IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 5, May 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

Study of the Dynamics of Cotton Production in Banikoara A Commune Based On an Econometric Model

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Abstract: Cotton production is a pathway out of poverty for the people of Banikoara and should be used judiciously in the face of climate variability. In recent years, climate instability has played a nasty trick on producers and decision-makers because expected production or yield statistics are not being met. Based on these findings, this study is part of an investigation into the impacts of this climate variation on agriculture in our field of study. Thus, we will analyze the agro-climatic determinants of cotton production in the commune of Banikoara from 1985 to 2016 using an autoregression vector (ARV) econometric model. After their PCA in order to measure the link between them and cotton production, the results show that only the rainfall heights and the areas sown in logarithmic terms could be used for the analysis in terms of elasticity. The positive tests of unit root and co-integration made it possible to estimate an ARV model. Shocks were also induced on the variables to assess their effect on the other variables after their Granger causality test. The results obtained are also confirmed by the analysis of the variance decomposition of the forecast error variance showing that the two parameters positively influence cotton production in Banikoara but in a relative way. Moreover, the ARV estimates showed that the signs of their coefficients are positive. The positive shock amplitude for cotton production is 0.41, the positive shock amplitude for rainfall is 166.5 and the positive shock amplitude for area sown is 0.67. In view of these important results, it is clear that there is a correlative relationship between cotton production and rainfall heights and the area sown in Banikoara.

Key words: model, co integration, variance, cotton and Banikoara.

Introduction

Agriculture continues to be the main economic sector on which the majority of the African population depends for survival. The sector employs more than 60% of the working population and contributes about 35% to the GDP of most African countries and more than 40% in the least developed countries of Africa, Guèye, 2006, p.22. The agricultural sector is the essential engine of economic and social development for most poor countries and most often employs the majority of the workforce. In Benin, cotton production is carried out by several million small farms spread over thousands of villages scattered over vast areas, AIC, 2010, p.19. Over the past four decades, cotton cultivation has played a major role in the agricultural development of tropical areas, particularly in Africa. Indeed, this crop has enabled farmers to obtain income, improve their standard of living and contribute to the modernization of the infrastructure used by the populations. The recognized importance of cotton in Africa is evident in Benin, which held the record for the highest rate of increase in cotton production (300% between 1990 and 2002) of all the countries of the West and Central Africa. However, this rate of increase subsequently fell drastically to 200% between 2003 and 2007, Matthess et al, 2005, p 18. Thus, the current problems of low productivity despite the existence of more or less efficient production technology, the decline in market share, and institutional, environmental and climatological problems are the main difficulties observed in recent years. This situation calls for an analysis of the determinants of cotton production in Benin and in particular in the commune of Banikoara. This production is practiced in a rainfed system without irrigation. The high variability of rainfall makes all forecasts at the beginning of the season very uncertain and constitutes an important risk factor. Cotton production in the commune of Banikoara represents more than 45% of national production. For these populations, the agricultural sector is a way out of poverty that should be judiciously exploited in the face of new climatic conditions. Consequently, this situation leads us to question the degree of involvement of certain factors to the point that they constitute a major constraint for cotton cultivation in the commune of Banikoara.

1. Material and methods

1.1 Study Environment

Located in northwestern Benin (Figure 1), the commune of Banikoara is bordered to the north by the commune of Malanville, to the south by the communes of Gogounou and Kérou, to the east by the commune of Kandi, and to the west by the Republic of Burkina-Faso. It covers an area of 4,383 km² of which nearly 2,148 km² is arable land, i.e. 48.15% of the total land area of the commune. There are two distinct seasons overlapping two consecutive years: a rainy season from May to October and a dry season from November to April. RGPH4, 2013, p 4. These natural and human conditions favor the production of a diverse range of crops such as: cotton, corn, sorghum, millet, rice, yams, cassava, etc. The commune of Banikoara has many developable lowlands, this agricultural activity is accompanied by livestock essentially large cattle, RGPH4, 2013, p 5. The geographical position and the importance of trade make Banikoara a zone of commercial and economic transactions between Burkina Faso, Togo and neighboring communes such as Kandi and Karimama. Banikoara also has tourist assets insofar as the Niger W Park occupies 2,235 Km² or more than 49% of the total area of the commune. RGPH4, 2013, p 5.

