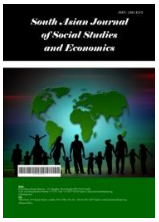

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Rising Temperatures and Cereal Production in Cameroon

Demanou Neigha Stephan[1*] and Mapa Kamdoum Géneviève Christel[1]

[1]Department of Public Economics, University of Dschang, BP: 110, Dschang, Cameroon.

Authors' contributions

This work was carried out in collaboration between both authors. Author DNS designed the study, performed the statistical analysis, wrote the protocol and drafted the first draft. Author MKGC collected the data, wrote the protocol and translated the manuscript into English. Both authors read and approved the final manuscript.

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ABSTRACT

This paper assesses the impact of rising temperatures on cereal production in Cameroon over the period 1980-2016. To achieve this objective, we used Auto Regressive Distributed Lags (ARDL). Short and long-term results show that rising temperatures do not affect cereal production in Cameroon. It would therefore be possible to extend this research work using climate projection data. Moreover, this work would also have been better if it had been done on all agricultural crops by subdividing the country into agro-ecological zones.

Keywords: Climate change; temperature; cereal production; ARDL.

1. INTRODUCTION

Climate change is also old as the world. It took on its full importance with the publication of the Meadows Report commissioned by the Club of Rome in 1972. This was followed by a series of summits and conferences, such as: The Brundtl and Report in 1987; the United Nations

**Corresponding author: Email: demanouneigha@gmail.com;*

Conference on Environment and Development in Rio in June 1992, also known as the Earth Summit; and the World Summit on Sustainable Development in Johannesburg in August 2002. All these summits have progressively led to the adoption of the concept of sustainable development as a reference framework for development policies. The adoption of Rio Agenda 21 reflects the commitment of governments to work towards the integration of global environmental issues into development programmes. The Copenhagen Summit in December 2009 and the 2015 Paris Conference of the Parties (Cop21) made adaptation to climate change the focal point of this commitment. Most recently, the 200 governments meeting at the COP22 in Marrakech in 2016 and the COP23 in Bonn in 2017 agreed to finalize by December 2018 the rules for implementing the Paris Accord, which was finally signed at the COP24 in Poland.

However, what is greatest concern is the scale and pace at which these changes are occurring (IPCC, [1]). Researchers of the Intergovernmental Panel on Climate Change (IPCC) are unanimous that the warming of the climate system is now unequivocal. Climate change has been identified as one of the major challenges facing the world in this millennium and this is particularly serious in developing countries. The African Union through its Agenda 2063, which is not only a common strategic framework for inclusive growth and sustainable development, but also a comprehensive strategy to optimize the use of Africa's resources for the benefit of all Africans, has made climate change one of its priorities. It should be noted that Agenda 2063 took into consideration the Sustainable Development Goals (SDGs) and post-2015 development objectives, and also defined certain concepts and objectives in close collaboration with the Millennium Development Goals (MDGs). The Report of the meeting of the African Heads of State and Government Committee on Climate Change (CAHOSCC) on the Gender and Youth Mainstreaming Programme held at the Inter-African Union Inter-African Bureau for Animal Resources (AU-IBAR) in Nairobi, Kenya from 7 to 10 June 2016, highlighted new and innovative solutions to mitigate climate change, while increasing the adaptive capacity of women and youth.

In 2011, the World Food Programme (WFP) notes that climate change threatens to significantly increase the number of people at risk of hunger and under nutrition. Its predictions also show that more powerful and more frequent droughts and storms will cause greater devastation. Rising sea levels will ruin fertile agricultural land. Changes in rainfall will reduce harvests. Increasingly scarce resources will lead to social tensions and conflict. Millions more people will be at risk of hunger and under nutrition. Most of them will be in the world's poorest countries, where hunger, undernourishment and food insecurity are already widespread. Africa, for example, with a population of more than 1 billion people, or 16% of the world's population, two-thirds of whom live in rural areas, derive their income from rain-fed agriculture.

This concern seems even more pronounced in sub-Saharan Africa. In this part of the world, agriculture plays a leading socio-economic role, contributing to food security, job and wealth creation, as well as to the maintenance of social peace. Although it accounts for less than 30% of the GDP of most countries, agriculture is a major contributor to total exports (Cleaver and Schreiber, 1994). It is the main by-product, and is a supplier of raw materials for the textile and agro-food industries. Nevertheless, this region remains the most affected by hunger and undernutrition. In some of these countries, yields from rain-fed agriculture could fall by 50% by 2020.

