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Analysis of the Determinants of Rice and Maize Productivity in the Southern Zone of Senegal

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Cereals occupy an important place in the consumption patterns of Senegalese populations. Among these cereals, rice and maize are expected to play a dominant role in the country's food security due to their importance in terms of the area sown. This study examines the determinants of rice and maize productivity in southern Senegal using a Cobb-Douglas production function with cross-sectional survey of 913 family farms. The results show that technical support, the number of plows, and the semi-manual mode have a significant impact on the productivity of both speculations. The technical support and the number of plows lead to an increase in rice and maize production while the manual sowing mode is negatively correlated with this production. Producers should be better equipped and technically supported in order to boost cereal production in Senegal.

Keywords: Family farm; productivity; rice; maize; Southern Senegal.

JEL Code: Q12, D13, Q10, Q19.

1. INTRODUCTION

The Senegalese population is highly dependent on cereals, which account for about 60% of national consumption and contribute between 12% and 15% of household income in production zones [1] to meet daily energy requirements. Indeed, the consumption patterns of Senegalese

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populations, both in the cities and in the countryside, are based on cereals which provide about 65% of calories and 61% of proteins [2]. The importance of cereals in Senegalese consumption combined with the annual increase in its population of 2.5% per year [3] implies an annual increase in the demand for cereals. However, the country's cereal production remains insufficient in relation to the needs of the population. Ndiaye and Niang [4], assert thus that agricultural production only covers about half of the food needs necessary for the consumption of the population. In this food dependency context, rice and maize can play a major role in the fight against food insecurity because of their importance in terms of area sown with 96,000 hectares for rice and 70,000 hectares for maize [5]. Rice accounts for 34% of the volume of Senegalese cereal consumption [6], yet only 20-30% of national demand for rice is covered by local production [5]. Rice production reached 469,649 tons of paddy rice in 2012 while the average annual production is 436,153 tons over the 2010-2013 period. In 2020, cereal production reached 2,768,406 tons, including 1,155,337 tons of rice, and 530,703 tons of corn, with an increase in corn production [7]. The gap to reach the threshold of 1,600,000 tons of paddy rice, necessary to ensure food self-sufficiency in Senegal, is more than 1,000,000 tons [8]. Also, maize, which is a crop of interest that contributes significantly to sub-regional food security, is characterized by low and highly variable productivity. Average yields increased from 900 to 1,000 kg/ha between 1998 and 2001 before decreasing by half between 2002/2003 (500 kg/ha), [9] while in 2001/2002 the average yield was 5.11 tons/ha globally, 7.16 tons/ha in Argentina and 6.68 tons/ha in the European Union [10]. Faced with declining productivity and thus the deficit in covering food needs, Senegal is resorting to imports, which are becoming increasingly important to meet national demand for cereals. Thus, from 1995 to 2011, rice imports in Senegal rose from 439,235 tons to 805,246 tons, an increase of more than 80%, while maize imports rose from 27,598 tons to 111,815 tons, an increase of 305% [11]. These massive imports are not without effect on the trade balance deficit caused in part by rice for about 16% [12].