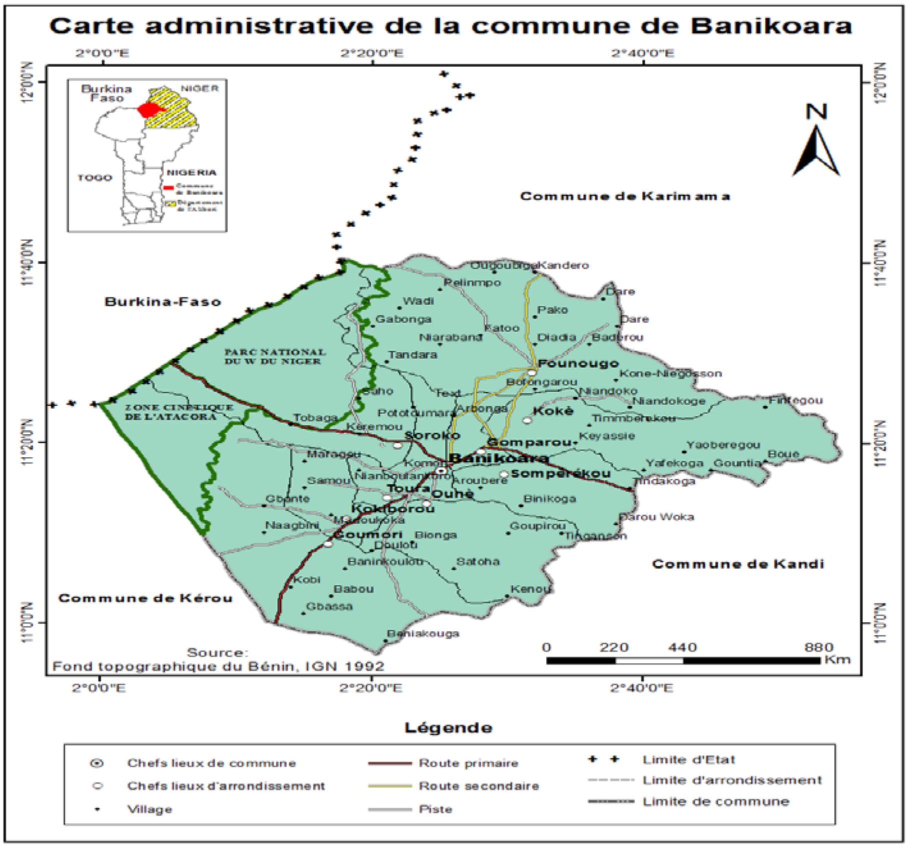

Figure 1 : Commune de Banikoara

1.2 Méthods

1.2.1. Identification of the model

Taking into account the scientific literature on agricultural production and on cotton mainly, several trends can be observed. Firstly, an increase in cotton production is due to good rainfall, so good rainfall has a positive impact on production, thus guaranteeing a good inflow of currency to the country and to producers. Secondly, the area planted also influences production, which encourages producers to produce more. Thus, taking into account all these considerations, we have chosen a Autoregressive Vector model for this model, possibly an error correction model (ECM) in the case of a single co-integration relationship or a Vector Error Correction Model (VECM) in the case of several co-integration relationships between variables. ARV models do not restrict the heterogeneity of the variables. It is a modeling without any a priori restriction other than the choice of the selected variables and the number of lags. This will be done according to the following tests: unit root tests; co-integration tests; causality and estimation tests according to the case of a simple ARV or an Error Correction Model (ECM), or a Vector Error Correction Model (VECM).