The IPCC also predicts that by 2050, crop yields in sub-Saharan Africa will have fallen by 14% (rice), 22% (wheat) and 5% (maize), pushing many poor people dependent on agriculture for their livelihoods deeper into poverty and vulnerability. It also predicts a decrease in food availability of 500 calories per month, or a 21% drop per person in 2050, and a further increase in the number of malnourished children by more than 10 million per year, corresponding to a total of 52 million in 2050 in Sub-Saharan Africa alone. The recent food riots recorded in most of these countries in 2008 and early 2017 are a telling illustration of this. According to FAO, of the 39 countries in the world that expressed a need for external food aid in 2006 to meet the consumption needs of their populations, 25 are in sub-Saharan Africa.

Cameroon, a country in this region, is also experiencing troubles linked to climate change. With an equatorial and tropical climate, the country has an unstable seasonal rainfall pattern, resulting in a late onset of the rainy season and a prolonged dry season. The phenomenon is likely to worsen. With the variability of the climate, farmers are finding it difficult to organize themselves. This leads to poor yields, while threatening food security. This situation degrades the standard of living and quality of life of the country's populations, where more than 6 out of 10 households practice agriculture. This situation is even more sensitive in the Far North and Northern Cameroon regions, where agriculture is by far the main income-generating activity. According to data from the National Institute of Statistics, 86.5% and 84.4% of households practice this activity in the North and Far North regions respectively.

Several studies on the effects of climate change on agriculture have been based on production function models (Barrios et al. [2]; Schlenker and Lobell, [3]; Rowhani et al. [4]; Lobell et al. [5]; Blanc, [6]). In view of these trends, the contribution of this paper is manifold. First, it uses the Ricardian model, which corrects the shortcomings of the production function approach by integrating the farmer's behaviour in the face of climate change; moreover, the method used is the cointegration test by staggered delays or Auto Regressive Distributed Lags (ARDL). This method is modern, in that it takes into account the simultaneous effects of short and long term. This makes it possible to better appreciate the evolution of the effects.

The objective of this paper is to assess the effect of rising temperatures on cereal production in Cameroon. We will first start by very briefly recalling the state of the art on the literature review debate; then we will present our methodology, and finally we will present our different results.

2. LITERATURE REVIEW

In order to better understand the relationship between temperature changes and cereal production, it will be useful to draw out a theoretical review (2.1) and an empirical review (2.2).

2.1 Theoretical Review: Land Rent Theory

The theoretical teachings of our study relate to the theoretical model adopted, which is that of David Ricardo. While it is based on the principle of scarcity of goods and diminishing returns, it draws its foundation from the theory of land rent. In order to better understand this theory, we will present its classical conception (2.1.1) on the one hand and its neo-classical conception (2.1.2) on the other hand.

2.1.1 The classical conception of the land rent

Among the classics, one can differentiate between Ricardo and Max's thesis and that of Von Thünen. All these authors consider the rent as a surplus from the land.

2.1.1.1 Ricardo-Max: differential fertility

Based on the principle of diminishing returns and increasing scarcity of goods, Ricardo, an English economist, is the founder of the concept of land rent. His thesis is part of the physiocratic line of thought. However, he breaks with their retrograde ideas according to which agricultural products have a divine origin. He defines rent as "a surplus on land of unequal fertility". His real contribution was the inclusion of calculation at the margin. According to his thinking, the price of agricultural crops is given according to the marginal productivity of very poor quality land. Since the cost of production remains the same on all land regardless of its fertility, an exogenous surplus value is generated on land of better quality: this is the differential rent.

As for Max, drawing on the work of his predecessor D. Ricardo, he bases his analysis on the concept of absolute rent and monopoly rent. The absolute rent, for Marx, all land, no matter how bad it is, is full of rent, which is why the landowner is tempted to rent it out. With regard to the monopoly rent, Marx thinks that the market price of agricultural land and vineyards located at the agglomeration level had a relatively high price. To explain this phenomenon, which is obviously not directly related to agricultural production, he develops the concept of monopoly rent, based on the scarcity of land. This monopoly rent is not subject to any technical constraint, compared to the differential rent, which is a function of soil productivity; and to the absolute rent, which depends on the difference between the rate of profit of the agricultural sector and the average rate of profit of the economy as a whole.

