

Impact of Climate Change on Cereal Production in Burkina Faso

Tégawendé Juliette NANA¹

Abstract

With the increase of greenhouse effect gas emissions, caused by human activities, climate change impacts on environment and economic activities, especially agriculture in developing countries, remain currently an international concern. In Burkina Faso, the share of the agriculture sector to the real GDP is the largest historically and represented 44% in 2016. Furthermore, this sector remains heavily dependent on climatic conditions. With regard importance to these facts, the objective of the present study is to analyze the vulnerability of the agricultural sector, mainly the production of maize, millet, sorghum and rice in Burkina Faso to the effects of climate change. To test the hypothesis whether "climate variables, such as rainfall and temperature have a positive impact on cereal production," a linear model was estimated by the stepwise method on panel data. The results show that increased precipitation would result in an increased production of maize, millet and sorghum and decreased that of rice. While an increase in temperature contributes to a decrease of the latter. Thus, the impact of climate change on agriculture is real in Burkina Faso and the adoption of effective adaptation and mitigation is of great importance.

Keywords: climate change, agricultural production, stepwise regression

JEL classification: Q15, Q54

I- Introduction

Global warming causing climate change is an international concern, as reflected in the COP 21 Conference, where commitment on a decrease of temperature between 1.5 ° C and 2° C were to be reached by 2100. The change Climate is manifested by the increased intensity, frequency and variability of random phenomena such as floods and droughts (Wane 2009). Indeed, it is reflected primarily by an increase in the variability and the extreme phenomena, becoming more severe and repeating more often (UNFCCC, 2010). This stimulates the development of new crop pests and diseases, resulting in increased crop yield variability from year to year. This phenomenon is now common in most developing countries like Burkina Faso.

Burkina Faso is one of the least developed countries with 82.7% of its population living in rural areas (PANA, 2007). Its economy is based on the sectors of agriculture, livestock and forestry. The agricultural sector employs more than 90% of the population, with a contribution of 40% to GDP, of which 25% for agriculture, 12% for livestock and 3% for forestry and fisheries. Poverty is a predominantly rural phenomenon with an incidence of 48.9% in 2008 compared to 20.3% in urban areas (Ouédraogo and al., 2010). The major food crops such as sorghum, millet, rice and corn are of strategic interest. In fact, these crops occupy more than 88% of the area sown and contribute 70% of Burkina Faso's food (Comité Interprofessionnel des Céréales du Burkina, 2006). Agricultural activity is the main source of income for the majority of the population (World Bank, 2008). Many low-income countries could be considered the most vulnerable to climate change, mainly because of their dependence on rainfed agriculture (Arndt and al., 2011).

The instability caused by climate change on the environment is a real problem for agricultural production and for farmers. Thus, knowledge of these impacts on agricultural production is an important step in the fight against poverty in rural areas.

¹ Teacher / researcher, department of Economics Sciences, Management, Trade and Political Sciences & Laws, University of Sine Saloum Elhadj Ibrahima Niass (USSEIN) in Senegal. E-mail: nanagbenou@gmail.com / nanajulie2005@yahoo.fr

The literature on the impacts of climate change on yields or on agricultural production is very diverse and the impacts differ from one country to another, from one culture to another and from the methodology used to assess these impacts. Some studies found that climate change has a negative impact on agriculture [Schlenker and Lobell (2008), Cline (2008), Yesuf et al (2008), Salack (2006), Hamani (2007), Doukpolo (2011),] and the magnitude varies from one area to another. However, according other studies, depending on crops and initial climatic conditions, yields could be expected to increase [Holts et al. (2011), Holst and Yu (2011), Kumar and Chamar (2013)].

In the case of Burkina Faso, very few empirical studies have been interested in analyzing the impacts of climate change on agriculture. Thus, the objective of this article is to analyze the vulnerability of the agricultural sector, mainly the production of maize, millet, sorghum and rice, to the effects of climate. For this purpose, a stepwise regression on panel data was applied.

The paper is organized as follows: the first section introduces the Climate change in the world and in Burkina Faso; the second section, the methodology; the third, the tests and results of the estimations. The last section concludes.

II. Climate change in the world and in Burkina Faso

II.1 Facts at a global level

Climate change has sparked a great deal of controversy and debate over its existence, its causes, the scale of the phenomenon and its future consequences, and the adaptation and mitigation measures to be undertaken. The warming of the climate system is unequivocal as the atmosphere and ocean temperature increased; snow and ice cover has decreased, sea levels have risen and greenhouse gas concentrations have increased. According to the IPCC (2007, 2013), the years 1983 to 2012 are probably the warmest 30 years in the northern hemisphere for 1,400 years. Thus, according to Courtillot (2008), the heart of the debate is no longer to know whether there is global warming, because it is accepted, as a truth well established by the greatest number now. In the same way Dubois and Ceron (2006) underlines that no research concludes with a stability or a refreshment. Thus, with the climatic events observed, a consensus has emerged when there is almost no doubt about the existence of climate change, but the causes and extent of this warming are disputed.