1.2.2. Principal Component Analysis PCA of the pre-selected variables

Principal Component Analysis (PCA) is a method of analysis of data tables of the type individuals X variables in the case where all the variables are numerical and very heterogeneous. This technique consists in reducing to a small number of variables called principal components, uncorrelated between them and summarizing as well as possible the initial data. The PCA used in this study made it possible to reduce superfluous variables while detecting the best correlations between production and these variables. It also allows the choice of variables for the model (ARV). The representation of the cloud of variables is as follows:

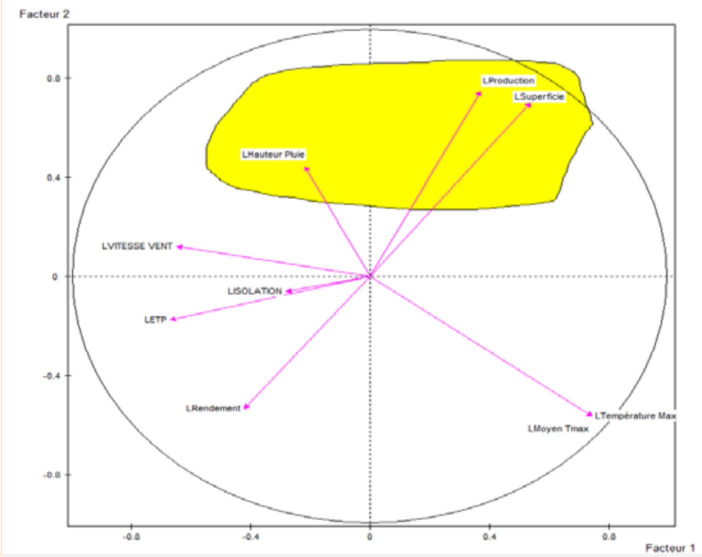

Figure 2: Representation of the cloud of variables

An analysis of Figure 2 shows that of all the variables initially chosen, only three emerged after the application of PCA. These are production, area sown and rainfall.

1.2.3. Choice of variables for the ARV

The cloud of variables shows that area and rainfall are the ones that are closest to production in the factorial design (PCA results). Furthermore, the correlation matrix between the variables shows that these variables have the best correlation with production. Therefore, for the purposes of the econometric study, we will focus on the following three variables: cotton production, area and rainfall.

1.3. Stationarity and its test

1.3.1. Concept of Stationarity

A process is stationary at second order if all its moments of order one and order two are independent of time. That is, a process (x_t, t∈Z) is said to be second-order stationary, or stationary in the weak sense, or second-order stationary if the following three conditions are satisfied:

•$\forall\ t \in z, E\ (x_t^2\ ) < \ \infty$
• $\forall\ t \in z, E\ (x_t) = m$ indépendant from *t*
• $\forall(t, h) \in z^2, cov(x_t, x_{t+h}) = E[(x_{t+h} - m)(x_t - m)] = \gamma(h)$ Indépendant from *t*.

In contrast, a non-stationary process is a process that does not satisfy either of these two conditions. Thus, the origin of the non-stationarity can come from a dependence of the first order moment (the expectation) with respect to time and/or from a dependence of the variance or the auto covariances with respect to time. The fact that a process is stationary or not conditions the choice of the modeling that one must adopt.

As a general rule, if we follow the methodology of Box and Jenkins, when the series under study comes from a stationary process, we look for the best model among the class of stationary processes to represent it, and then we estimate this model. On the other hand, when the series comes from a non-stationary process, we must first of all try to "stationarize" it, i.e. find a stationary transformation of this process. Then, we modelize and estimate the parameters associated with the stationary component. The difficulty lies in the fact that there are different sources of non-stationarity and that each origin of non-stationarity is associated with its own method of stationarization. We will make the analysis from two processes: the TS (Trend Stationary) processes which represent a non-stationarity of deterministic type. DS (Differency Stationary) processes for random non-stationary processes.

1.3.2. Augmented Dickey Fuller test (ADF)

The ADF test is a parametric correction of the simple Dickey-Fuller tests which assumes that the errors of the models are white noise. The ADF test is an extended case in which the error follows an AR (p) process.

1.4. Co-integration

1.4.1. Concept of co-integration

When the series are not stationary, there is a risk of co-integration between these variables. Several statistical properties apply only to stationary series. This raises problems insofar as most series representing economic variables are affected by a long-term trend. Empirical simulations allowed Granger and Newbold to show that the distribution of Student's t in a simple model of the type $Yt = ax + b + a_t$ in the presence of unit roots can no longer be interpreted according to Student's and Fisher's law. Between series admitting unit roots, there are chance correlations that have no real meaning and no real basis. It can therefore be concluded that relationships exist that in reality do not. Granger and Newbold showed that this is very likely if the regression has a low Durbin Waston (DW) and a high R^2.

