13] used the Cobb-Douglas functional form for rice farmers in the Philippines. The results showed that fuel, fertilizer, land rent, cropping period and area are the factors that influence production and technical efficiency in rice production. They found an average technical efficiency score of 0.54. A similar study was carried out by [14] on rice production in South. Their study found that it was possible to

2 Food and Agriculture Organization of the United Nations, 2017

3Agricultural Business Survey, 2013

4 National Institute of Statistics, 2017

increase production efficiency and that the effect of location was significant on production yield [15]. estimated the technical efficiency of a sample of 411 maize farms in the main production zones in Benin using the Cobb- Douglas stochastic production frontier model. The results show that the technical efficiency score varies from 37.37 to 96.22%, with an average score of 80.35% and that variables such as access fertilizers and herbicides, use of animal traction and tractors, technical supervision and access to credit influence the technical efficiency of the farms in the sample.

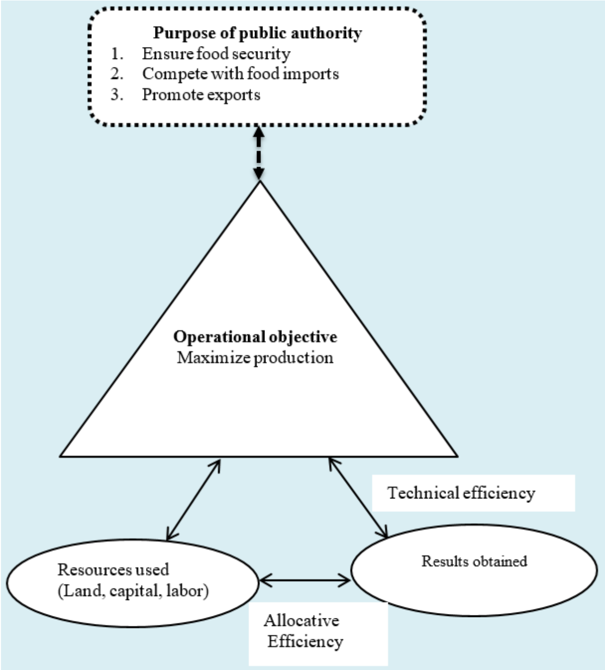
Fawaz studied the determinants technical efficiency among rice farmers Mali's Office du Niger [16]. The results showed an average efficiency score of 0.66. Experience, equipment, membership of a farmers' organization and plot rental were the variables identified as determinants of the efficiency of these rice farmers. On the other hand, access to credit was identified as a variable increasing the level of inefficiency. Fawaz and Adechinan, 2018, studied the technical efficiency of small-scale maize farmers in Benin. The Cobb-Douglas stochastic production frontier method is used to estimate producers' technical efficiency levels. The average technical efficiency score farmers in the sample were estimated at 65.40%. The results indicate that the gender of the farmer, the use of improved seeds, the selling price of maize, the share of off-farm income, the contact with an NGO, access to credit and the production zone play a positive and significant role in reaching the production frontier.

Based on our review of the literature, technical efficiency have been carried out in Mali in general, but specifically in these two zones of agricultural production par excellence in Mali. It is therefore interesting to analyze the performance of rice growers in these two zones from the angle of their efficiency.

2.2. Theoretical Framework

The notion of efficiency is rooted in economic optimization theory. In the figure below, we make a clear distinction between the two concepts of technical and allocative efficiency (figure 1). Allocative effectiveness or efficiency refers to the relationship between the means used to achieve results, while technical effectiveness is the relationship between the results obtained and the objectives set. It is the latter concept that is the focus of our study here.

The farmer can maximize his production under the constraints of the inputs at his disposal, characterizing the frontier on the production side. He can also minimize his production costs, subject to the constraints of technology and the market price of inputs. This characterizes the cost frontier. [17, 18] were the first to explore this field of investigation. [19], following on from these authors' work, proposed an evaluation of technical efficiency.