In 2007, the IPCC estimated the "probability" that warming is due to human activities "greater than 90%". Certainty is not absolute, however, and this question is still the subject of research involving both measurements and observations as well as modeling in climatology. According to the IPCC (2013), the causes of global warming are due to the concentration of greenhouse gases in the atmosphere, which may be of natural or anthropogenic origin, and humans are very likely to be the main cause of the causes of this warming. EPA and ONERC (2014) find that its anthropogenic origin is no longer debated, and it is up to governments to reach an agreement to reduce greenhouse gas emissions despite the difficulties of such a policy. In the same vein, COMEST (2010) emphasizes that analytical and predictive knowledge about climate change has evolved to the extent that it is possible to predict, mitigate and adapt to its effects in a way that was previously impossible and to discern a causal link between human action and current processes of climate change. Moreover, Kergomard (2014) points out that the extent of warming in recent years is illustrated by the succession of "record" years: the years 2001, 2004, 2003, 2006, 2002, 1998, 2009, 2004, 2005 and 2010 are thus in increasing order of temperature, the 10 warmest years recorded since 1880. Today, climate change is a global challenge given the importance of its adverse effects, which can affect the stability of a number of sectors, and even damage the existence of living things. The modeling of the Intergovernmental Panel on Climate Change (IPCC) on the consequences of global warming meet a scientific consensus, with forecasts that worsen over time (current 20th and 21st century). Thus, the IPCC emphasizes the importance of adaptation and mitigation measures.

II.2 Evidence of climate change in Burkina Faso

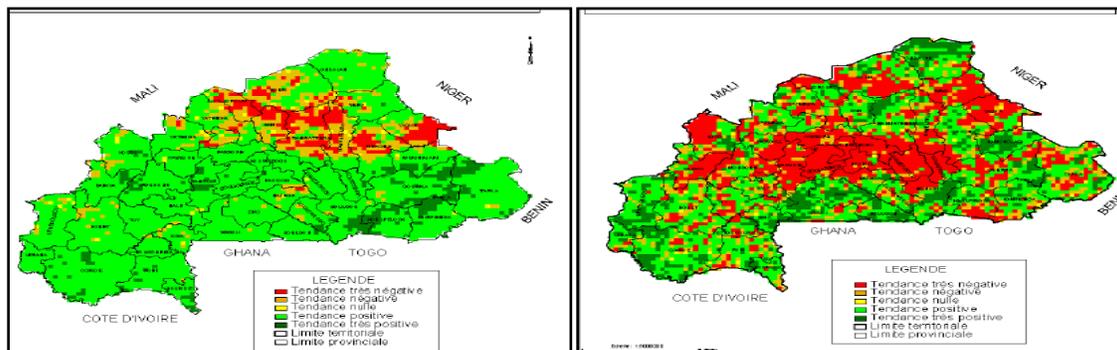
Burkina Faso is a landlocked country with an area of about 274.000 km² and a population of 18.6 million inhabitants in 2016 (World Bank, 2016). It is one of the poorest countries in the world with 46.4% of its population living below the poverty line (IFAD, 2011). The country is one of the low-income and food-deficit countries according to FAO criteria (MAHRH / DADI, FAO, 2010). According to the IPCC, global warming is a global

phenomenon, so Burkina Faso is not spared. While there is no consensus on the magnitude, consequences and the means to fight against it, the Government of Burkina Faso aligns itself on the the IPCC views and is implementing various strategies to cope with this change. This evidence of the climate change in Burkina Faso can be confirmed with regard to its manifestation even if the attribution of certain climatic events to the manifestation of climate change is not always obvious.

II.2.1 Evolution of vegetation in Burkina Faso

The changes of the vegetation map for the period 1982-1991 (10 years) shows negative trends (*in red*) in the northern part of the country. The negative trend means that vegetation tends to decrease. Based on the fact that during the period 1992 to 2000, there is a major change. Only a few parts of the country (weak for that matter) show a positive trend, the negative trend occurs in several localities throughout Burkina. This means that in only 8 years vegetation has only decreased in most localities. This is caused partly by the abusive cutting of wood for commercial or non-commercial purposes, such as bush fires, overpopulation (search for cultivable or residential land), On the other hand, it can be linked to natural phenomena (decrease in rainfall or temperature rise, desert locusts etc.). This decline in vegetation is part of the anthropogenic actions that only favor climate change and its variability.

