Analysis of climate change effect on agricultural production in Benin

Abstract

The purpose of this article is to analyze the effect of climate change on agricultural production in Benin. As climate is the primary determinant of agricultural productivity, agriculture remains highly vulnerable to climate change. To achieve this, cereal production is estimated based on rainfall, average temperature and carbon dioxide emitted in Benin, growth rates of land used for cereal production and the rural population. These results show that agricultural production is always dependent on climatic hazards through the average temperature in the different models. This influence is globally negative. Note that rainfall is not significant in any of the models. In addition, the concentration of CO2 has a downward influence on agricultural production. Finally, adaptation is beneficial for cereal production. It is therefore necessary to strengthen the adaptation capacities of producers.

Keywords: Agricultural production, climate change, production function, ARDL, Benin

Classification JEL: Classification JEL: C22; E23; O13;Q54

1. Introduction

The climate of the earth has been in a constant change state. For more than a century, however, the changes that have occurred are significant. Thus Arrhenius (1896) was the first scientist who speculated that the concentration of carbon dioxide, a greenhouse gas, in the atmosphere could significantly alter the temperature of the planet. This hypothesis, today, is verified because the scientific basis of climate change is no longer disputed (Boko et al., 2007). The warming of the climate system is unequivocal. From the 1950s to today, many unprecedented changes for decades or even millennia are observed. The effects are visible on all continents.

The African continent, not even among the major polluters, suffers the consequences in the same way as the others. The manifestations of climate change are not identical from one region to another and from one country to another. In terms of rainfall, the recent climatic variability in Africa, and particularly in sub-Saharan Africa, has shown a marked decline in rainfall and hydrometric series leading to an average decline observed in some rivers of the order of 40 -60% since the early 1970s (Niasse et al., 2004). In terms of temperatures, Africa

is likely to experience warming, whatever the season, during this century (Boko et al., 2007). The increase in temperatures is likely to be greater within the semi-arid margins of the Sahara and central southern Africa (Eriksen et al., 2008). On the other hand, the driest subtropics should experience higher temperature rises than those experienced in the humid tropics. Also, it is expected that higher temperatures would increase both the frequency and intensity of extreme weather events for the continent: very heavy rains, floods, forest fires.

Climate is the primary determinant of agricultural productivity (Adams et al., 1998). Thus, agriculture is very vulnerable to climate change: high temperatures and high carbon dioxide (CO2) concentration can cause changes in rainfall, affect agricultural and forestry systems and reduce crop yields, as well as lead to the spread of weeds, infections and diseases. As a result, for rural farming communities in Africa, which produce a substantial portion of their own food, and also rural low-income non-farm households and urban households, the impacts of climate change on food production may reduce food availability (Mendany et al., 2006), which is one of the important dimensions of food security. The impacts of climate change on food availability will be felt differently depending on the location. For example, moderate warming (1 to 3 ° C increase) is expected to benefit crops and pasture yields in temperate regions, while in tropical regions in the dry season it is likely to negative impacts, especially for cereal crops. Warming over 3 ° C is expected to have negative effects on production in all regions (IPCC, 2007).

Two main methods are used in the literature to study the economic impact of climate change on agriculture: the production function and the Ricardian approach. The traditional approach is a production function method that relies on empirical or experimental production functions to predict environmental changes (Mendelsohn et al., 1994). From the limits of the production function approach, Mondelsohn et al (1994) developed the Ricardian approach. The basic concept of the approach is that land values and agricultural practices are correlated with climate.

Literature seeking to quantify the impacts of climate change on the agriculture sector is abundant. However, we present that of West Africa. Mendelsohn et al. (2000), Maddison et al (2007) find a negative impact of climate change on Africa. Indeed, they use the Ricardian approach to examine how farmers in 11 African countries have adapted to existing climatic conditions. They then estimate the effects of projected changes in the climate while taking into account the adaptation of farmers. The results confirm that African agriculture is

particularly vulnerable to climate change. Even with perfect adaptation, regional climate change in 2050 would lead to losses of 19.9% and 30.5% of production respectively for Burkina Faso and Niger.