To cope with this situation of insufficient cereal production, the Senegalese government has therefore made food self-sufficiency a major concern. Large-scale actions have been undertaken, particularly for rice and maize. As part of the Great Agricultural Offensive for Food and Abundance (GOANA) launched in 2008, the national rice self-sufficiency program (PNAR) that was developed in 2012 did not achieve its self-sufficiency objective. The revised PNAR, as part of the Plan Senegal Emergent (PSE) had a target of one million tons of with rice by 2018 [13]. The PRACAS which aimed at self-sufficiency in rice in 2017 with a production of 1,600,000 tons of paddy. In addition, the "special maize program" launched in 2003 has achieved a growth rate of 399% compared to 2002 [14]. Despite the implementation of this program and the GOANA, maize production started to decline again from 2010. The Loi d' Orientation Agro-Sylvo-Pastoral (LOASP), that aims to formalize the agricultural sector and to reach in the medium term the level of food security that guarantees food sovereignty of the country, adopted in 2004 to serve as a vision of the agricultural sector for 20 years, the Programme d'Accélération de la Cadence de agriculture (2014-2017); the National Livestock Development Plan (PNDE 2017-2021), the new Fisheries and Aquaculture Development Sector Policy Letter (LPSDPA) 2016-2023, the Environment and Sustainable Development Sector Policy Letter (LP/SEDD), the National Nutrition Development Policy (2015-2025), among others, have also been adopted by Senegal for the development of its agricultural sector. With the objective of achieving food self-sufficiency in rice in Senegal, progress has been made at certain levels such as access to quality seeds, supervision of producers, etc. Thus, rice production, which has become the driving force behind cereal production, is estimated at 945,617 tons in 2016 against 469,649 tons in 2012, representing an annual average increase of 25.3%. This performance corresponds to 65.4% of the growth objectives targeted for the sector within the framework of the PRACAS [15]. The performance achieved is therefore still insufficient with regard to the ambitions of rice self-sufficiency by 2022 and beyond. The Senegalese government thus seems resolutely committed to achieving emergence through self-sufficiency in cereals, despite the poor performance recorded in the implementation of agricultural development programs. But why is the productivity of rice and maize still low? What are the factors that could explain this low productivity? The answers to these questions should ensure greater effectiveness in achieving agricultural policy objectives. This is the interest of the present study, which seeks to analyze the determinants of rice and maize productivity in the southern zone of Senegal, which has one of the highest agricultural potentials in the country, with not only high rainfall but also water availability through rivers. The overall objective of this study is to analyze the determinants of cereal productivity in the southern zone of Senegal. Specifically, it is to analyze the contribution of socio-economic factors and cultivation practices on both rice and maize productivity.

Literature on the analysis of the determinants of agricultural productivity is quite extensive: [16,17, 18,19,20,21,22,23]. Overall, these studies show that soil fertility conservation practices as well as socio-economic factors such as off-farm income, fertilizer, training, dissemination of agricultural messages, improved seeds, etc. play an important role in improving agricultural productivity. Apart from these variables, agricultural equipment (number of ploughs and seeders) will be assessed from a productivity point of view as did [24] and [25], as well as technical support and seeding mode.

2. MATERIALS AND METHODS

2.1 Model Specification

Productivity estimation can be done with a flexible translog function, a quadratic function or a Cobb Douglas function. The theoretical framework adopted follows on from the work of [26,27,22] who used the Cobb-Douglas function to analyze agricultural performance in India, internationally and in China respectively. This function makes it possible to dissociate the different factors of production and consequently obtain the distinct elasticities and productivities of each factor [28]. However, there is a limitation of this function when applied in agriculture is that it does not admit zero inputs. In other words, a single zero input implies zero output. Production functions were developed as early as the end of the 19th century, at the same time as the theories of equilibrium and marginal productivity were developing [29]. A production function establishes, in the most general form, a relationship between outputs and inputs. It makes it possible, in a given environment, to express the entrepreneur's technological horizon, that is, the set of eligible choices available to him when he has adopted the most advantageous technical production process [29]. One of the production functions that is most often cited is the one studied around 1928 by Charles W. Cobb and Paul H. Douglas, called the Cobb Douglas function.

The general form of the Cobb-Douglas function is:

$$Y = a.\prod_i x_i^{\beta_i} \text{ Avec } a>0,\ \beta_i \geq 0,\ i = 1 \ldots .n \quad (1)$$

Where x_i represents the factors of production, βi the elasticity of production with respect to factor i

The linear model of equation (1) is obtained by taking the logarithm

$$\ln(Y) = \ln(a) + \sum_i \beta_i . \ln(x_i) \quad (2)$$

The application of the Cobb Douglas function to the two-factor production function gives the following general form:

$$Y = c\, K^{\alpha}\, L^{\beta} \quad (3)$$

Where Y is the level of output, it is a constant, K is capital and L is labor, and β and α are coefficients. The authors had imposed an additional condition of linearity and claimed that the sum of the exponents (+) was equal to 1. The expression of the function is then of the type:

$$Y = c\, K^{\alpha}\, L^{1-\alpha} \quad (4)$$

In this particular case where the sum of the coefficients is equal to 1, the returns to scale are constant (the function is homogeneous of degree 1), which means that if inputs are increased by a certain percentage, output is increased by the same percentage. In this study, constant returns to scale are assumed.

