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Rainfall variability and agricultural production in the Lower River Region (Gambia): Case of rice and maize

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ABSTRACT: In the Gambia, particularly in the Lower River Region, agricultural production in mt has increased over the past two decades despite variability in rainfall conditions. In response to this finding, the study aims to analyze the evolution of rice and maize production in the Lower River Region, and to determine, in particular, the dependence or independence of each production on rainfall and cultivated areas. To do this, data on production in mt and hectare cultivated areas of rice and maize between 1981-2016, and precipitation data over the same period are used. These data are derived respectively at the level of the Gambia Department of Agriculture Planning Services and the Department of Water Resources. Their treatment was based on statistical data, including descriptive statistics, Pearson correlation, and simple linear regression. The calculation of the simple linear regression at the $p<0.05$ threshold indicated a non-significant relationship between rice and rainfall. In other words, rice does not depend on rainfall. This is not the case for corn, where the linear regression equation was found to be significant with $b=0.395$, $(1,34)=-0.606$, $p<0.05$. On the other hand, with respect to cultivated areas, the results show that rice production is highly dependent on it. The linear regression equation was found to be significant with $b=0.679$, $(1,34)=2,485$, $p<0.05$. Adjusted R^2 is 44.5%. It is even more significant for corn with an adjusted R^2 of 100%.

KEYWORDS: agricultural production, rainfall variability, crop area, statistical analysis, lower river region.

1 INTRODUCTION

Climate is the most important factor governing food production and causes inter-annual variability in socio-economic and environmental systems related to the availability of water resources [1] and their use. In West Africa, agriculture is a major economic sector and is most vulnerable to climate change [2]. For the West African monsoon, which rhythms the agricultural calendar, is becoming shorter as we move north, and its abundance is becoming smaller [3]; those, despite a return to wet rainfall conditions noted since 1999 [4].

In the Gambia, since 1988, agricultural production has faced the consequences of climate variables such as reduced precipitation and increased temperature [5]. However, in the Lower River Region, despite a variability in rainfall conditions since the 1970s-80s, with periods ranging from wet to dry [6], production in mt of the two main food crops, rice and corn, has tended to increase. On the contrary, estimated by annual trends in historical precipitation, minimum and maximum temperatures, relative humidity and sunshine, production in kg/ha declined between 1987-2016 [7]. According to the same source, 50% of the decline in rice production and 19% of the decline in maize production is related to climate variability. It is therefore obvious that rainfall variability is not the only and main explanation for the variability of production in the Lower River Region.

In response, this study attempts to analyze the evolution of rice and maize production in the Lower River Region and, above all, to determine the dependence or independence of each production on rainfall and cultivated areas.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The study was conducted in Lower River Region of The Gambia which is located between latitudes 130 34' 0" N and longitude 140 47' 0" W (Figure 1). The region has an agrarian economy and more of its inhabitants are directly or half involved in crop production [7]. It has a Sudano-Sahelian climate characterized by a short rainy season from June to October. Mean annual rainfall varied from 900 mm in the South West to about 600 mm in the North East [8]. Mean temperatures from 25°C to 28°C are generally higher in the Eastern part of the country. It has a total land area area of 1,618 km2 [9].