In addition, Mohamed (2002) examines the impact of current climate variability and future climate change on millet production in three major producing regions in Niger. Based on the analysis of rainfall and production data for the last 30 years. In 2025, it estimated 13% decrease in millet production is a consequence of climate change, resulting in a reduction in the total amount of rainfall for the months of July, August and September, combined with an increase in of temperature everything being equal elsewhere.

In Burkina Faso, climate change has a negative impact on the agricultural sector. Indeed, Ouedraogo (2012) evaluates the impact of climate change on farmers' agricultural incomes in Burkina Faso, using the Ricardian approach. The results of the study showed that the relationship between income and climate is non-linear. The marginal impact of temperature on farm income is -19.9 US $ per hectare while that of precipitation is +2.7 US $ per hectare. Elasticity analysis shows that agriculture is very sensitive to precipitation in Burkina. The increase of 1% in rainfall results in an increase in farm income of 14.7%. However, a 1% rise in temperatures leads to a decrease in farm income of 3.6%. Sensitivity analyzes showed that farmers will lose 93% of their income following a temperature increase of 5 ° C. They will lose all their income due to a 14% decrease in precipitation. Because of the already difficult climatic conditions, the scenarios of reduction of precipitations and / or temperature increase are very damaging to agriculture in Burkina.

For Benin, according to Boko et al. (2012), we can expect a positive impact on different regions and cultures. The climatic variability and in particular the decrease of the precipitations from March to May poses a significant risk on the food security of the country. In the same way, for Nonvide and Porgo (2014) find that cereal yield is sensitive to temperature in Benin.

The objective of this paper is to analyze the effects of climate change on agricultural production in Benin. In what follows, the research methodology is set out in section 2 and the results presented in section 3. We end with the conclusion.

2. Methodology

2.1 Presentation of the model

The production function approach relies on empirical or experimental functions of production to estimate the relationship between production and environmental changes in agriculture (Mendelsohn and al., 1994). A baseline function of production is then estimated to assess the observed impact of climate change (temperature, precipitation levels and carbon dioxide CO2) on cereal production.

Let the production function whose mathematical form is as follows:

$$Y = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + u \qquad (1)$$

Where: u = is the error term, F and F^2 capture linear and quadratic terms for temperature and precipitation. The introduction of quadratic terms for climatic variables reflects the non-linearity of the relationship between production and climate. And finally Z being control variables such as factors of production.

More specifically, the model chosen is the following:

$$Prod_t = \alpha_0 + \alpha_1 Plu_t + \alpha_2 Plu_t^2 + \alpha_3 tm_t + \alpha_4 tm_t^2 + \alpha_5 Co2_t + \alpha_6 txter_t + \alpha_7 txpr_t + \varepsilon_t$$

(2)

With: t time in years; $Prod_t$ cereal production in tons, Plu_t the average rainfall in Benin; Tm_t being the average temperature in Benin in years t; CO_{2t} the carbon dioxide emitted in Benin in year t; $txter_t$ the growth rate of land used for cereal production (hectares) in Benin; $txpr_t$ the growth rate of the rural population aged 15-65 in Benin in years t; and εt the error term.

2.2 The variables of the model

- The dependent variable:

Cereal production ($Prod_t$): It represents cereal production in Benin. It's measured in tonnes, for most cereals and refers to crops harvested for dry grain only.

- The explanatory variables:
  - ✓ The average temperature(Tm_t) of Benin in year t:

This variable represents the average temperature in Benin. It is the average of the minimum and maximum temperatures recorded in the six synoptic stations of Benin. The influence of this variable on cereal crop production is assumed to be indefinite.

  - ✓ Average rainfall (Plu_t) in Benin:

This variable indicates the average level of rainfall in Benin. It is also the average of the rainfall heights recorded in the six synoptic stations of Benin. As in the case of average temperature, its influence is undefined on cereal production.

- ✓ The carbon dioxide emitted (CO_{2t}) in Benin:

This variable indicates the level of CO2 produced in Benin. It is supposed to capture the fertilization effect of carbon dioxide. It takes into account, the emission of carbon dioxide from the use of fossil fuel or the manufacture of cement. Also, it includes carbon dioxide produced during the consumption of solid, liquid or gaseous fuels. It is expected to improve the yield of cereal crops.