Thus from equation (1), the functional form of the Cobb-Douglas function can be written as follows:

$$Y = A x_1^{\beta 1} x_2^{\beta 2} x_3^{\beta 3} \ldots\ldots\ldots\ldots\ldots . x_n^{\beta n} \quad (5)$$

$$\log Y = A + \beta_1 \log x_1 + \beta_2 \log x_2 + \beta_3 \log x_3 \ldots\ldots\ldots + \beta_n \log x_n \quad (6)$$

With Y: Output; x_i the inputs and A the constant, takes into account the efficiency of the factors β_i: Production elasticities with respect to input i.

2.2 Definition of Explanatory Variables

The dictionary of independent variables as well as the expected theoretical signs of the associated parameters are presented in Table 1.

2.3 Empirical Specification of Econometric Models

Starting from equation (6) of the functional form of the Cobb-Douglas function, the estimated econometric models are as follows:

The econometric model estimated for rice productivity:

$$LYr = \beta_0 + \beta_1 \text{ EXPER} + \beta_2 \text{ MAN\_VRE} + \beta_3 \text{ FORM\_AGR} + \beta_4 \text{ NBR\_CHAR} + \beta_5 \text{AS\_ARB\_ARBU\_FERT} + \beta_6 \text{ SEX\_EXP} + \beta_7 \text{ APPUI} + \beta_8 \text{ MOD\_SEMr} + \beta_9 \text{ PEST\_RIZ} + \beta_{10} \text{TAILL\_MEN} + \beta_{11} \text{ NBR\_SEM} + \varepsilon_t \quad (7)$$

The econometric model estimated for maize productivity:

$$\text{L}Ym = \beta_0 + \beta_1 \text{ NBR\_CHAR} + \beta_2 \text{ JACH} + \beta_3 \text{ PAILLAGE} + \beta_4 \text{ MOD\_SEMm} + \beta_5 \text{ TAILL\_MEN} + \beta_6 \text{ FORM\_AGR} + \beta_7 \text{EXPER} + \beta_8 \text{ENGR\_MAIS} + \beta_9 \text{ APPUI}\varepsilon_t \quad (8)$$

Where, LYr and LYm are the logarithms of rice and maize productivity respectively. β_0 is the constant term. β_i are elasticity seedlings of rice and maize productivity with respect to the corresponding factors; ε_t is the error term.

There were about 20 variables that could explain the productivity of rice and maize. To retain only the statistically significant and non-collinear variables, the "stepwise" procedure was applied during the estimation for each of the two models.

2.4 Data Source

Within the framework of the agreement between the Programme de Développement des Marchés Agricoles du Sénégal (PDMAS) and the Institut Sénégalais de Recherches Agricoles (ISRA) on measuring the impact of PDMAS, these data were collected for the characterization of family farms in order to establish a baseline situation before the monitoring phase. The study covered the southern regions of Senegal, particularly the regions of Kolda, Sédhiou and Ziguinchor. The observation unit of the survey is the farm defined as the rural agricultural household in the National Agricultural Census (RNA). The family farm is understood in this study as "a family group within which agricultural production and the preparation and consumption of meals are organized". The stratified survey method was used, with the district, rural community and village as the criteria for differentiation. The choice of farms was made randomly. Nevertheless, the villages were selected according to a division respecting the subzones to ensure good representativeness. This choice was made in a participatory manner during workshops in which the representatives of the stakeholders participated. Thus, 38 villages were covered.