Source: author

Figure 1. *Lien entre efficacité technique et efficacité allocative.*

3. Methodology

3.1. Estimating the Boundary

To measure the level of productive efficiency of any given operator, it is first necessary to estimate the production frontier, which is the point indicating the maximum quantity of output that can be obtained for a given volume of input. There are two methods for estimating technical efficiency: the non-parametric approach and the parametric approach.

The non-parametric approach enables the empirical construction of production functions, based on mathematical optimization models and linear programming techniques. The production frontier is estimated using a convex polyhedron that envelops all observations, and has the particularity of imposing no pre-established shape on the frontier production function. The most efficient are those that lie on the frontier.

Proposed by [20], the non-parametric approach consists of enveloping the observed production activity in such a way that the set of production possibilities is convex. [21] introduced the Data Envelopment Analysis DEA method, assuming, as Farrell did, constant returns to scale. This model was improved by [22] to take account of variable returns to scale. In agriculture, very few applications have used the DEA approach to estimate the production frontier. However, it has been widely applied in other fields, particularly in management science and multi-product industries.

Unlike the non-parametric approach, the parametric approach imposes a functional form on the production function, and poses the problem of parameter estimation. Parameters are estimated using either mathematical programming techniques, the ordinary least squares method or the maximum likelihood method. In the literature, we distinguish two main parametric methods, depending on how the production frontier is determined. The deterministic frontier estimation approach: these functions take their name (deterministic) from the fact that they have a fixed frontier, in the sense that they have a single positive error term. The deterministic approach consists in considering any deviation between the frontier production function and the observed production function as being due to technical inefficiency. The estimation of the deterministic parametric frontier production function by [23] is based on the assumption of a production function giving the maximum possible output from the factors of production. The model is as follows:

$$Y = f(Xi; \beta)\, e^{-Ui} \quad (1)$$

Where y_i, observed production;

x_i, the vector of inputs;

β, the vector of coefficients of the parameters to be estimated;

u_i, error term due technical inefficiency.

Estimating frontier production functions using the deterministic parametric method has its limitations, in that we cannot perform statistical tests on the coefficients deduced. In addition, it does not take into account measurement errors and random effects with regard to the operator.

Stochastic frontier estimation was developed to take account of these hazards, which do not depend on the individual under consideration. This approach was initially proposed by [24-26] to enable the estimation of firm-specific efficiency indices. This approach stipulates that the error term is composed of two independent parts, namely a purely random component (v) and a component technical inefficiency (u). The stochastic production frontier function takes the following general form:

$$Y = f(Xi; \beta)\, e^{(Vi-Ui)} \quad (2)$$

With Yi: the total production obtained by the rice farmer;

$_{Xi}$: the factor production vector β: unknown parameters to be estimated; exp: is the exponential function; Vi: random error;

The maximum likelihood method can used to estimate this frontier function and separate out the error component reflecting the technical inefficiency (u) of the purely random component.

(v). The main criticism of the stochastic production frontier is that measures technical efficiency based on this frontier remain sensitive to distribution assumptions, the choice of which is not justified. The parametric stochastic approach is the most appropriate for this study, since rice farmers, who are mostly illiterate, are subject to measurement errors, climatic hazards and random disturbances.

In addition, the expression of technical efficiency remains consistent with that of the deterministic function. However, the difference lies in the values obtained in the two cases. The technical efficiency score obtained for the same database is higher with a stochastic function than with a deterministic function, because random shocks are not taken into account. [27] following on from the work of [28]), proposed a model for expressing technical inefficiency using the following formula:

$$U_i = Z_i\delta_i + W_i \quad (3)$$

The vector Z groups together all the variables likely to determine the individual's technical efficiency; δ is the vector of unknown parameters; Wi is a random term.

It's important to note that whether equation (1) or (2) and (3), the variables determining the production function are distinct from those characterizing technical inefficiency, although those included in production are used to determine the level of efficiency.