Figure 1a: Evolution of vegetation from 1982 to 1991 **Figure 1b: Evolution of vegetation from 1991 to 2000**



Source: Traoré L. B. (2005)

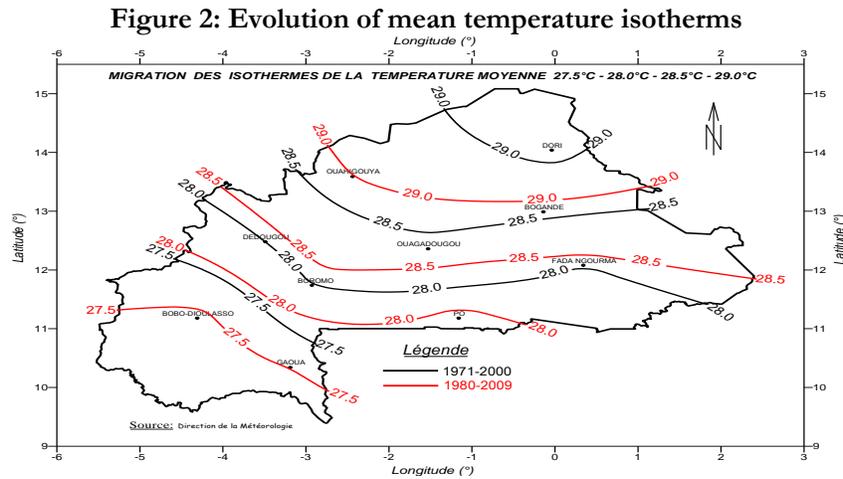
II.2.2 Evolution of the isohyets in Burkina Faso

An isohyete is a line joining the points of a region where the mean precipitation height collected is the same over a given period. The map on the next page presents the isohyets over three periods of 30 consecutive years. From 1951 to 2000, there is an important migration of 600mm, 800mm and 1000mm isohyets from north to south. This migration of isohyets marks both a strong inter-temporal and spatial variation of the rainfall and a tendency to decrease it. This has resulted in significant changes in the delimitation of the country's climate zones.

II.2.3 Evolution of mean temperature isotherms

The isotherms designate lines that pass through all the places of the globe where the average temperature of the year is the same.

By observing the evolution of the isotherms of the mean temperature, we observe a latitudinal displacement of the latter towards the South in the space of two consecutive periods of 30 years (1971-2000 and 1980-2009). There is therefore an upward trend in average temperature.

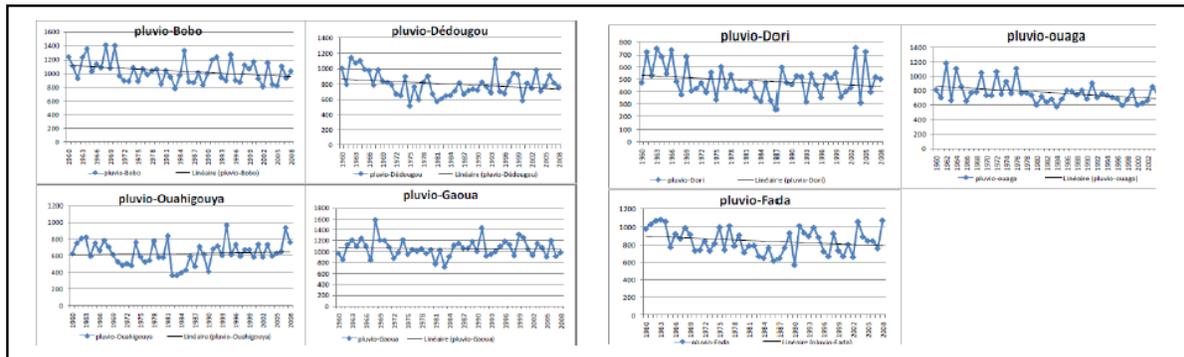


Source: Dioma (2012)

II.2.4 Trends in rainfall in the main stations

By observing the evolution of rainfall over 48 years (from 1960 to 2008), there is generally a very high variability (temporal and spatial) and a downward trend on all the main stations. However, in Ouahigouya, there is an increasing trend, but this can be explained by the implementation of the “SAAGA program” undertaken by the government of Burkina, which consists in bombarding the clouds in hopes of possible rainfall.

Figure 3: Evolution of rainfall in the main stations



Source: The author

In short, it is clear that climate change is a reality in the world and in Burkina Faso. Awareness at the international level has been progressive. There is a consensus on the existence of global warming, but the extent and causes of this warming are disputed. Uncertainties related to the issue of climate change are at the root of the debate around this issue. The septic climate is increasingly criticizing the IPCC reports. As for Burkina Faso, it is rather how to reduce vulnerability to climate change which is at the heart of the debates because the effects are already being felt. In fact, anthropogenic actions have strongly influenced the vegetation, which shows a downward trend and reinforces the process of climate change and variability. The displacement of the isohyets from north to south explains the high variability and downward trends in rainfall in the various localities of Burkina Faso and the climatic breakdown of the country. The displacement of the isotherms also from north to south also explains the changes of the temperature which present an increasing tendency on the extent of the territory. In addition to this, extreme events such as floods, pockets of drought, dust winds etc.; become recurrent. Nevertheless, awareness has been materialized by the ratification of several treaties and actions in favor of adaptation.

III. Methodology

This section presents the framework of the econometric analysis, i.e. the model specification and the estimation method, a description of the variables, and finally the source of the data as well as the choice of geographic locations of the study.