3. RESULTS AND DISCUSSION

3.1 Descriptive Analysis

The objective of this section is to analyze the data using descriptive statistics that summarize the variables that explain productivity. The results in Table 2 thus indicate that most of the farmers have not received any agricultural training (79.41%). In the Sédhiou region, for example, none of the farmers surveyed had received agricultural training. This may be due to the level of education. Of the three regions in the study area, the Sédhiou region has the highest rate of farmers with no education at all (80% of farmers in the region). The presence of the practice of fallowing is quite significant in the study area, in fact the results show that 43.7% of farmer’s fallow. The presence of other cultural practices such as straw burying and the combination of trees/bushes/fertilizers are low, with rates of 10.73% and 2.74% respectively. As a possible explanation, producers generally use straw to feed livestock, hence the low rate of straw burying. The results in Table 2 also show that only 34.17% of producers receive technical support (advice and assistance to producers). Farmers practiced both manual (52.14%) and mechanical (47.86%) sowing for rice cultivation Table 2. This is explained by the fact that this rice is grown in the uplands where both sowing methods can be used. This method of sowing rice is virtually the same as that practiced in the Ziguinchor region. In fact, 90.94% of farmers in the region use this method. The hand seeding method is less frequent for maize compared to rice. Only 27.60% of respondent’s sow maize manually.

The results in Table 3 show that the level of equipment of farmers is very low. The average number of ploughs is 0.26 per farmer and the average number of seeders is 0.77. The average number of ploughs is 0.26 per farmer and the average number of seeders is 0.77 per farmer. This shows that not all producers are equipped with a plough or seeder. As a result, the non-equipped producers rely on the equipment of the equipped farmers, and this can lead to non-compliance with the seeding period. Failure to observe the seeding period can have a negative impact on farm productivity. In each family, there are on average 18 people but only less than 10 are on average active (average labor force) and constitute the labor force. Farmers in the area are experienced, with an average of 17 years of experience. The average number of bags of fertilizer used per hectare is 8.70 for maize and 7.22 for rice. However, the high values of standard deviations (34.55 for maize fertilizer and 30.13 for rice fertilizer) show that fertilizer use is not well distributed in the zone. The averages found therefore hide disparities. As shown in the problem area, maize production per hectare rarely exceeds 1 ton. Indeed, the results show that the average maize production per hectare is 805.72 kg/hectare. The average rice production per hectare does not exceed 1 ton. It is 916.57 kg/hectare.

3.2 Econometric Analysis

Table 4 presents the results of the estimation of rice and maize productivity using the ordinary least squares method.

3.3 Post- Estimation Tests

In order to verify the model specification and lucidity of the ordinary least squares method used in this study, the following tests are performed before interpreting the results:

-Error Homokedasticity Test: After each estimate, the error homokedasticity test is performed to verify the optimality of the ordinary least squares method used. The identification of heteroskedasticity can be done using several tests, such as the Breusch-Pagan test, the Goldfeld test, the Gleisjer test and the White test. In this study, the Breusch-Pagan test is used to test the heteroskedasticity of errors. The hypotheses of the test are:

H_0 : Error heteroskedasticity

H_1 : Heteroskedasticity of errors

The null hypothesis is not rejected when the probability associated with the Chi-2 statistic is greater than the threshold. The results give a Chi (2) value of 0.24 with a probability of 0.62 for the maize productivity estimate and a Chi (2) value of 0.00 with a probability of 0.99 for the rice productivity estimate. The probabilities (0.62 and 0.99) are above the 1% threshold, so the null hypothesis of error homoscedasticity cannot be rejected for both estimates at the 1% threshold. The ordinary least squares method is valid for the estimates.

-Ramsey specification test: This test is performed to see whether or not the model is well specified. The model is incorrectly specified when relevant explanatory variables are missing.

The assumptions of the test are as follows:

H_0 : The model is well specified.

H_1 : The template is incorrectly specified

The results give an F-stat value of 0.76 with a probability of 0.51 for maize productivity and an F-stat value of 1.79 with a probability of 0.15 for rice productivity. Both probabilities being above the 1% threshold, one cannot reject the null hypothesis at the 1% threshold that the models are well specified. Both the rice and maize productivity models are well specified, so there is no lack of relevant variables in the estimation of the determinants of rice and maize. Since both econometric models are well specified and the ordinary least squares method is usable according to the Ramsey specification and error homoscedasticity tests performed, the following development presents the interpretation of the estimation results.