3.2. Model Specification

Estimating the production frontier involves choosing a functional form. The literature specifies the following functional forms: Cobb Douglas, CES (Elasticity of Substitution Constant) and translogarithmic. To estimate the rice farmers' production frontier and the associated β parameters, we chose the Cobb Douglas form. The advantage of this functional form lies in the fact that it gives elasticities directly from coefficient values [29]. Thus, using the selected variables, the production function to be estimated is as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln Sup + \beta_2 \ln Sem + \beta_3 \ln Fertilizer + \beta_4 \ln MO + \beta_5 \ln Herb + v_i - U_i \quad (4)$$

The inefficiency to be estimated is expressed by the function:

$$U_i = \delta_0 + \delta_1 \text{Access finance} + \delta_2\, Access\ land + \delta_3 Equip + \delta_4 OP + \delta_5\, Dist. + \delta_6\, Age + \delta_7\, Sex + w_i \quad (5)$$

3.3. Data Collection and Analysis

Data were collected from 110 rice growers in the Office du Niger zone and 97 other rice growers in the Office zone of the Baguinéda Irrigated Perimeter. They were collected via a questionnaire administered to the head of household by interview, and the main information collected concerned socio-economic variables and the various production factors mobilized by the farmers.

As for data analysis, the maximum likelihood method is used to estimate both the production function and the inefficiency function. The estimation is carried out using the Frontier 4.1 program implemented by Coelli, which enables the parameters of the production function and those of the inefficiency to be estimated in a single step. Indeed, two-stage estimation has been beaten by several authors [30, 31].

After the 1990s. These authors had argued that the assumption made in the first stage, i.e. that the technical inefficiency term was independently and identically distributed, was not compatible with the search for a possible relationship with other socio-economic variables that takes place in the second stage.

4. Results

This section presents the results of maximum likelihood estimation of the Cobb-Douglas stochastic production frontier and technical inefficiency model.

4.1. Border Estimates

4.1.1. Office Du Niger Zone - ON

By estimating the production frontier with a translogarithmic function, we found that the relationship between the variables, when crossed, is not significant. This is confirmed by the validation of the null hypothesis (coefficient equals zero) of the βjk parameters. means that the restriction to a Cobb-Douglas production function remains sufficient in this case.

As far as the explanatory variables are concerned, the coefficients of the three production factors (area, fertilizer and herbicide) are all positive and significant at the 1% level, indicating their positive influence on production. A 1% increase in each of these factors increases production by 0.41%, 0.44% and 0.21% respectively. In addition, gamma (γ) is significant at 1% and its value 0.91 is between 0 and 1; this means that the deviation from the frontier can be explained both by the technical inefficiency of the rice farmers and by random phenomena (measurement errors, locust invasions, climatic hazards, etc.) beyond the farmers' control.

Table 1. Boundary.

Variables	Parameters	Coefficients	Standard deviation
Constant	β_0	0,085***	0,01
Area	β_1	0,419***	0,04
Fertilizers	β_2	0,448***	0,02
Herbicide	β_3	0,213***	0,03
Gamma	γ	0,91***	0,03

Source: Author
*** Significant at 1% threshold

4.1.2. Zone Office Du Périmètre Irrigué de Baguinéda -OPIB

The likelihood statistic being significant at the 1% threshold indicates that the model is globally significant. The gamma value (γ=0.84) is statistically significant at the 1%. This allows us to conclude that 84% of the deviation from the production frontier is due to technical inefficiency of rice farmers, and only 16% of production gap can be attributed to random shocks.

As for the explanatory factors, Area and Seed are significant at 1%. This means that a 1% increase in each of these two factors will increase production by 0.39% and 0.15% respectively. The other two factors, Herbicides and Fertilizers, are significant at the 10% and 5% thresholds. This means that a 1% increase in each of these factors will increase production by 0.10% and 22% respectively.