1.4.2 Co-integration test

Co-integration tests are used to statistically verify the existence of co-integration relationships and actually evaluate the number of co-integration relationships that exist between variables. There are two methods, which we will discuss in turn.

2.4.3. Engel and Granger's two-step method

When the variables are integrated in the same order, this method proposes to first run a statistical regression between these variables, recovering the residuals as new variables, and then testing the stationarity of the residuals using the DFA tests. It should be noted that the use of Dickey and Fuller tables is no longer possible. In fact, the test concerns the residuals estimated from the statistical relationship and not the "true" residuals of the co-integration relationship. These variables are then said to be co-integrated when this test concludes that the residuals are stationary and we can distinguish either the absence of a linear trend in the data or the presence of a linear trend in the data or the presence of a quadratic trend in the data.

1.5. Method of data collection

The data used are of two types, those relating to cotton production (area, yield and production) are taken from the database of the Direction de la Statistique Agricole (DSA) over the period 1985-2016. Meteorological data were taken from the compendium of the database of the Agro-Meteorological Service of the National Meteorological Department (DMN) for the period 1985-2016 at an annual time step, i.e., over 30 years. The choice of this range of years is necessary in order to respect the requirements of the WMO on the climatic phenomena whose representative temporal unit is in the order of thirty years.

2. Result

2.1. Econometric analysis

The Unit Root Test, the Order of Integration Test and the Augmented Dickey Fuller Test performed on the three series reveal the following results: the rainfall variable is stationary at level. As for the production variable, it is stationary with trend, so we collected the residuals of an OLS regression model of the series on its trend on which we performed again an ADF test. It is stationary at level. For the area variable, it has been differentiated and thus made stationary. It is therefore stationary in first difference. The Johansen co-integration test showed that the production and rainfall variables are stationary at level while the area variable is stationary in first difference. Given the unit root results above, there is no risk of co-integration, hence the appropriate model for the data in this study is the Autoregressive Vector (ARV). The determination of the number of lags of the ARV was done using the information criteria. The choice of the optimal order here is easy in that the criteria follow a similar chronology. However, it is easy to decide this issue by looking at the order of the criteria with the smallest value. The optimal number of delays here is 1 if we take all these considerations into account. These results are reported in Table II below.

Table II: Number of Delays

VAR Lag Order Selection C Endogenous variable : RESIDLPRODUCTION DLAREA RAIN_LEVEL						
lag	LogL	LR	FPE	AIC	SC	HQ
0	-2288498	NA	1765.5250	15.98964	16.13108	16.03394
1	-2080258	35.90332*	785.1495*	15.17420*	15.73997*	15.35139*
2	-2034915	68.79665	1094.1100	15.48217	16.47228	1579226

Source: Authors' calculation results

In Table II, only criterion 1 has the smallest value of LR, FPE, AIC, SC and HQ then the lag order is 1.

In order to know the most relevant equations to be analyzed after the VAR, we need to do the causality test whose results are presented in Table III.

Table III: Causality in the sense of Granger

Null Hypothes		Obs	F-Statistic
0	LAREA does not Granger Cause LPRODUCTION LPRODUCTION does not Granger Cause LAREA	30 30	0.66910 1.57814
1	RAIN_LEVEL does not Granger Cause LPRODUCTION LPRODUCTION does not Granger Cause RAIN_LEVEL	30 30	**0.04629** 1.16385
2	RAIN_LEVEL _does not Granger Cause LAREA LSUPERFICIE does not Granger Cause RAIN_LEVEL	30 30	0.09511 0.06385

Source: Authors' calculation results

From this table, we read the influence of rainfall on production is statistically significant in the granger sense because 0.04629 is less than 0.05.

2.2 Estimation of the ARV model

Selection of the optimal model as it is recommended in case of choice between several models, we referred to the information criteria so we estimated the ARV with the variable RESIDLPRODUCTION. In this case, we distinguished the sub-cases with constant and without constant. The results of the information criteria are shown in Table IV

Table IV: Optimal model

CRITERION D'INFORMATION	MODEL WITH RESIDLPRODUCTION VARIABLE	
	With constant	Without constant
AIC	16.02	16.88
SC	16.58	17.30

We therefore retain an ARV model with the three variables with constant because the AIC and the SC of the variables with constant are lower than those of the variables without constant.