III .1 Econometric Model

Several models have been used for measuring the impact of climate change on agriculture. These include: (i) agronomic modeling which is a tool for quantifying the link between climate and agriculture. it is a model that can be used to transcribe climate information for example temperature and/or precipitation in terms of agronomic variables such as agricultural yields, biomass in order to synthesize existing knowledge about climate and plant relationships (Sultan, 2012); (ii) empirical modeling consists in constructing a link between dependent variables (eg performance) and explanatory variables without explicitly representing the agronomic mechanisms (Sultan, 2012, 2011). It is a method for modeling the effects of meteorology and climate on crops and consists in making direct statistical comparisons between meteorological and climatic elements and actual yields (Roberts and al., 2012); (iii) the Ricardian approach developed by Mendelsohn and al. (1994) following the limitations of the agro-economic model and which, instead of considering crop yields, examines the impact of climate on net income or land value.

Each method has its specificity. For example, the agronomic model based on production function approach captures the biological response of plants, whereas the Ricardian approach captures the importance of adaptation in the model (Laurent, 2009). Each approach has its advantages and disadvantages. Since climate change is a dynamic process, static analysis would be very limited. Overall, the application of panel data for the analysis of the impacts of climate change yielded more robust results. Thus, the present study makes use of panel data to evaluate the impact of climate change on agricultural production.

Thus, to test the hypothesis on the effects of rainfall and temperature on yields, a Cobb-Douglas production function is defined and a specific model is derived for the study.

The Cobb-Douglas function is the functional form generally used to establish the link between agricultural production and the factors explaining its growth. Such specification is a reasonable empirical approximation of the production process in various parts of the economy, including agriculture, and has been frequently used for research on agricultural production (Holst R and al., 2011). To analyze the impact of climate change on agricultural productivity Kumar and Sharma (2013) consider a Cobb-Douglas production function, which assumes that total agricultural production is a function of several exogenous and endogenous variables such as area under cultivation ,Irrigated area, tractors and motor pumps, and annual average precipitation and temperature values. Moreover, several authors used similar models to analyze the climatic impact on production or agricultural productivity (Iglesias and al., 2009), Nastis and al. (2012), Schlenker and Lobell (2010).

On our part, we will be looking at the impact of climate change on the production of maize, millet, rice and sorghum that are of strategic interest to Burkina Faso. Thus, we make use of the methodical approach proposed by from Kumar and Sharma (2013) to define a model of multiple regression adapted to our study. For the estimation, panel data are used.

Model specification and estimation method

Following Kumar and Sharma (2013), we incorporate the Cobb-Douglas production function into regression analysis. A model of agricultural production is considered. It is assumed that the production of a crop is a function of several exogenous variables such as crop area, agricultural labor, irrigated area, tractors and motor pumps, and annual mean values of precipitation and temperature. Due to missing data, agricultural labor (which can be measured by farm labor) and equipment over several years are not included in the estimations of the model.

Equation (1) describes the production process and its functional form can be written as:

$$PROD_{it} = f\{AERA_{it}, PRECI_{it}, TEMP_{it}, VWIND_{it}, D_SUNS_{it}, D_RAINY_{it}\} \quad (1)$$

Where the production ($PROD_{it}$) depends on the area under cultivation ($AERA_{it}$), precipitation ($PRECI_{it}$), temperature ($TEMP_{it}$), velocity Winds($VWIND_{it}$), the duration of sunshine (D_SUNS_{it}) and the number of rainy days (D_RAINY_{it}).

According to the original form of the Cobb-Douglas production function model, equation (1) can be rewritten as:

$$\ln (PROD_{it}) = \alpha_0 + \alpha_1 \ln (AERA_{it}) + \alpha_2 \ln (PRECI_{it}) + \alpha_3 \ln (TEMP_{it}) + \alpha_4 \ln (VWIND_{it}) + \alpha_5 \ln (D_SUNS_{it}) + \alpha_6 (D_RAINY_{it}) + \varepsilon_{it} \quad (2)$$

Where ε_{it} represents the error term, i the province or the location where the crop is produced, I ranges from 1 to 7 and the data covered the period t from 1996 to 2012. $\alpha_0 \dots \alpha_6$ are parameters to be estimated. Various versions of the Equation (2) are estimated

Description of Variables

As aforementioned $PROD_{it}$ represents the dependent variable of the various models, measured in tons of crop. That is the production of each crop of the province i at time t . It should be noted that the production of four crops are estimated. These include the production of maize, millet, rice and sorghum, which is the staple food for the majority of the population in Burkina Faso. Seven provinces based on data availability, namely the provinces of Houet, Kadiogo, Mouhoun, Seno, Gourma, Poni and Yatenga, are considered. The time span of the data collected is 16 years, from 1996 to 2012.

The explanatory variables

Cultivated area ($AERA_{it}$) is a quantitative variable measured in hectare (ha). This variable may affect positively or negatively the production.