Table 2. Border.

Variables	Parameters	Estimated coefficients	Standard deviation
Constant	β_0	0,2025***	0,09

Variables	Parameters	Estimated coefficients	Standard deviation
Area	β_1	0,397***	0,04
Fertilizers	β_2	0,220**	0,02
Herbicide	β_3	0,101*	0,03
Seed	β_4	0,154***	0,07
Gamma	γ	0,81***	0,02

Source: Author
******* Significant at 1% level; ****** Significant at 5% level; ***** Significant at 10% level

4.2. Technical Efficiency

4.2.1. Office Du Niger Zone

The following table shows the estimation of the technical inefficiency model for rice farmers in the ON zone. Estimated coefficients with a negative sign contribute to reducing the technical inefficiency of farmers, while those with a positive sign contribute to increasing their inefficiency. Thus, of all the potential explanatory variables, the estimation reveals that it is access to equipment and membership of a farmers' organization that are significant at the 5% level, while technical support is significant at the 10% threshold. These variables are therefore considered to be determinants of technical efficiency in the ON zone.

Table 3*. Technical efficiency.*

Variables	Coefficients	Standard deviation
Constant	-23.101***	8,890
Age	0.140	0,815
Access to agricultural financing	3.205	2,002
Access to farm equipment	-2.242**	0,927
Gender	4.863*	2,631
Education level	0.449	0,734
Experience	0.002	0,001
Membership Peasant Organization	-3.851**	1,778
Technical support	-1.111*	1,076

Source: Author
******* Significant at 1% level; ****** Significant at 5% level; ***** Significant at 10% level

4.2.2. Baguinéda Irrigated Perimeter Office Zone

In the OPIB zone, five of the potential variables proved significant. These were membership of a farmers' organization and access to agricultural equipment all significant at the 1% level; main activity significant at 5% and gender and marital status significant at 10%.

Table 4. *Technical efficiency.*

Variables	Coefficients	Standard deviation
Constant	-17.171***	6,449
Age	0.099	0,149
Membership Peasant Organization	-4.137***	1,666
Access to farm equipment	-1.324***	1,713
Gender	-3.362*	1,213
Education level	0.129	0,402
Marital status	-0.600*	1,002
Main activity	-1.222**	2,803

Source: Author

******* Significant at 1% level; ****** Significant at 5% level; ***** Significant at 10% level

The frequency distribution of technical efficiency scores is shown in Table 5. For the ON zone, the score varies between 27% and 95%. The average technical efficiency of rice farmers is 79%. This means that through better optimization of available production factors, farmers can increase their production level by 21% without incurring additional production costs. As for the OPIB zone, the minimum is 32% and the maximum is 91%. The average technical efficiency score is 72%. This leads to the conclusion that rice farmers in the Baguinéda zone can also improve their efficiency level by 28% at no additional cost.

Table 5. *Distribution of technical efficiency scores.*

Score	Frequency (%)
Office du Niger	
Minimum	27
Average	79
Maximum	95
Baguinéda Irrigated Perimeter Office	
Minimum	32
Average	72
Maximum	91

Source: Author

5. Discussion

By estimating the production frontier using the Cobb Douglas form, we found that all production factors (area, fertilizer and herbicide) are positive and significant at the 1% level in the ON zone. This indicates their positive influence in increasing production. Indeed, a 1% increase in each of these three factors contributes to an increase in production of 0.41, 0.44 and 0.21 respectively. This result is similar to that of [32] However, in the OPIB zone, of the four factors that tested positive, two (area and seed) were found to be significant at the 1% level. This means that a 1% increase in these two factors increases production by 0.39 and 0.15 respectively. The two factors (fertilizer and herbicide) were significant at 5% and 10% respectively.