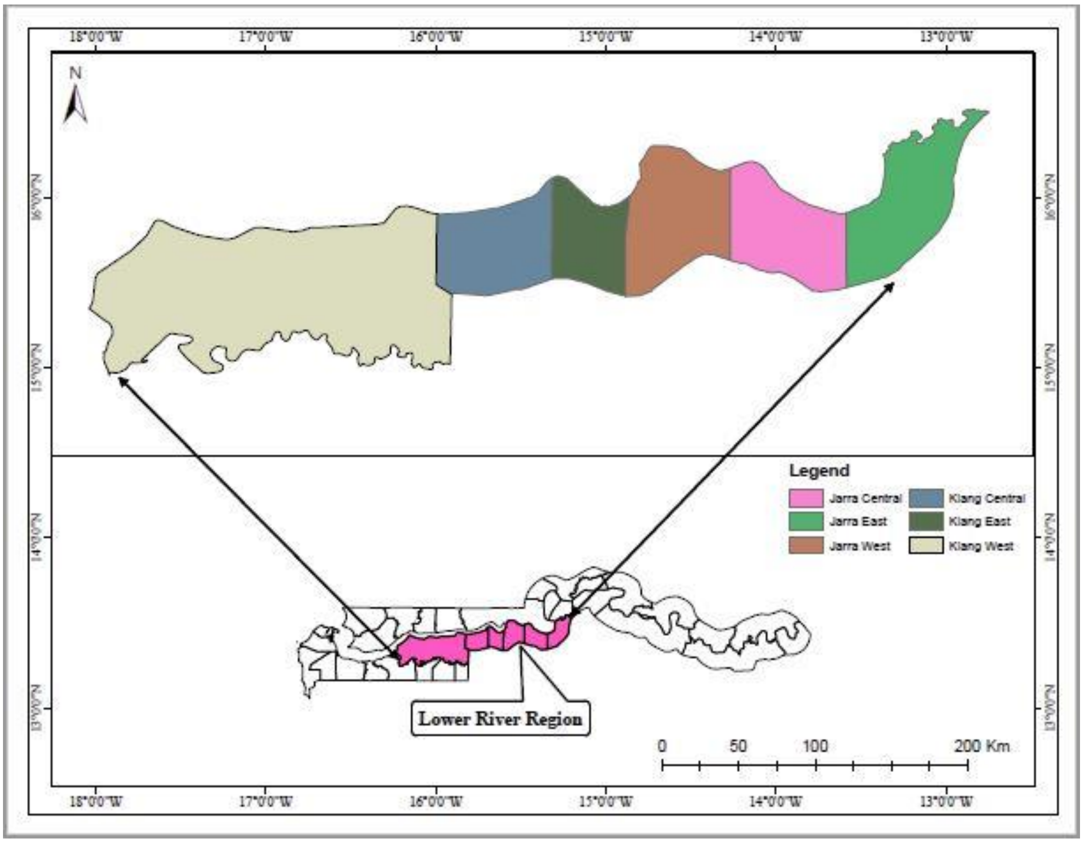

Fig. 1. Location of study area

2.2 DATA USED

Two data sources are used in this study. First, we have data on rice and maize production in the Lower River Region between 1981-2016. This data is from the Department of Agriculture Planning Services of the Gambia. Then we have the precipitation data from the Jenoi station over the same period, provided by the Department of Water Resources. In this study, production in kg/ha will not be taken into account, much less the data on minimum and maximum temperatures, relative humidity and sunshine duration as [7].

2.3 METHODS

The data were processed using statistical processes using the SPSS software. This is the calculation: of descriptive statistics, Pearson correlation, and simple linear regression. Descriptive statistics include trend measures (mean), dispersion measures (standard deviation and interquartile interval), minimum and maximum.

Pearson's correlation measures the linear relationship between two variables. It is essential to check the linearity of the relationship. It can take values between -1 and 1. When it is close to -1, there is a strong negative relationship. When it is close to 0, there is no linear relationship. When it's close to 1, we're talking about a strong positive linear relationship.

For simple linear regression, it not only measures the linear relationship between two continuous variables, but also the effect of an independent variable (IV) on a dependent variable (DV), depending on the number of samples and the nature of the variables studied. In this study, the dependent variable is yield; while the independent variable is rainfall or cultivated area. For this, we used adjusted R^2 and ANOVA. The significance threshold used is 0.05, a 95% confidence interval.

3 RESULTS AND DISCUSSION

3.1 ANALYSIS OF THE EVOLUTION OF RICE AND MAIZE PRODUCTION BETWEEN 1981 AND 2016 IN THE LOWER RIVER REGION

The development of rice and maize production between 1981 and 2016 is shown in Figures 2 and 3 respectively. For rice, the result generally indicates a boom-and-bust development with periods of high and low production. Between 1981-1984, production was significant with output exceeding 4000mt. Between 1984 and 1986, it fell before experiencing a sharp increase in the next two years (with 4975mt in 1987, and 7744mt in 1988). In fact, 1988 was the year with the largest production in the Lower River Region. After this year, production declined overall; those until 2007 (year of lowest production with 535mt) (Table. 1). Between 2008 and 2012, rice production increased further, before falling in 2013, 2014 and 2015; the area, despite the increase in cultivated areas.