- ✓ The growth rate of land used for cereal production ($Txter_t$) in Benin.

This variable refers to the area harvested for cereals such as rice, maize, millet, sorghum, etc. This variable represents natural capital. Production data for cereals refer to crops harvested for dry grain only. The expected sign for this variable is a positive sign.

- ✓ The growth rate of the rural population aged 15-65 in Benin ($txpr_t$) in year t:

This variable indicates the evolution of the rural population in Benin. It represents the human capital in the model. It is obtained by multiplying the rural population by the proportion of the total population between 15 and 65 years old. It is expected to positively influence cereal production.

2.3 Analysis techniques and data source

In order to evaluate the impact of climate variables on agricultural production in Benin, we use the autoregressive lagged scale model developed by Pesaran and Shin (1999) and Pesaran et al. (2001). The use of this technique is based on various reasons. The bound test allows a mix of the variables I (0) and I (1) in the model, which implies that the order of integration of the variables is not necessarily the same. Thus, the method of ARDL has the advantage of not imposing a specific order of integration of the variables of the model. Also, the use of this model is justified by the fact that it takes into account both the short-term and long-term relationships of the variables tested. Third, this approach is valid for small samples (Pesaran et al., 2001).

To study the presence of the long-term relationship, a bound test based on the Wald or the F statistic was proposed by Pesaran et al. (2001). The asymptotic distribution of F statistics is non-standard under the null hypothesis of no cointegrating relationship between the variables studied, regardless of whether the explanatory variables are purely I (0) or I (1). The cointegration relationship for the grain production equation is estimated using the bound test, which is based on the following unrestricted error-correction model:

$$\Delta Prod_t = a_0 + \sum_{i=1}^{P} a_{1i}\Delta Prod_{t-i} + \sum_{i=0}^{P} a_{2i}\Delta Plu_{t-i} + \sum_{i=0}^{P} a_{3i}\Delta Tm_{t-i} + \sum_{i=0}^{P} a_{4i}\Delta CO_{2\,t-i} + \sum_{i=1}^{P} a_{5i}\Delta Ter_{t-i} + \sum_{i=1}^{p} a_{6i}\Delta Poprur + b_1 Pib_{t-1} + b_2 Plu_{t-1} +$$

$b_3Tm_{t-1} + b_4CO_{2\,t-1} + b_5Ter_{t-1} + b_6Poprur_{t-1} + u_t$..... (5)

Where $\Delta Prod_t$, ΔPlu_t , ΔTm_t , $\Delta CO_{2\,t}$, ΔTer_t + $\Delta Poprur_t$ are the first differences of the variables of the model, and u_t represents the error term which is a white noise. The terms a_{1i} to a_{6i} represent the short-run dynamics of cereal production and those b_1 to b_6 represent the long-run dynamics of the model.

To verify the existence of a long-term relationship between the variables, the cointegration test is based on the Fisher statistic where it is assumed that the coefficients of the variables in level are all equal to zero under the alternative hypothesis that, no coefficients are nil i.e. no cointegration between the variables studied (Pesaran et al., 2001). More formally, we carry out a test of common significance, where the null and alternative hypotheses are:

$$\begin{cases} H_0: b_1 = b_2 = b_3 = b_4 = b_5 = b_6 = 0 \text{ (No long-term relationship)} \\ H_1: b_1 \neq b_2 \neq b_3 \neq b_4 \neq b_5 \neq b_6 \neq 0 \text{ (Existence of long-term relationship)} \end{cases}$$