Precipitation ($PRECI_{it}$): this is a variable related to the climate. It is a quantitative variable measured in millimeters (mm). The cumulative precipitation of the rainy season, which runs from May to October is considered. Cumulative precipitation is a good measure in the study of the impacts of climate change on production and commonly used by several authors (Schlenker and Lobell (2010), Ouedraogo (2008) and Prakash, Lall and Luni (2011)). The temperature $TEMP_{it}$ is also a variable reflecting the climate and it is measured in degrees *Celsius*. In the present study, mean values of temperature were used. The period covered is from May to October. The effect of temperature on the crop production may be positive or negative.

Wind speed $VWIND_{it}$ is a quantitative variable measured in meter per second (m/s). The expected sign is negative. The duration of sunshine D_SUNS_{it} : this is the average daily duration of insolation expressed in hours. Its effect is mixed. This variable can have either a positive or a negative impact on the production.

Number of rainy days D_RAINY_{it} is quantitative variable, measuring the number of rainy days. The expected sign is positive.

III .2 Estimation

Several versions of equation (2) were estimated. The method of estimation retained is the stepwise regression. The method "stepwise regression" is one of the most complete procedure, (Bourmont, 2012). This method consists of adding variables one after the other into the model according to their partial correlation and by progressive selection. At each step, the partial correlations of the set of variables already introduced are checked to verify if they are still significant. Hence, a variable that would no longer be significant, would be rejected (Frédéric, 2010). The process continues until no more variables can be introduced or removed from the model.

III .3 Source of data and choice of study areas.

In this study, secondary data were used. The areas of study are chosen according to the data availability, one hand, and on the other hand, according to the agro-climatic divisions. The provinces hosting the main synoptic stations were selected because the data from these stations are much more representative.

Considering the agro climatic division, the selected zones are distributed as follows: the province of Houet and that of Poni in the Sudanian climate; the provinces of Kadiogo, Mouhoun and Gourma in the Sudano-Sahelian climate and the provinces of Yatenga and Séno in the Sahelian climate. Data on temperature, precipitation, duration of sunshine and wind speed that are collected from the General Direction of Meteorology (DGM). The production and area data were obtained from AGRI-STAT of the Direction of Agricultural Statistics (DSA), supplemented by the statistical yearbook of 1996 and 2012.

For the econometric estimation, only four crops were retained, namely maize, millet, sorghum and rice. In fact, these cereals represent the basic food in Burkina Faso. According to Monitoring and Analysing Food and Agricultural Policies (MAFAP) (2013), 44% of cereal production is dominated by sorghum, followed by millet, maize and rice with 31%, 21% and 4%, respectively.

IV. Tests and results of the estimations

IV.1 Tests

Prior to the estimations, stationarity tests were conducted using panel test of Im, Pesaran and Shin (2003). It shows that variables measuring the production of millet, sorghum, precipitation, temperature and rainy day are integrated of order zero (I (0)) while the production of maize and rice production, the different areas (maize sorghum, millet, rice), degree of sunshine and wind speed are stationary in first difference (I (1)). Additional tests were applied.

Normal testing

For each production function of crop, the normality test indicates that residues are normally distributed. The statistics of the normality test of Jarque-Bera. Jarque-Bera are 0.44, 1.73, 0.10 and 1 for maize, millet, sorghum and rice, respectively. All these statistics are below 5.99 at the 5% level.

Heteroskedasticity test

To test the heteroscedasticity, the Breusch-Pagan / Godfrey test was applied. For each model considered, the probabilities associated with the Fischer are respectively greater than 5%. Thus, the hypothesis of heteroscedasticity is rejected.

Autocorrelation test

The autocorrelation test on the residues shows that the errors are uncorrelated. The probabilities associated with the Lagrange Multiplier (LM) are less than 5%. The error terms are not correlated.

Nonlinear restriction test on the parameters

The nonlinear restriction test on the parameters, in particular the Wald test, shows the linearity hypothesis of the model parameters because the probabilities associated with the Wald statistic (according to a Chi-2 law) are all greater than 5%. For all the equations of the four speculations. Indeed, according to this test, the null hypothesis (H0) (hypothesis of constant yields) indicates that the sum of the coefficients of the model parameters is equal to 1 against an alternative hypothesis (non-constancy of return) H1 or this sum is different from 1. The results reject the hypothesis H1; consequently, the choice of a function of production with constant yield is better adapted to our different specifications.

IV.2 Presentation and interpretations of estimation results

Presentation of results

Table 1: Results of the estimates using the stepwise regression method

	LPROD ms	LPRODmi	LPRODso	LPROD ri
C	-5.158*** (1.836)	2.781 (1.450)	1.758* (1.049)	8.589*** (1.608)
LPRECI	0.804*** (0.120)	0.530*** (0.077)	0.434*** (0.071)	-0.061 (0.117)
LAREA	0.997*** (0.023)	0.973*** (0.025)	0.9548*** (0.025)	0.910*** (0.024)
LTEMP	-1.352*** (0.324)	-0.909*** (0.215)	-0.956*** (0.190)	-0.211 (0.274)
LD_SUNS	0.904** (0.396)	-0.896*** (0.282)	-0.478** (0.235)	-2.900*** (0.365)
LD_RAINY	0.627*** (0.172)	-0.274** (0.104)	0.0003 (0.098)	
LVWIND	0.050 (0.056)	-0.085** (0.033)	0.011 (0.045)	
R²	0.998	0.975	0.983	0.984
F-statistic	5783.785***	366.575***	570.297***	654.788***