In the estimation of the efficiency function, the variable membership of a farmers' organization, with its negative and significant coefficients the 5% and 1% thresholds respectively in the Office Niger and Baguinéda Irrigated Perimeter Office, indicates that a farmer who is a member of an organization is technically more efficient than one who does not belong to a rice- growers' group. This result meets expectations, as being part of a common-interest group has virtues such as experience and synergy effects. In addition, social capital also facilitates the mobilization internal funds for the acquisition of agricultural equipment and materials, which is a determinant of technical efficiency in both farming zones. This result seems to confirm the realities on the ground, as we record 1,618 farmers' organizations (FOs) in the Office zone (Bilan de la campagne, 2017/2018). These elements therefore constitute a real lever for increasing the individual efficiency of rice growers in particular and that of these two production zones. This result is in line with that of Coulibaly et al., 2017.

As for the variable access to agricultural equipment, it recorded two negative coefficients in both zones, significant at the 5% and 1% thresholds respectively. These negative coefficients indicate that a farmer's access to agricultural equipment increases his efficiency and therefore decreases his inefficiency. This result is similar to that of Abedullah [11]. Accessibility to equipment therefore significantly increases agricultural production. This reality is also confirmed by the fact that the supply of agricultural equipment and materials is now a priority.

In addition, the main activity variable, with a negative elasticity coefficient significant at the 5% threshold in the OPIB zone, reveals that its effect reduces the technical inefficiency of rice farmers. This explanation is easy to find, because farmers whose main activity is rice growing spend most of their time on their farms. It therefore goes without saying that they are more efficient than those who carry out other types activity as their main occupation.

Technical support, with a negative and significant coefficient of inertia at 10%, also tells us that rice growers in the Office du Niger zone who have received technical support from extension agents are more efficient than those who have not. This result is in line with our expectations, as technical support also plays an important role in farmers' openness and mastery of technical itineraries. This result goes hand in hand with that of [28].

As for the marital status variable, it also recorded a negative and significant coefficient at the 10% threshold. This concludes that in the OPIB zone, being married helps to reduce the technical inefficiency of farmers. The interpretation is also easy to find, as a married farm manager also benefits from the support of other family members on his farm. This support can be, for example, the use of family labor in farming activities. It is therefore logical that those who are married perform better than those who are single.

6. Conclusion

The aim of the present study was to make a comparative analysis of the productive performance of rice growers in the Office du Niger (ON) zone compared with those in Baguinéda Irrigated Perimeter Office (OPIB). To achieve this objective, a survey was carried out in these two agricultural production zones par excellence. A sample of 207 rice farmers was selected, 110 from the ON zone and 97 from the OPIB zone. The stochastic production function (one-step estimation) was applied to the data collected. At the end of the analysis, the data reveal that the Cobb Douglas stochastic function is the most appropriate for our study. The coefficients inertia of the four production factors (Area, Seed, Fertilizer and Herbicide) used in the analysis are all significant and positive. This indicates that these factors all contribute to increasing rice productivity.

In addition, it emerges that growers are on average technically inefficient in rice cultivation. Indeed, the average technical efficiency index displayed by the production frontier estimate is 0.79 for rice farmers in the Office du Niger zone and 0.72 for farmers in the Office zone of the Baguinéda Irrigated Perimeter. This means that rice farmers in both zones are exploiting only 79% and 72% of their production potential respectively. In deduction, the level of technical inefficiency is 0.21 and 0.28, concluding that the production level of these rice farmers can be increased by 21% in the ON zone and 28% in the OPIB zone at no additional cost.

Furthermore, analysis of the determinants of technical efficiency shows that variables such as membership of a farmers' organization, equipment ownership, main activity, marital status and advisory support improve the technical efficiency of rice growers in the study area. Therefore, policies to improve the technical efficiency of rice farmers should be based on these variables.

Abbreviations

GDP	Gross Domestic Product
ON	Office Niger
OPIB	Baguinéda Irrigated Perimeter Office
DEA	Data Envelopment Analysis
FO	Farmers' Organizations

Author Contributions

Beidari Traoré is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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