The use of the Wald test or the F statistic makes it possible to test the significance of the lag of the variables by taking into account the constraint of an error correction model (ECM). The asymptotic distribution of this test (Fisher's respectively) is non-standardized under the null hypothesis of no cointegration between the variables. Therefore, the calculated value of this statistic must, to validate or invalidate one of the hypotheses, be compared with the critical values tabulated in Table CI (III) of Pesaran et al. (2001). According to these authors, the critical values of the lower limit assume that the explanatory variables are integrated of order zero, or I (0), while the critical values of the upper limit assume that they are integrated of order one, or I (1). Therefore, if the computed F statistic is lower than the lower limit value, the null hypothesis is not rejected and the non-existence of a long-term relationship between production and its determinants is concluded. Conversely, if the calculated F statistic is greater than the upper limit value, then the output and its determinants have a long-term level relationship. On the other hand, if the calculated F statistic is between the lower and upper limit values, the results are inconclusive. To determine the quality of adjustment of the ARDL model, diagnostic and stability tests are performed

The estimation of the model will be done by the Ordinary Least Squares (OLS) method on the STATA 12 software. Preliminary tests (ADF test on the variables, KLEIN multicollinearity test) and validation (the global significance test and model variables, error quality, stability test of the model) are needed for the interpretation of the results.

The data to be used in this section is secondary data. Cereal production, land under cereal production and rural population, and carbon dioxide come from World Development Indicators (2015). Rainfall temperatures and heights come from ASCENA Benin. The data used for the analyzes start from 1971 to 2013, ie 43 observations.

3. Results and discussions

3.1 Descriptive analysis of exogenous variables

This model includes five exogenous variables. It should be noted that over the study period from 1971 to 2013, the minimum area of cereals is about 380 thousand, whereas it has never exceeded 1.2 million hectares, or an average of 708 thousand hectares. During this period the rural population ranged between 2.4 and 5.6 million inhabitants. For climatic variables, the amount of water dropped varies between 749 and 1381 mm, an average of 1138 mm. Throughout the study period, the average temperature was around 28 ° C. Finally, CO2 emissions ranged between 260 and 5152 tonnes, an average increase of 8% per year. The correlation matrix asserts that the links between the growth rate of land under cereal production and all other exogenous variables in the model are small. All correlation coefficients are lower than 0.12 and are also insignificant at the 5% threshold. In addition, the correlation coefficients between all the other exogenous variables that are significant at the 5% threshold range from 0.28 to 0.76. Thus, all are less than 0.90 decreasing the risk of an endogenous relationship between the variables.

3.2. Results of stationarity tests

Before any estimate, it is useful to see if the variables are stationary. A series is said to be stationary when its mean and its variance are constant over time. Several tests make it possible to study stationarity of time series. The Augmented Dickey-Fuller (ADF) test was used. The realization of this test shows that the cereal production, the CO2 emission level and the growth rate of the areas are stationary in first difference. On the other hand, all other variables, namely rainfall, average temperature, and growth of the rural population, are stationary in level. The results are shown in Table 3.1.

All series are not stationary at the same level so there is a risk of cointegration. In addition, the presence of a mixture of I (0) and I (1) variables in the model excludes the feasibility of Engle and Granger (1987) and Johansen (1988) tests. Thus, to test cointegration we rely on

the procedure proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). Therefore, the ARDL model is used for the estimates.

Table n°3.1 : ADF test on the model variables

Variables	Level difference	type of Model	Lags	P-value	Observation
Prod	1	3	1	0.0000	Stationnary
Plu	0	2	0	0.0000	
Tm	0	3	0	0.0000	
CO_2	1	1	0	-	
Txter	0	2	1	0.0000	
Txpr	1	1	0	-	

Source : Authors from estimations

NB: Model [1] = model without constant nor trend; - Model [2] = model with constant and without trend; - Model [3] = model with constant and trends

From Table 3.2, it emerges that the calculated F-6.94 for the model with adaptation (respectively 4.93 for the model without adaptation) is greater than the highest critical value of the table of Pesaran et al. (2001) at 5% which are 3.79 (respectively 4.35 for the model without adaptation). Therefore, we can conclude that there is a long-term relationship between cereal production and its determinants in Benin.

Table n°3.2 Cointegration test result for agriculture production model

Wald Statistic		Critical threshold	Lower limit value	Upper limit value
Model without adaptation	4,93	1%	4,29	5,61
		5%	3,23	4,35
		10%	2,72	3,77
Model with adaptation	6,94	1%	3,41	4,68
		5%	2,62	3,79
		10%	2,26	3,35

Source: Authors from estimates

Note: the calculated statistic F: 4.0517 (significant at 0.05 of the marginal value). Critical values are quoted from Pesaran et al. (2001), Table CI (iii), Case 111: without drift and trend.