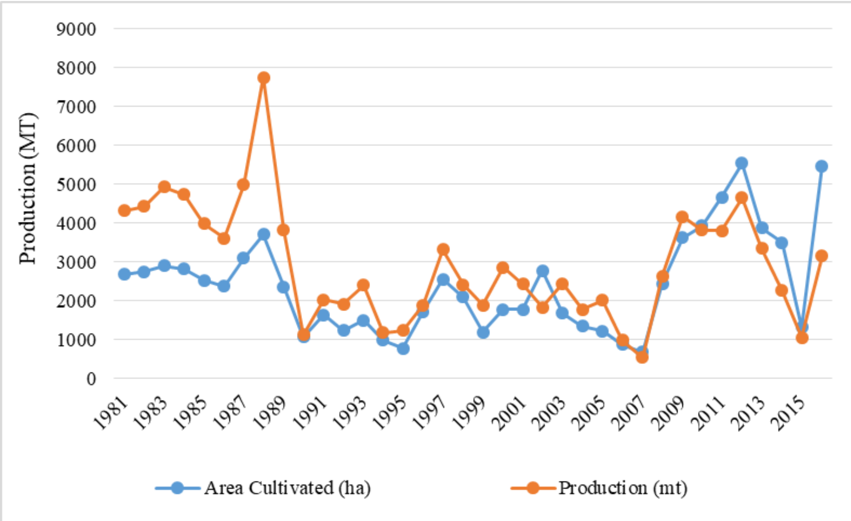

Fig. 2. Rice Production Trends 1981-2016 in the Lower River Region

As for maize, the result indicates a gradual evolution of production, with both an increase and a decrease. The maximum of successive years of increase in production shall not exceed six years. The year 2009 was the year with the highest production at 3537mt (Table. 1). The year 1998 was the lowest production with 346mt. Moreover, between 2009 and 2011, production fell sharply from its normal level. This is because 2011 saw the lowest rainfall recorded since 1990 [8].

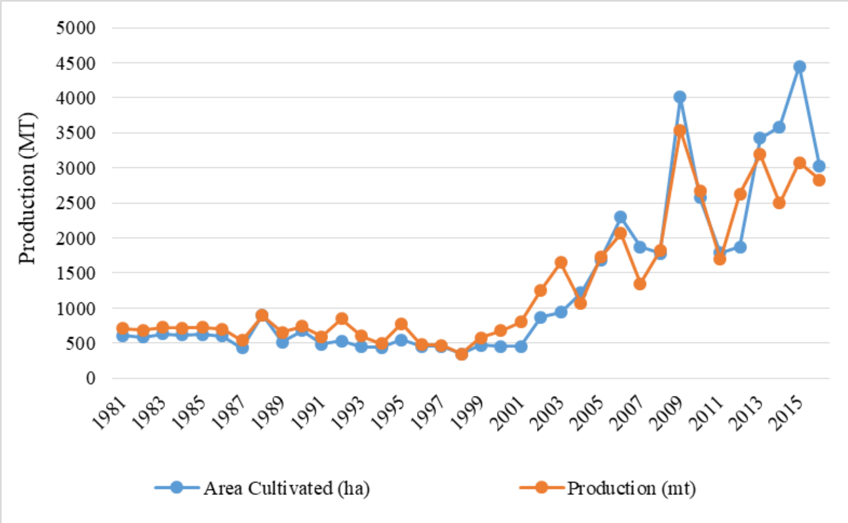

Fig. 3. Trends in maize production between 1981 and 2016 in the Lower River Region

However, it should be recalled that despite these encouraging productions in recent years, projections from climate models all foresee reductions in crop yields (in the range of 11 to 18%) in West Africa mainly due to warming [2]. Using CSIRO_RCP4.5 and NOAA_RCP4.5, [7], predict a decrease in future yields of maize and rice due to the vulnerability to climate variability in our study area.

The results of the descriptive statistics for both products indicate that the average rice production is 2928mt (Table. 1). For maize, the average production is 1301mt.

Table 1. Descriptive statistics on rice and maize production

		Year	Rainfall	Area Cultivated Rice (ha)	Rice Production (mt)	Area Cultivated Maize (ha)	Maize Production (mt)
N	Valid	36	36	36	36	36	36
	Missing	0	0	0	0	0	0
Mean		1998.50	810.53	2393.853919	2928.194909	1297.013859	1300.884318
Std. Deviation		10.536	214.693	1264.9904052	1499.8081232	1155.0332248	920.5622474
Minimum		1981	383	670.0000	535.3300	346.0000	346.3460
Maximum		2016	1338	5526.0000	7744.1000	4447.6000	3536.5730
Percentiles	25	1989.25	636.00	1316.125000	1885.250000	470.555200	662.456838
	50	1998.50	803.05	2361.727723	2535.518000	630.298896	789.355507
	75	2007.75	963.30	3041.500000	3928.750000	1853.500000	1794.771000

3.2 Analysis of dependence or independence of rice production and rainfall maize between 1981 and 2016 in the Lower River Region

The Pearson correlation calculation yielded the following results: 0,101 for rice, 0,395 for corn. These results indicate that there is a strong positive linear relationship between corn production and rainfall, which is the dependent variable. For rice, the result indicates a weak positive linear relationship.