3.4 Interpretation of Results

Table 4 presents the results of the rice and maize productivity estimation. The probabilities associated with the F-stat obtained with the estimates are below the 1% threshold, which means that the rice productivity model and the maize productivity model are significant overall. They are therefore good models. The interpretation of the statistically significant explanatory variables is then carried out. The coefficients associated with the variables are semi-elasticities of productivity with respect to the same variables. The coefficient of each explanatory variable is interpreted as an approximation of the percentage of productivity for a one-unit change in the explanatory variable, all other things being equal, i.e. the other variables having remained constant. Analysis of the study shows that variables such as experience, labor, number of ploughs and technical support positively affect rice productivity.

Table 1. Definition of explanatory variables

Variables	Description	Expected effect
	Gender	
SEX_EXP	(1=mal , 0= female)	+
EXPER	Experience of the farmer (in years)	+
MAN_VRE	Workforce (in persons)	+
	Agricultural training	
FORM_AGR	(1=those who have received training, 0=if not)	+
	Technical support	
APPUI	(1=those with support , 0=if not)	+
Pest_RIZ	Pesticides used for rice(liter/ha)	undetermined
NBR_SEM	Number of seeders	+
TAILL_MEN	Household size (in persons)	+
NBR_CHAR	Number of ploughs	+
	Association trees/shrubs/crop fertilizers	
As_Arb_Arbu_Fert	(1=association, 0=if not)	undetermined
	Mode of sowing rice	
MOD_SEMR	(1=hand sowing , 0=mechanical sowing	-
	Mode of sowing corn	**-**
MODE_SEMM	(1=hand sowing, 0=mechanical sowing	
ENGR_MAIS	Quantity of fertilizer used for corn	+
JACH	Fallow land (1=those who practice, 0= if not)	+
	Burying the straw	
PAILLAGE	(1=those who practice, 0=if not)	+

Source: Author's construction from the literature review

Table 2. Descriptive analysis of dichotomous variables (%)

Dichotomous variables	Presence	Absence	Total
FORM_AGR	20.59	79.41	100
JACH	43.70	56.3	100
PAILLAGE	10.73	89.27	100
AS_ARB_ARBU_FERT	2.74	97.26	100
APPUI	34.17	65.83	100
MODE_SEMm	27.60	72.4	100
MOD_SEMr	52.14	47.86	100

Source: Author's calculation based on ISRA/BAME survey data

Table 3. Descriptive analysis of quantitative variables

Quantitative variables	Minimum	Mean	Maximum	Standard deviation
NBR_CHAR	0	0.26	2	0.5
NBR_SEM	0	0.77	5	1.05
EXPER (years)	1	17.15	70	11.91
TAILL_MEN (in personnes)	3	18.07	37	11.36
PEST_RIZ (litre/hectare)	0	0.26	5	0.97
ENGR_MAIS (number of bags/hectare)	0	8.7	300	34.55
ENGR_RIZ (number of bags/hectare)	0	7.22	250	30.13
MAN_VRE (number of active member)	1	9.76	26	7.04
Rice productivity (Kg/hectare)	166.67	916.57	2000	2403.12
Maize Productivity (Kg /hectare)	120	805.72	2666.67	886.25
Nonfarm income (of a year in FCFA)	0	64 791.89	1800000	160 388.20

Source: Author's calculation based on ISRA/BAME survey data

An increase of one point (one year) in the number of years spent in agriculture translates into an increase in rice productivity of 0.009% per hectare. The complexity of rice cultivation is evidenced by this result. This crop requires special knowledge and a good mastery of practices, and therefore experience. A similar result was found by [19] in Nigeria. An improvement of one point of labor (one asset) leads to an increase in rice productivity of 0.0207%. This confirms economic theory, particularly that of the importance of human capital in the production process. Technical support has an important effect on rice productivity. Farmers who have benefited from technical support have a 0.322% improvement in their productivity. Technical support can enable producers to overcome emergencies and meet pressing needs in the short term. The establishment of technical assistance committees to advise producers could then help boost cereal production.