2.2.1. ARV model

Table V: Estimated Autoregressive Vector Model (ARV)

	RESIDLPRODUCTION	DLPAREA	RAIN_LEVEL
RESIDLPRODUCTION (-1)	0.053056 (0.20783) [0.25529]	-0.652718 (0.33750) [-1.93397]	161.5553 (84.0757) [1.92154]
DLPAREA (-1)	0.122934 (0.11364) [1.08175]	-0.253667 (0.18455) [-1.37451]	-15.70788 (45.9736) [-0.34167]

RAIN_LEVEL (-1)	0.000807 (0.00048) [1.68620]	0.000535 (0.00078) [0.68882]	-0.137331 (0.19353) [-0.34167]
C	-0.760715 (0.45884) [-1.65791]	-0.432252 (0.74513) [-0.58010]	1075.089 (185.620) [5.79187
R^2	0.672251	0.52989	0.386160
R^2 Adjusté	0.076742	0.143372	0.025333
AIC	1.185952	2.155663	13.19146
SC	1.372778	2.342490	13.37829

Source: Authors' computational results, standard errors in ( ) and t-statistics in [ ].

The analysis of figure 7, shows that no root of the characteristic polynomial is out of the unit circle, i.e., all roots are smaller in modulus than 1

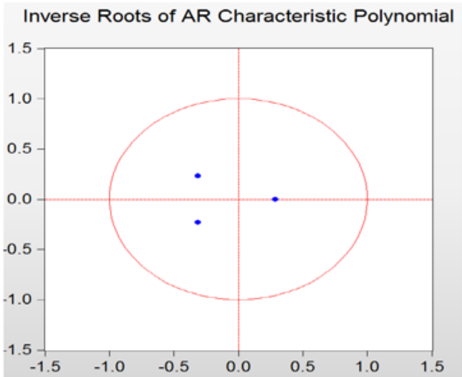

Figure 7: Characteristic polynomial

The arrangement of the three parameters in the orthonormal field of figure 7, confirms the efficiency and stability of the model.

2.2.2. Autocorrelation of the residuals

We test the null hypothesis of no autocorrelation of the residuals (table VI)

Table VI: Autocorrelation of residuals

Lags	LM-STAT	PROB	Lags	LM-STAT	PROB
1	4.416883	0.8819	6	1.910331	0.9928
2	5.412666	0.7970	7	3.884577	0.9188
3	3.793127	0.9245	8	6.788255	0.6592
4	8.427006	0.4918	9	11.33271	0.2536
5	8.362826	0.4980	10	7.733396	0.5612
6	1.910331	0.9928	11	6.935293	0.6439

Source: authors' estimates

The results in Table VI indicate that the residuals are not self-correlated.

2.2.3 Error heteroscedasticity test

It is used to test the constancy of the error variance over time. This test measures the risk of the magnitude of the error whatever the period. The errors are heteroscedastic if the probability is lower than the critical threshold of 5%. The test used is White's and the probability is 0.4258 so < 5% then the errors are heteroscedastic.

2.2.4 Test of normality of the residuals

This test is done using the Jarque and Bera statistics. We test the null hypothesis of normality of the residuals. J-B follows a Chi-square distribution with 2 degrees of freedom under the normality hypothesis. We accept the normality hypothesis at the 5% threshold if J-B< 5.99 or if Probability >0.05. Here J-B is 4.632307 and the probability is 0.0. We conclude that the residuals follow a normal distribution for the explained variable which is cotton production.

Table VII: Summary of the validity tests of the estimated ARV model.

Equations (Dépendant Variable)	Jarque-Bera Normalitéy Test	White thomoscedasticity Test	Breush-Godfrey résidual of autocorrélation Test
PRODUCTION	+	+	+
RAIN_LEVEL	+	+	+
AREA	-	+	+

Source: Authors' estimation results

We note from the table that the tests on the model explaining the output are all good as positive.