*Note: ***, **, and * indicate significance level at the 1, 5, and 10% levels, respectively and the standard deviations are in parentheses. Endogenous variables are taken in log.*

Adequacy of the model and overall significance of the parameters

The adequacy of a model makes it possible to account for the relevance of the model specified and estimated. The Fisher statistic gives the variation of the dependent variable due to the presence of the explanatory variables. These statistics are 5783.78; 366.57; 570.29 and 654.788 for maize, millet, sorghum and rice and the probabilities associated with these statistics are all significant at 1%. This implies that the variables taken as a whole explain the model. The model is thus globally significant. The R² are respectively 0.99; 0.97; 0.98 and 0.98 for maize, millet, sorghum and rice. This means that 99% of the change in maize production, 97% of the variation in millet production, 98% of the change in sorghum production and 98% of the variation in rice production are explained by the set of variables included in each estimated model.

Interpretation of results

In this section, we will give the individual significance of the variables and the impact of each variable on the production of the speculation considered.

The results show that precipitation is a significant and positive variable for the production of maize, millet and sorghum and is not significant but negatively influences the production of rice. An increase in precipitation of 1% results in an increase in maize, millet and sorghum production of 0.8%, 0.53% and 0.43%, respectively. These results are consistent with the theory and are consistent with Sridhar's conclusions, and Raj Ganesh (2010), Massetti and Mendelsohn (2011). In the case of Burkina Faso, in view of the current climatic conditions and with mainly rainfed agriculture, a rise in rain plays positively on the production of these three speculations. However, an increase in rainfall of 1% leads to a decrease in rice production of 0.06% even if its impact is not significant. Indeed, in Burkina, the cultivation of rice is generally carried out in the lowlands, which a priori have a strong capacity of water retention. Rice cultivation requires a certain level of water beyond which production decreases. This means that following the current conditions; an additional 1% increase would contribute to a decrease in rice production, which is in line with the results found by Deressa 2011).

The surface plays a decisive role in the production of the various speculations. It has a positive coefficient and is significant at 1% for all the crops considered. An increase in area of 1% leads to an increase in maize, millet, sorghum and rice production of 0.99%, respectively 0.97%; 0.95% and 0.91%. These results are in line with the theory in that an extension of the area can only play a positive role on production. We thus join the theory of the producer. The temperature is significant at 1% for maize, millet and sorghum with negative coefficients of -1.35; -0.90; -0.95 and -0.21 for maize, millet and sorghum and rice. Temperature has no significant effect on rice production. Thus, a 1% increase in temperature contributes to a decrease in maize, millet and sorghum production of 1.35%, respectively; 0.90% and 0.95%.

The degree of insolation is significant at 1% for millet and rice and 5% for sorghum with negative coefficients of -0.89; -2.9 and -0.47. An increase in insolation, that is to say the duration of solar radiation of 1%, leads to a decrease in millet production of 0.89%, rice of 2.9% and sorghum of 0.47%; this variable is also significant at 5% for corn but has a positive coefficient (0.90). This means that an increase in the solar radiation duration by 1% leads to an increase in maize production of 0.90%.

The number of rainy days is significant only for maize and millet production. For corn, it is significant at 1% with a positive coefficient of 0.62. An increase in the number of rainy days by 1% leads to an increase in maize production of 0.62%. On the other hand, this variable is significant at 5% for the production of millet but has a negative influence on it. Indeed, a 1% increase in the number of rainy days leads to a decrease in millet production of 0.27%. The wind speed is only significant for millet at 5% and has a negative effect on the production of this one. An increase in wind speed of 10% leads to a decrease in millet production of 0.85%.

V. Discussion and conclusions

Global warming is indeed a reality around the world. Experts from the IPCC have shown that the scale of climate change observed in recent times is rather anthropogenic. The consequences of climate change are already being felt throughout the developing countries, including Burkina Faso. Anthropogenic actions have strongly influenced vegetation, which has a downward trend and reinforces the process of climate change and variability. The displacement of the isohyets from north to south explains the high variability and downward trends in rainfall in the various localities of Burkina Faso and the climatic division of the country. The shift of isotherms from north to south also explains changes in temperature, which tend to increase over the territory. In addition, extreme phenomena such as floods, drought pockets and dust winds have become more and more recurrent. Despite the awareness at national level, materialized by the ratification of several treaties, of actions of sensitization of the population on the anthropic activities accentuating the climatic changes must be reinforced.

The present study makes use of econometric estimation based on the stepwise method to analyze the impact of climate change on agricultural production. The results show that this sector is under the influence of climatic factors such as precipitation and temperature. These findings confirm those of other empirical studies on the impact of climate change on agricultural production.