The number of ploughs has a positive impact on rice cultivation, in fact one more plough unit implies a 0.141% improvement in rice production per hectare. According to [30], the plough increases the working capacity by a factor of four or five, and thus increases the harvest. In order to achieve the country's cereal production objectives, particularly in rice, the state can strengthen the level of agricultural equipment, particularly ploughs, in southern Senegal. The results associated with the variables household size, agricultural training, sex of the farmer (male), number of seeders and the semi in hand prove that they have a negative effect on rice productivity. An increase in the family size of the farmer by one point (one person) leads to a drop in production of 0.019% per hectare. This result can be explained by the high dependency rate (85.24% by calculation). This attests to the non-intervention of off-farm income in agricultural productivity. The larger the size of the household and therefore the higher the dependency rate, the more the off-farm income is used to cover other family needs such as health, housing, etc. and this can reduce agricultural production. Farmers who have received agricultural training have a 0.148% drop in production per hectare compared to those who have not. It can be argued that the training provided is not in harmony with cereal production. Training focused on cereal growing techniques is then to be promoted in the zone. Rice is generally grown by women in Casamance, so they have more experience than men. As experience is a factor that plays a positive role on productivity, as the results have shown, the difference in experience between men and women is noticeable at the level of productivity. Indeed, the results show that male farmers have a production per hectare of less than 0.565% compared to female farmers. Hand sowing of rice reduces productivity by 0.214% compared to mechanical sowing. Indeed, when hand sowing more precisely on the fly, the required spacing between the rice stems will not be respected and as a result, the cobs do not develop properly and this reduces productivity. Indeed [25], showed that mechanized sowing, unlike manual sowing, makes it possible to a large extent to secure production on the plots concerned because it allows the varieties to complete their cycle correctly.

To solve the problem caused by the hand seeding method, farmers need to thin the ears at a certain level of maturity. However, the number of seeders negatively affects rice production per hectare. An increase of one unit in the number of seeders reduces rice productivity by 0.122%. This result is in contradiction with that of [30] who shows that the seeder increases sowing capacity by a factor of six and thus increases productivity. The obsolescence of the seeders may be the explanation of our result. Indeed, the data show that the age of the seeders used by producers can go up to 38 years. The amount of pesticide used per hectare reduces rice production per hectare by 0.0922%. This result may be the cause of non-compliance with pesticide use standards or the fact that pesticides are used preventively. [31] argues that pesticides have a positive impact on crop yield when applied curatively but a negative impact when applied preventively. Among cultivation practices, only the association of shrubs/trees/fertilizers with crops is involved in rice productivity and affects it negatively. Farmers who associate rice cultivation with trees, shrubs and fertilizers experience a 1,416% drop in productivity. This is because a high density of trees and shrubs in the field can prevent photosynthesis and thus the proper development of the rice plants, resulting in lower productivity. The cultivation practices selected for this research are therefore not to be encouraged for rice cultivation. As for the productivity of maize, like that of rice, the number of ploughs and technical support have a positive impact. An increase of one plough unit translates into an increase in maize production of 0.1411% per hectare and farmers who have benefited from technical support have an improvement in maize productivity of 0.424%. In addition, similar to the results for rice, agricultural training and household size negatively affect maize productivity. An increase of one point (one person) in household size leads to a decrease in maize productivity of 0.0196% and farmers with agricultural training see their maize productivity decrease by 0.2562% compared to those without agricultural training. The explanations may be the same as for rice.