2.3 Analysis of impulse response functions and variance decomposition.

In this section, we are mainly interested in the impulse response functions and the variance decompositions of the forecast errors. The variance decompositions will tell us the relative importance of each shock in explaining the other variables in the system. As for the shock response functions, they will allow us to highlight the nature of the effects of the different shocks on the variables. The following figures show the impulse response functions; the dotted lines represent the confidence interval. We assume that the amplitude of the shock is equal to twice the standard deviation and we are interested in the effects of the shock over 10 periods (i.e. 10 years). This horizon represents the time required for the variables to return to their long-term levels.

2.3.1. Response function following a shock to cotton production.

A positive shock to past values of cotton production of magnitude 0.41 has a positive effect on the current value of production until the third year, at which point the variable returns to its long-run level (Figure 7)

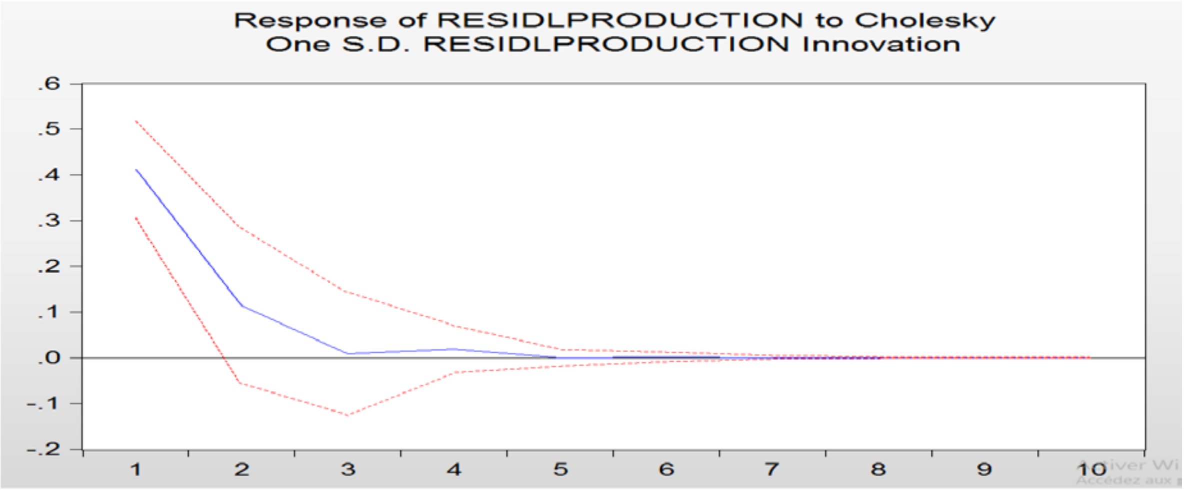

Figure 7: Response function following a shock to cotton production

2.3.2. Response function following a shock to the area sown

A positive shock of magnitude 0.67 to the area under production has a positive effect on the current value of cotton production until the second year. From then on, the effect begins to stabilize. (Figure 8).