3.3 Presentation and analysis of model results

3.3.1 Presentation of the preliminary results

Two models are highlighted. The first without adaptation captures the influence of climate variables on production and the effect of CO2 concentration on production. The second one says with adaptation takes into account the rate of increase of the cereal lands and the rate of

increase of the rural population of the age group 15 - 65 years. The results presented in Table 3.3 are derived from the model estimate. The Fisher-Snedcor test shows that the regressions are globally significant. The adjusted coefficient of determination R^2 of the model without adaptation is 0.47. The integration of the area and the rural population improves the quality of the adjustment with adjusted coefficient of determination R^2 equal to 0.60.

On the other hand, the quality of the residue remains important in the respect of the conditions which make the OLS a BLUE estimator; in this case normality, homoscedasticity, and non-correlation of errors. The normality test of Jarque-Bera residuals makes it possible to accept the null hypothesis of normality of errors. The P-value being greater than 0.05 for both models then the model residuals follow a normal distribution. For the first two properties, the Breusch Godfrey autocorrelation test gives an P-value greater than 0.05 for both models, which asserts that the residues are not autocorrelated. However, for the Breusch Pagan heteroscedasticity test, only the residues of the model with adaptation are homoscedastic. The same is true for the Ramsey RESET variable omission test. Indeed, for the omission test, only the P-value of the model with adaptation is greater than 0.05 that does not allow to reject the null hypothesis of absence of omitted variables in the model. With regard to the multi-collinearity test, in the two models estimated, the average of the VIF is less than 5. Thus, there is no multi-collinearity between the exogenous variables of the model.

3.3.2 Presentation and Analysis of the model results

The Table 3.3 shows the short and long-term dynamics for each of the two models. The results of the estimations show that the restoring force (- 0, 24) is significantly negative and less than unity in absolute value for equation (1) of the model without adaptation. The introduction of quadratic terms for climate variables to test the non-linearity of the relationship between production and climate gives equation (2). Note that the return force is significant, so the error correction model is valid. On the other hand, climate variables and their quadratic terms are not significant in the short term as well as in the long term. Thus, we can conclude a linear relationship between cereal production and climate. For the model with adaptation, the restoring force is -0.31 and is significant at the 1% threshold.

The model without adaptation shows that climate change affects grain production. Indeed, the temperature is significant at long-term and short-term. Its marginal propensity is 581447.7 and -144295 respectively. In other words, a rise (or a decrease) of about one degree Celsius in the average temperature would lead to an increase (or a decrease) in cereal production by 581

thousand tonnes at long-term. On the other hand, in the short term, a rise (or a fall) in the order of one degree Celsius of the average temperature would lead to a decrease (respectively an increase) in cereal production of 144 thousand tons. It is also noted that the emission of CO2 significantly influences cereal production at the 5% threshold. The effect is positive at long-term but negative at short-term. For this variable, in the short term, a drop (or a rise) of one kilotons of CO2 emissions would lead to an increase (respectively a decrease) in cereal production of about 204 tonnes. However, at long-term, a rise (respectively a decrease) of the same order would lead to an increase (respectively a decrease) in cereal production of about 184 tonnes.

It should be noted that without adaptation, climate influences cereal production through average temperature. The influence is positive at long-term but negative at short term with the effect of short term higher than that of long-term. Also, the emission of carbon dioxide influences the cereal production in Benin. It is also noted that the negative impact at short term is greater than that at long-term in absolute value.

The results of the model with adaptation, go in the same direction like the first with some nuances. It should be noted that adaptation in this model is limited since it takes into account, depending on the availability of the data, only two adaptation variables. Estimates suggest that production is always influenced by climate, particularly by temperature. However, the influence is significant only at short-term. In other words, with adaptation the climate does not influence long-term agricultural production. However, a rise (respectively a fall) of about one degree Celsius in average temperature would lead to a decrease (respectively an increase) in cereal production of 103 thousand tonnes at short-term. Note that with or without adaptation to short -term, the average temperature negatively influences the production but the magnitude is reduced by about 30% in the model with adaptation.