An increase in rainfall increases the production of maize, millet and sorghum. This result is consistent with the empirical study by Doukpolo (2014) who shows that future trends in precipitation indicate a decrease of up to 20% to 42%, particularly in the Sudanian and Sudano-Sahelian sectors of the western region of the Central African Republic. These trends would lead to decreases in cereal and oilseed yields in the order of 20% to 50% in the study area in the near and distant future horizons. However, our result shows that maize productivity is negatively affected by the increase in rainfall and thus an increase of 1% of rainfall and negatively affects maize productivity up to 0.17. This finding is contrary to the result found by Kumar and Chamar (2013) in the case of India.

The results showed that an increase in temperature contributes to the reduction in the production of the cereals considered. This finding contradicts the results in the case in South China, where an increase in average annual temperature of 1° C could lead to an increase in cereal production according to Holts and al., (2011). Overall, the study finds that climate change has real impacts on the agricultural sector in Burkina Faso. Effective and efficient adaptation measures are therefore needed to reduce the vulnerability of producers.

Acknowledgment:

I would like to thank Professor Taladidia THIOMBIANO, Dr. Anatole GBENOU and Dr. Komi AMEGANVI for helpful comments and suggestions. Any mistakes or faulty interpretations are completely of my own.

Bibliography

- Arndt C. Farmer W., Strzepek K. and Thurlow J. (2011). *Climate change, agriculture, and food security in Tanzania*. Working Paper, World Institute for Development Economics Research, N°. 2011,52, ISBN 978-92-9230-419-5
- Bourmont M. D. (2012). *La résolution d'un problème de multicolinéarité au sein des études portant sur les déterminants d'une publication volontaire d'informations : proposition d'un algorithme de décision simplifié basé sur les indicateurs de Belsley, Kub et Welsch (1980)*. Comptabilités et innovation, May, Grenoble, France.
- Centre de Conférences des Nations Unies(CCNU). (2010). *Changements climatiques, agriculture et sécurité alimentaire*. Septième forum pour le développement de l'Afrique document de travail N°2
- Cline W. R. (2008). *Réchauffement Climatique et agriculture*. Finances & Développement. <https://www.imf.org/external/pubs/ft/fandd/fre/2008/03/pdf/cline>.
- COMEST. (2010). *Les implications éthiques du changement climatique mondial*. Rapport
- Comité Interprofessionnel des Céréales du Burkina. (2006). *Note de synthèse filière céréale*, CIC-B.
- Courtillot V. (2008). *Quelques éléments de débat scientifique. Responsabilité & environnement* N° 50.
- Deressa T.T. (2011). *Effects of climatic conditions and agro-ecological settings on the productive efficiencies of small-holder farmers in Ethiopia*. Working Paper University of Pretoria
- Doukpolo B. (2014). *Changements climatiques et productions agricoles dans l'Ouest de la République Centrafricaine*. Earth Sciences.
- Dubois G. et Ceron J. P. (2006). *Adaptation au changement climatique et développement durable du tourisme*. Étude exploratoire en vue d'un programme de recherche rapport final
- EpE et ONERC. (2014). *Les entreprises et l'adaptation au changement climatique*. Travaux du Groupe de Travail Adaptation, entre 2010 et 2013
- FIDA (2011). *Œuvré pour que les populations rurales pauvres se libèrent de la pauvreté au Burkina Faso*. www.ifad.org.
- FIDA (2011). *Reverdier le Sabel: développer l'agriculture dans le contexte du changement climatique au Burkina Faso*. Fiche d'information Afrique de l'Ouest et du centre.
- Frédéric B. (2010). *Choix du modèle. Cours d'économétrie*. IRMA, Université de Strasbourg France ESIEA 4^{ème} année
- Friedlingstein P. (2004). *Incertitude de l'amplitude du changement climatique liée aux rétroactions entre le climat et le cycle du carbone*. in Agrawala S.et al , 2004. *Science du changement climatique*. Acquis et controverses.
- GIEC. (2012). *Résumé à l'intention des décideurs*. In Field C.B et al: *Gestion des risques de catastrophes et de phénomènes extrêmes pour les besoins de l'adaptation au changement climatique*. Rapport spécial des Groupes de travail I et II du Groupe d'experts intergouvernemental sur l'évolution du climat. Cambridge University Press, Cambridge, Royaume-Uni et New York (État de New York), États-Unis d'Amérique, pp. 1- 20.
- GIEC (2013). *Résumé à l'intention des décideurs, Changements climatiques 2013: Les éléments scientifiques. Contribution du Groupe de travail I au cinquième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat* [sous la direction de Stocker T.F., D. et al Cambridge University Press, Cambridge, Royaume-Uni et New York (État de New York), États-Unis d'Amérique.
- GIEC. (2007). *Résumé à l'intention des décideurs*. In: *Changements climatiques 2007 : Les éléments scientifiques. Contribution du Groupe de travail I au quatrième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat*. University Press, Cambridge, UK et New York, NY, USA.
- Hamani D. O. (2007). *Adaptation de l'agriculture aux changements climatiques : Cas du département de Téra au Niger*, Mémoire présenté pour l'obtention de Master en Développement 2007, pp 69.
- Holst R. et Yu X. (2011). *Climate change and production risk in Chinese aquaculture*. Courant Research Centre: Poverty, Equity and Growth - Discussion Papers, N°. 64, Courant Research Centre Poverty, Equity and Growth, Göttingen
- Iglesias A., Garrote L., Quiroga S. et Moneo M. (2009). *Impacts of climate change in agriculture in Europe*. PESETA-Agriculture study. EUR 24107-EN, JRC 55386. Office for Official Publications of the European Communities
- IPCC (2007). *Rapport du Groupe de travail II - Conséquences, adaptation et vulnérabilité*. Fourth Assessment Report: Climate Change