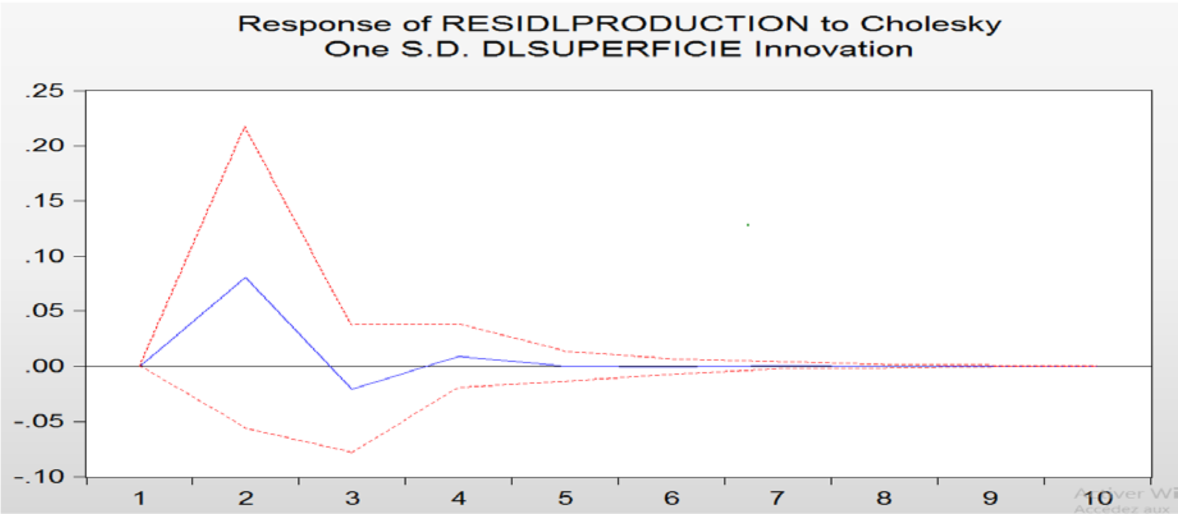

Figure 8: Response function following a shock to the sown area.

2.3.3. Response function following a shock to rainfall

A positive shock of magnitude 166.50 in rainfall has a positive effect on the current value of production until the second year. From then on, the effect starts to stabilize. (Figure 9)

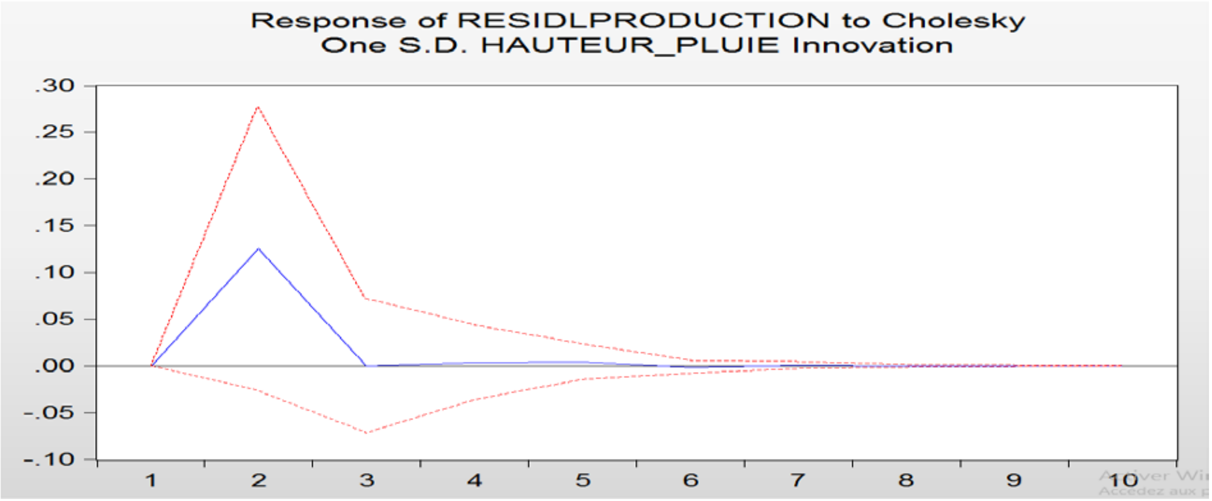

Figure 9: Response function following a shock on rainfall heights

2.3.4. Variance decomposition

The previous study, based on impulse response functions, can be completed by an analysis of the variance decomposition of the forecast error. The objective is to calculate the contribution of each innovation to the variance of the error in percentage. When an innovation explains a significant part of the forecast error variance, we deduce that the variable studied is very sensitive to the shocks affecting this series. The results of the variance decomposition study are reported in Table VIII.

Table VIII: Variance decomposition of the production forecast error

Périods	S.E.	RESIDLPRODUCTION	DLAREA	RAIN_LEVEL
1	0,411583	100	0	0
2	0,452293	89,13050	3,165742	7,703754
3	0,452836	88,94624	3,368416	7,685348
4	0,453314	88,92180	3,402830	7,675372
5	0,453335	88,91417	3,402540	7,675372
6	0,453339	88,91334	3,402640	7,684024
7	0,45334	88,91297	3,402791	7,684241
8	0.45334	88,91294	3,402813	7,684243
9	0.45334	88,91294	3,402813	7,684243
10	0.45334	88,91294	3,402813	7,684243
Moyenne		90,04000	3,03000	6,91000

Source: Authors' estimation results

The variance decomposition results indicate that 90.04% of the variance in the prediction error of production is due to its own innovations, 3.03% on average to those of area and 6.91% to those of rainfall. These results support those we obtained from the impulse response functions. Thus, we can see that rainfall has a large influence on the evolution of production.