For the emission of CO2, the influence is present as well in short long-term as in short long-term as in the first model.However, for the long-term, the beneficial effect on production of an increase of one kilotons of emission increases from 184 tons to 200 tons with the adaptation being an increase of 9%. Also, at short-term, there is a reduction in the magnitude of the negative impact of a one-unit increase in CO2 emissions from 204 tonnes to 177, a decrease of 13%. In conclusion, adaptation is beneficial in every respect. It makes it possible to cancel the effect of the temperature on cereal production at the long-term and makes it possible to obtain a reduction of the magnitude of approximately 30% at short-term. For the emission of CO2, the adaptation makes it possible to increase of 9% the agricultural

production, to long-term . Also, it helps reduce the decline in agricultural production by 13% at short -term.

These results show that agricultural production is always dependent on climatic hazards, particularly through the average temperature in the different models. This influence is globally negative. Note that rainfall is not significant in any of the models. In addition, the concentration of CO2 has a positively influence on agricultural production. Finally, adaptation is beneficial for cereal production.

Table 3.3: Result of the model for estimating cereal production.

	model without adaptation		model with adaptation
	D.prod (1)	D.prod (2)	D.prod
Tm	581447,70**	42800000	220919,8
Plu	286,73	-4638,80	285,02
Co2	184,01***	285,34***	200,15***
Tm^2		-769337,6	
Plu^2		2,34	
Txter			1733943**
Txpoprur			10200000**
L1.Prod	-0,24**	-0.18**	-0,31 ***
D1.tm	-144295***	3275833	-102866,3**
D1.plu	10,81	482,74	-62,92
D1.co2	-204,23***	-170,34***	-177,24***
$D1.tm^2$		-61044,27	
$D1.plu^2$		-0.20	
D1.txter			-237828**
D1.txpoprur			-798418,7
Constant	-3767416**	-110000000	-1926542
Observations	42	42	42
Adj R-squared	0,47	0,58	0,60
Prob> F	0.0001	0.0000	0,0000
*significant at 10% level; ** significant at 5% level; *** significant at 1% level			

Source: Authors from estimation result

NB: D1.X: first difference of the variable X and L1.X: The variable X delayed by one period.

3.1.3 discussion of the model results

According to PANA (2008) it is expected in the north a significant increase in surface temperatures of about 1 to 2 ° C in 2025 both during the dry season and during the rainy season. Thus, we can expect a decline in cereal production from about 144 to 288 thousand tons in the years before the 2025 horizon before experiencing an increase in production all

else being equal in the absence of adaptation. This analysis remains to be relativized because, this increase in yields can be counteracted by a greater variation of very strong precipitations at the beginning and at the end of the rainy season; monsoons of shorter duration, delayed with irregular rainfall, i.e. climatic shocks that are not taken into account in this model.

Moreover, according to Boko et al. (2012), "In the southern region of Benin (at latitudes less than 7.5 ° N), an almost constant annual rainfall could be observed up to 2050, with variations observed every five years not exceeding hardly 0.2% with a maximum of 0.2% in the West sector (increase) and a minimum of -1% in the East sector (decrease) .North of this latitude, a slight increase would be observed, which could up to 3.3% and 3.8% in 2050 respectively in the North West and North East ". Thus, it can be assumed that the influence of rainfall on agricultural production in the north of the country will not be perceptible until 2050 since it is not significant and its variations are not large.

In conclusion, it should be noted that the average temperature has a negative impact on agricultural yields, particularly cereals on long term and positively on long-term. However, the adaptation would cancel the long term effect of the climate on production or reduce its magnitude to short term. Also, that the rainfall is not determinant in the grain production all other things equal. This situation can be explained by the fact that rainfall heights do not capture inter-temporal and interregional disparities. Indeed, we can have two years with the same amount of rain, so that it is beneficial for one year and not for the other. This is possible, for example, if the rain is in phase with the agricultural calendar in one year and not the other. Lastly, the increase in CO2 emissions is profitable for agricultural production, especially cereal production at long-term but not at short term. Thus, agricultural production remains dependent on climatic hazards, with more or less beneficial effects of CO2 concentration. Finally, adaptation is profitable for cereal production.