The chemical fertilizer composed of NPK and urea increases corn productivity to the 1% threshold. An increase of one unit of fertilizer (one bag) per hectare increases maize production by 0.0064%. This confirms the results of [23] and [22]. Maize is indeed a very demanding plant in terms of nutrients. Cultivation practices such as straw burial and fallow positively affect maize production per hectare. Certainly, there is an increase of 0.6915% and 0.2334% respectively in maize productivity per hectare for farmers who practice them compared to those who do not. The hypothesis of the favorable effect of cultivation practices on agricultural productivity is then verified in the case of maize. These results confirm the findings of [21] of the positive effect of soil conservation practices on agricultural productivity. In contrast to rice cultivation, cultural practices such as straw burying and fallow are to be promoted for maize. As with rice productivity, the hand-semi

Table 4. Results of Ordinary Least Squares (OLS) productivity estimation for rice and maize

Variables	Rice productivity (logYr)	Maize productivity(logYm)
Constant	7.458*** (0.195)	6.8254*** (0.1052)
MODE_SEMm		-0.3952*** (0.1203)
MOD_SEMr	-0.214** (0.0824)	
APPUI	0.322*** (0.0815)	0.427*** (0.1058)
SEX_EXP	-0.567*** (0.188)	
AS_ARB_ARBU_FERT	-1.416*** (0.236)	
NBR_CHAR	0.141** (0.0587)	0.141** (0.0698)
NBR_SEM	-0.122*** (0.0346)	
PEST_RIZ	-0.0922** (0.0362)	
FORM_AGR	-0.148* (0.0827)	-0.2562** (0.1199)
MAN_VRE	0.0207* (0.0112)	
EXPER	0.009*** (0.0034)	-0.0082* (0.0045)
TAILL_MEN	-0.019** (0.0078)	-0.0196*** (0.0050)
ENGR_MAIS		0.0064*** (0.0017)
JACH		0.2334** (0.0937)
PAILLAGE		0.6915*** (0.2114)
F-stat	6.15	6.89
Prob >F-stat	0.0000	0.0000
R^2	0.34	0.29

Source: Author's estimate based on ISRA/BAME survey data.
(*), (**), (***) Significant at 10%, 5% and 1%, respectively.
Values in parentheses are standard deviations

mode reduces maize productivity by 0.3952% per hectare. The explanations may be the same as for rice. However, the experience is negatively affecting maize productivity. One more year in maize production reduces productivity by 0.0082%. This result may suggest that experience is not needed to grow maize, which is an easy crop.

Only the variables technical support and number of ploughs positively affect both rice and maize productivity. Household size, agricultural training and manual sowing method have a negative impact on the productivity of the two crops under consideration.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This research analyzes the determinants of rice and maize productivity in the southern zone of Senegal through a Cobb-Douglas production function. Microeconomic cross-sectional data collected in 2012 through surveys of 913 family farms are used. The analysis identified other factors, in addition to off-farm income, fertilizers, and soil conservation techniques, that affect rice and maize production. Indeed, the results show that rice and maize productivity are correlated by variables such as technical support, a number of plows, and hand-semi mode. Producers who received technical support had an increase of 0.322% and 0.427% in production per hectare respectively for rice and maize at the 1% threshold. The results also showed that an increase of one plow unit boosts production per hectare for rice and maize by 0.141% at the 5% threshold. On the other hand, the semi hand plow mode negatively affects the production per hectare of both crops. At the 5% threshold, hand sowing reduces rice productivity by 0.214% and maize productivity by 0.3952% at the 1% threshold. With the government's objective of food self-sufficiency through the national rice and maize development strategies, a contribution can be made through the following recommendations made in view of the results obtained.

Firstly, technical support to producers should be promoted through advice and assistance on cultivation techniques and methods, all of which would increase the productivity of rice and maize. Policies to strengthen and modernize agricultural equipment, especially plows, would give producers the opportunity to intensify their cereal production. Modern and adapted seed drills should be used to respect sowing density. The semi-mechanical mode should then be promoted to the detriment of semi-manual. Specifically, for rice, the dosage and period of pesticide application should be respected by the producers through technical support. For the intensification of maize, which is a nutrient demanding crop, producers should have greater access to fertilizers through, for example, fertilizer price subsidies.

A limitation of this study is the fact that it does not take into account climate change and its effects such as sea level rise on our study area. For future research, it would be interesting to take this limitation into account in order to better analyze the determinants of cereal production in the southern zone of Senegal.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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