- Kergomard C. (2014). *Changement climatique : certitudes, incertitudes et controverses* », Territoire en mouvement. Revue de géographie et aménagement URL : <http://journals.openedition.org/tem/1424> ; DOI : 10.4000/tem.1424
- Kumar A. et Sharma P. (2013). *Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India*. Economics Discussion Papers, N° 2013 43, Kiel Institute for the World Economy.
- Laurent D. S. (2009). *L'impact économique des changements climatiques sur l'agriculture canadienne*. Sciences de la gestion (Option Économie Appliquée). Mémoire présenté en vue de l'obtention du grade de maître ès sciences (M. Sc.). HEC MONTRÉAL.
- MAHRH/DADI, FAO. (2010). *Cartographie des zones socio-rurales du Burkina Faso*, Projet Agricultural Water Management Solutions Fondation Bill et Melinda Gates (BMGF).
- Massetti E. et Mendelsohn R. (2011). *Estimating Ricardian Models With Panel Data*. Working Paper 17101, National Bureau of Economic Research, Cambridge, MA.
- Nelson, G. C.(2009). *Climate change: impact on agriculture and costs of adaptation*. Food policy report 21, from the international food policy research institute (IFPRI). <http://www.ifpri.org/publication/climate-change-1>
- Ouedraogo M. (2008). *Impacts des changements climatiques (cc) sur les revenus agricoles au Burkina Faso*, INERA / station de recherches de FARAKO-BA.
- Ouedraogo M., Dembélé Y. et Somé L. (2010). *Perceptions et stratégies d'adaptation aux changements des précipitations : cas des paysans du Burkina Faso*. Sécheresse vol. 21, N° 2, avril-mai-juin 2010.
- PANA (2003). *Synthèse des études de vulnérabilité et d'adaptation aux changements climatiques : étude de cas du Burkina Faso*.
- Parry M.L., Canziani O.F., Palutikof J.P., van der Linden et Hanson C.E. (2007). *Résumé technique in: Bilan 2007 des changements climatiques: Impacts, adaptation et vulnérabilité. Contribution du Groupe de travail II au quatrième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat*. Cambridge University Press, Cambridge, Royaume-Uni et New York, NY, E.-U.
- Prakash J. N.; Lall M. K. et Luni P. (2011). *Effect of climate variables on yield of major food-crops in Nepal A time-series analysis*. Published in: Journal of Contemporary India Studies: Space and Society, Vol. 1, (March 2011): pp. 19-
- Rhôneénergie-Environnement (2013). *Comprendre la complexité du changement climatique*. Volume 3 - éléments scientifiques.
- Salack S. (2006). *Synthèse sur la collecte, la mise en forme et le stockage des données climatologiques des pays du CILSS, et Etude d'impacts des changements climatiques sur la production agricole au Sabel*. Centre Régional Agrhymet. Rapport Final.
- Schlenker W. et Lobell D. B. (2010). *Robust negative impacts of climate change on African agriculture*. Environmental research letters . IOPscience.
- Seguin, B. (2003). *Adaptation des systèmes de production agricole au changement climatique*. C. R. Geoscience 335 (2003) pp. 569–575.
- Seguin, B. (2007). *Le réchauffement climatique : impacts sur les agricultures européennes* ; Publicado Originalmente na Revista Ciencia & Ambiente N°34.
- Sridhar, T. et Ganesh, R., J. (2010). *A ricardian analysis of the climate change impact on Nepalese agriculture*. MPRA paper n°. 2978.
- Sultan B. (2011). *L'étude des variations et du changement climatique en Afrique de l'Ouest et ses retombées sociétales*. Université Pierre et Marie Curie. Habilitation à diriger des recherches. Defended in 2011.
- Sultan B. et al. (2009b). *Multi-scales and multi-sites analysis of the role of climate in cotton yields in West Africa*. International Journal of Climatology.
- Sultan B. et al. (2012). *La question de la vulnérabilité et de l'adaptation de l'agriculture sabélienne au climat au sein du programme AMMA*. La Météorologie - Spécial AMMA.
- Vandaele D., Lebreton A. et Faraco B. (2010). *Agriculture et gaz à effet de serre : état des lieux et perspectives*. Réseau Action Climat. ADEM.
- Yesuf M ., Di Falco S., Deressa T., Ringer C. et Kohlin G.(2008). *The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia*. Environmental and Resource Economics