These results are similar to those of Nonvide and Porgo (2014). These authors conclude that cereal yield is sensitive to variations in rainfall in Burkina Faso and temperature in Benin. However, it does not seem to be influenced by the temperature in Burkina Faso and the rainfall in Benin. The results of the model differ from those of Nonvide and Porgo (2014) in relation to the concentration of CO2. Their regression model with CO2 emission shows a non-significant impact on grain yield in Benin and Burkina Faso. In this model, however, the concentration of CO2 influences agricultural production. .

The model's conclusions confirm those of Christensen et al. (2007) that show that food production remains highly vulnerable to the influence of adverse weather conditions. The results of this model are contrary to those of Lee et al. (2012) who using panel data for Asian

countries for the period from 1998 to 2007, show that higher temperatures and more rainfall in summer have increased agricultural production while high temperature falls are harmful. Similarly, these results run counter to that of Von Braun (1991), who concludes in the case of Ethiopia that 10% decrease in the amount of rainfall below the long-term average leads to a 4.4% reduction in food production.

It should be noted that the model does not support the assertion of a threshold effect as suggested by the conclusions of (IPCC, 2007). For the IPCC (2007) moderate warming (increase of 1 to 3 º C) is expected to benefit crops and pasture yields in temperate regions, while in the tropical regions of Africa and in the dry season it is likely to have negative impacts, especially for cereal crops. Warming over 3 ° C is expected to have negative effects on production in all regions.

These results are similar to those of Nonvide and Porgo (2014). These authors conclude that cereal yield is sensitive to variations in rainfall in Burkina Faso and temperature in Benin. However, it does not seem to be influenced by the temperature in Burkina Faso and the rainfall in Benin. The results of the model differ from those of Nonvide and Porgo (2014) in relation to the concentration of CO2. Their regression model with CO2 emission shows a non-significant impact on grain yield in Benin and Burkina Faso. In this model, however, the concentration of CO2 influences agricultural production. .

The model's conclusions confirm those of Christensen et al. (2007) that show that food production remains highly vulnerable to the influence of adverse weather conditions. The results of this model are contrary to those of Lee et al. (2012) who using panel data for Asian countries for the period from 1998 to 2007, show that higher temperatures and more rainfall in summer have increased agricultural production while high temperature falls are harmful. Similarly, these results run counter to that of Von Braun (1991), who concludes in the case of Ethiopia that 10% decrease in the amount of rainfall below the long-term average leads to a 4.4% reduction in food production.

It should be noted that the model does not support the assertion of a threshold effect as suggested by the conclusions of (IPCC, 2007). For the IPCC (2007) moderate warming (increase of 1 to 3 º C) is expected to benefit crops and pasture yields in temperate regions, while in the tropical regions of Africa and in the dry season it is likely to have negative impacts, especially for cereal crops. Warming over 3 ° C is expected to have negative effects on production in all regions.

4. Conclusion

The objective of this paper is the analysis of the effect of climate change on agricultural production in Benin. To achieve this, the methodology is based on an estimated production function to assess the observed impact of climate change (temperature, precipitation and carbon dioxide CO2 levels) on cereal production. Thus, cereal production in tons is estimated according to rainfall and average temperature in Benin, carbon dioxide emitted in Benin, the growth rate of land used for cereal production and the growth rate of the rural population of Benin. 15-65 age group in Benin.

The results of the estimates show that without adaptation, climate change affects grain production. Indeed, it will be remembered that without adaptation, the climate influences the cereal production through the average temperature. The influence is positive at long term but negative at short term with that of short term higher than that of long term. Also, the emission of carbon dioxide influences the cereal production in Benin. It is also noted that the negative impact at short term is greater than that at long term in absolute value.