The simple linear regression equation applied for each product at the $p<0.05$ threshold indicated that corn is the crop that significantly depends on rainfall (Table 2). Indeed, a significant linear regression equation was found with b=0.395, (1, 34)=-0.606, $p<0.05$. Adjusted R^2 is 13%; This means that rainfall in the Lower River Region accounts for some of the changes in maize production. For rice, however, the regression equation was found to be insignificant with b=0.101, (1, 34)=2.361, $p>0.05$ (Table 3). Adjusted R^2 is -1.9%. This is due to the geographic location of the study area. Indeed, with little rainfall, the rice fields are submerged because of topographic nature of the landscape. Most of the rice ecologies in the study area are swampy lowland behind the mangroves. When it rains, water from the residential areas emptied around this area causing inundation and water will stay for days for the rice plant to utilize. It is also noted that the water table around these ecologies normally rise during the wet season, which could also be a contributing factor why rice is not depending on only rainfall. This would have being the reason why rice production was not directly depending on rainfall unlike maize.

Table 2. Result of simple linear regression applied to maize

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.395[a]	.156	.131	2171.135	.156	6.273	1	34	.017

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	29569078.254	1	29569078.254	6.273	.017[b]
	Residual	160270115.163	34	4713826.917		
	Total	189839193.417	35			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-868.031	1431.694		-.606	.548
	Rainfall	4.281	1.709	.395	2.505	.017

Table 3. Result of simple linear regression applied to rice

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.101[a]	.010	-.019	1513.977	.010	.349	1	34	.558

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	800592.805	1	800592.805	.349	.558[b]
	Residual	77932248.195	34	2292124.947		
	Total	78732841.000	35			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2357.184	998.539		2.361	.024
	Rainfall	.704	1.192	.101	.591	.558

3.3 ANALYSIS OF THE DEPENDENCE OR INDEPENDENCE OF RICE PRODUCTION AND MAIZE ON THE AREA CULTIVATED BETWEEN 1981 AND 2016 IN THE LOWER RIVER REGION

The Pearson correlation calculation yielded the following results: 0,679 for rice, 1,000 for corn. This means that there is a strong positive linear relationship between rice and maize production and cultivated areas.

The simple linear regression equation showed that both rice and corn are significantly dependent on cultivated areas (Table 4 and 5). For rice, the regression equation was found to be significant with b=0.679, (1, 34)=2.485, $p<0.05$. Adjusted R^2 is 44.5%. For corn, the linear regression equation gave b=1,000, (1, 34)=-8.688, with $p<0.05$. The adjusted R^2 is 100%.

Table 4. Result of simple linear regression applied to rice

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.679[a]	.461	.445	1117611	.461	29.034	1	34	.000

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36264989.176	1	36264989.176	29.034	.000[b]
	Residual	42467851.824	34	1249054.465		
	Total	78732841.000	35			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1001.883	403.109		2.485	.018
	AreaCultivatedRice_ha	.805	.149	.679	5.388	.000

Table 5. Result of simple linear regression applied to maize

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1 .000[a]	1.00 0	1.000	6.334	1.000	473253 2.722	1	34	.000

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	189837829.562	1	189837829.562	4732532.722	.000[b]
	Residual	1363.855	34	40.113		
	Total	189839193.417	35			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-13.899	1.600		-8.688	.000
	AreaCultivatedMaize_ha	2.016	.001	1.000	2175.439	.000

4 CONCLUSION

The purpose of this study was to analyze the development of rice and maize production over the last 35 years in the Lower River Region through a joint use of mt production data, rainfall data and cultivated area data. The results showed that agricultural production in mt increased overall. The Pearson correlation calculation showed that there is a strong positive linear relationship between rice and maize production with cultivated area. The calculation of the simple linear regression at the $p<0.05$ threshold indicated that maize is significantly dependent on rainfall; This is not the case with rice. On the other hand, in terms of cultivated areas, the results show that rice production is highly dependent on it. The linear regression equation was found to be significant with b=0.679, (1.34)=2.485, $p<0.05$. Adjusted R^2 is 44.5%. It is even more significant for corn with an adjusted R^2 of 100%.

These results are important to the country's farmers, development actors, and agricultural production directorates and programs. However, the study did not take into account certain parameters that also influence production, such as: the number of rainy days per year, the average precipitation per rainy day, the start and end date of the "agronomic" monsoon, as well as its duration, agricultural policies, technical constraints, and organizational constraints. The study therefore recommends that these parameters be included in future analyzes

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