3. Discussions

Considering the statistics of the different hypothesis tests, the residuals come with success for all the diagnostic tests: absence of autocorrelation and homo-scedasticity of the residuals.

Moreover, the stability test indicates that the ARV is stationary and the different shocks are sensitive. Thus, we can validly interpret the results. The ARV model used to analyze determinants such as rainfall and area sown on cotton production showed a unidirectional causal relationship between cotton production and rainfall and between rainfall and area sown. There is complete independence between cotton production and area planted. Rainfall causes and influences cotton production and the area sown. Cotton production in the commune of Banikoara is effectively linked to rainfall and also to the area sown. This production is much more influenced by rainfall and then by the evolution of the area sown over time. When rainfall is abundant and significant, it has a positive impact on cotton production. On the social level, when cotton production is good, this allows farmers to have enough income to increase their purchasing power. This income allows them to deal with their various concerns as fathers of the household, to satisfy the five basic needs of man. And also to make some savings. On the national level, the State, which is the only and first buyer of cotton, also benefits from it. After selling it on the international market, it brings in a lot of foreign currency, thus increasing the GDP. These currencies allow the State to have the means to carry out its policy in terms of the realization of its major projects, namely: the construction of road infrastructures, hospitals, universities, schools etc. Internationally, when production is good, it reassures the technical partners in development and consolidates international relations, which allows our state to benefit from special aid. But before claiming to have a good production, it is necessary that the rain came at the right time, in normal quantity, sufficient and well distributed in time. We suggest that in their agricultural policy, governments take into account variables such as rainfall and the areas to be planted. Rainfall, which here is synonymous with the height of liquid precipitation, the normal and annual quantity should not be missing, because rainfall extremes are also harmful to crops such as cotton or other crops. And since rainfall is the most unstable climatic parameter and therefore not controllable, governments must take care of adaptation measures in case of shortage or flooding. Therefore, providing for irrigation systems in the event of a lack of rain and evacuation systems in the event of severe overflow would be a way out for agricultural populations whose main economic activity remains working the land in rain-fed conditions. In relation to the surface area, the state must also secure the land so that producers do not lack cultivation land. It is true that there are now laws on land that protect agricultural land in one way or another. However, currently in our country, there is a speculation of land that does not say its name. All the cultivated lands are being sold off for commercial and industrial purposes. Thus, the State must ensure the rigorous application of these different laws on land, especially rural land, in order to avoid hoarding in rural and agricultural areas. In addition, it is necessary to think and encourage intensive agriculture as the FAO, 2014, p 79 recommended since 2014. Considering the demographic effect and the continuous degradation of agricultural land, it is without doubt that the interest today to cultivate on small area is no longer to be demonstrated, when the climatic conditions and treatments are met, a small area also can give as a large area or even more yields.

Conclusion

This study analyzed cotton production, its determinants and especially climatic factors in the commune of Banikoara over thirty years, an area considered to be the leading cotton-growing basin in Benin for decades. The results of the unit root and co-integration tests were used to estimate an ARV model with the variables in first difference. Shocks were also applied to the variable to assess their effect on the other variables. The results of this ARV model allowed us to determine that before claiming to have a good production, we should not forget in agricultural development programs to diagnose climatic resources, in this case rainfall, which are very sensitive determinants for a good production. This study does not claim to have addressed all the parameters that interact to determine annual cotton yields in the commune of Banikoara. Other studies could focus on the importance of soil quality in agriculture in the context of climate change, other studies could be conducted on the analysis of the impacts of rainfall and the area planted on food crops, or the impact of land productivity on production, so that the data could be used as a whole. Notwithstanding all of the limitations of this study, the results are nonetheless significant and contribute to the improvement of agricultural yields, especially those of cotton in the commune of Banikoara. These results can be applied throughout Benin for the well-being of farmers.

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