For the results of the model with adaptation, they go in the same direction as the first with some nuances. It should be noted that the adaptation in the model is limited since taking into account, depending on the availability of the data, only two adaptation variables. It shows that the production is always influenced by the climate, especially by the temperature, although the influence is significant only at short term. Thus, with adaptation the climate does not influence agricultural production at long term. For the emission of CO2, the influence is present as well in long term as in short term as in the first model.

These results show that agricultural production is always dependent on climatic hazards, particularly through the average temperature in the different models. This influence is globally negative. Note that rainfall is not significant in any of the models. In addition, the concentration of CO2 has a downward influence on agricultural production. Finally, adaptation is beneficial for cereal production.

In view of the results obtained, it is necessary to strengthen the adaptation capacities of producers. The adoption of adaptation strategies will help mitigate the impact of climate change on production in general and cereal production in particular. Since rural households consume the majority of their produce, this measure will allow them to stabilize their consumption, making them less vulnerable to food insecurity.

REFERENCES

[1] Arrhenius, S. On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground. *Philosophical Magazine and Journal of Science;*1896; *41* (5), 237-276.

[2] Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. et Yanda, P. "Africa: *Climate change 2007: impacts, adaptation and vulnerability.Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*." Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P. J. et Hanson, C.E., (Eds.), Cambridge University Press, Cambridge UK, ;2007; 433-467.

[3] Niasse, M., Afoud, A., et Amani, A. *Reducing West Africa's Vulnerability to Climate Impacts on Water Resources, Wetlands and Desertification: Elements of Regional Preparedness and Adaptation*. IUCN, Gland, Switzerland and Cambridge, UK. 2004; xviii + 66pp.

[4] Eriksen, S., O'Brien, K. et Losentrater, L. *Climate Change in Eastern and Southern Africa: Impacts, Vulnerability and Adaptation*. Global Environmental Change and Human Security, Report 2008:2.

[5] Adams, R.M., Hurd, B.H., Lenhart, S., et Leary N. "Effects of global climate change on agriculture: an interpretative review". *Climate Research;*1998; *11, 19 – 30.*

[6] Mendany, M., Niang-Diop, I, Nyong, T. Tabo, R et Vogel, C. "Background paper on impacts, vulnerability and adaptation to climate change in Africa. For the African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention" Accra, Ghana, 21 -23 September, 2006 United Nations Framework Convention on Climate Change.

[7] IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007; 976 pp.

[8]Mendelsohn R., Nordhaus W.D. et Shaw D.,. The impact of Global Warming on Agriculture: A Ricardian Analysis, The American Economic Review; 1994;4 (84), pp 755-771.

[9] Mendelsohn R, Dinar A et Dalfelt A,. Climate change impacts on African agriculture; 2000. http://www.ceepa.co.za/Climate_Change/pdf/(5-22-01)afrbckgrnd-impact.pdf.

[10] Maddison, D.,. The Perception and Adaptation to Climate Change in Africa, *The World Bank Development Research Group, Sustainable Rural and Urban Development Team;* 2007

[11] Mohamed AB, Van Duivenbooden N et Abdoussallam S. "Impact of climate change on agricultural production in the Sahel" – Part 1. Methodological approach and case study for millet in Niger. *Climate Change*; 2002; 54(3): 327–48.

[12] OUÉDRAOGO Mathieu "Impact des changements climatiques sur les revenus agricoles au Burkina Faso" Journal of Agriculture and Environment for International Development - JAEID 2012, 106 (1): 3 - 21

[13] Boko M.,Kosmowski F., et Vissin W.E. " Les enjeux du changement climatique au Bénin" Rapport du Programme pour le dialogue politique en Afrique de l'Ouest Konrad Adenauer Stiftung ; 2012; french

[14]NONVIDE, G.M.A et PORGO, M" Effect of climate change on cereal yield: evidence from Benin and Burkina Faso" mimeo.;2014

[15] Pesaran MH, Shin Y.. An autoregressive distributed lag modelling approach to cointegration analysis.Chapter 11 in Econometrics and Economic Theory in the 20th Century:

The Ragnar Frisch Centennial Symposium, Strom S (ed.). Cambridge University Press: Cambridge;1999.