2.1.1.2 Von Thünen: The spatial rent

Von Thünen's conception of rent is relative to the distance between the place of production of agricultural crops and the market. The aim of the landowner is to make a maximum profit.

Thünen's thinking also takes into account the perishable nature of agricultural products, and the cost of transport, which varies considerably depending on the type of agricultural products. His idea is also based on the principle of balance and optimisation.

Ultimately, the classical conception of rent theory is understood as a "surplus". It is differential, as in Ricardo, and spatial, as in Thünen. However, this conception admits points of divergence. For example, in Ricardo and Max, land use determines prices, whereas in Thünen, it is the price of land that determines its use. This classical conception will be supplemented by the neo-classical conception of the rent.

2.1.2 The neo-classical conception of the annuity

In contrast to the classics, which see the annuity as a surplus, the neo-classics see it as "value-utility". This neo-classical conception is advantageous in that it goes beyond the conditions of production, although it does not tell us anything about the differences in wealth from the land. Walras' design, along with Marshall's, will form the backbone of this section.

2.1.2.1 Walras: The marginal productivity of the land

Léon Walras bases his concept of land rent on the principle of marginal utility. In his conception, land is not considered as a particular productive good deriving its value from labour, but rather as an ordinary good whose intrinsic value is defined by its utility or scarcity. He states: "Land rent, as it exists and as we explain, comes from the fact that land, being a useful thing and limited in quantity, is an element of social wealth that is appropriable, valuable and exchangeable, and that land, being capital, produces income that can be sold by the owner.

In short, for Léon Walras, land rent is equivalent to income from land. In the rental market, for example, it corresponds to the conditions of demand and supply. At equilibrium, the value of the rent is given by the productivity of the land.

2.1.2.2 Marshall and the singular approach

Despite being a neoclassical economist, Marshall equates the annuity with a surplus. As with his classical predecessors (Ricardo and Marx), this surplus is determined on the cost of production under the most disadvantageous conditions. Marshall's main contribution to land rent theory is the definition of the concept of external savings arising from the special qualities of the environment.

It goes without saying that the concept of land rent depends on each paradigm. This theoretical review will be supplemented by an empirical review (2.2).

2.2 Empirical Literature Review

In order to elucidate a body of work relating to adaptation to climate change (1.2.2), we will first present the work relating to the effects of climate change on cereal production (1.2.1).

2.2.1 Review of the effects of climate change on cereal production

Because of its links with environmental factors, mainly climate, it seems clear that climate change affects agricultural production, determining food availability. In most studies, it is agreed that worsening climate conditions can reduce agricultural productivity (Deschenes and Greenston, [7]; Schlenker and Lobell, [3]; Feng et al. [8]). This low productivity can be explained by the lack of fresh water, the prevalence of pests and poor soil quality. A frequently noted production function approach specifies the relationship between climate and agricultural production (Adams, [9]; Kaiser et al. [10]; Adams et al. [11]). Authors such as Mendelsohn et al. [12] developed a second approach, which they called the Ricardian approach. Deschênes and Greenstone [7], in an important methodological contribution, demonstrate that this approach could be biased by the non-observation of agricultural productivity determinants that are correlated with climate. These authors suggest that the frequency of annual temperature and precipitation could be used to estimate whether agricultural benefits are affected when the year is warmer or wetter than normal. They do not find a statistically significant relationship between weather and U.S. farm benefits through wheat and/or soybean yields. Conclude that short-term fluctuations have no impact on agriculture. In the long term, however, where adaptation is possible, climate change is likely to have little impact or could even be beneficial to agricultural yields. These results were later questioned by Fisher et al. [13], who believe that the data were biased, and that when corrected, climate fluctuations have a negative effect on US agriculture.

Many of the researchers have also focused their work in Africa. Barrios S et al. [2], examining the impact of climate change on agricultural production in developing countries, particularly in sub-Saharan Africa, come to the conclusion that climate, as measured by variations in rainfall and temperature at the country level, is a major determinant of agricultural production in sub-Saharan Africa. However, countries in the region do not seem to be affected to the same extent. The same results were found by Schlenker and Lobell [3]. Anton V et al. [14], studying simultaneously the phonological characteristics of vegetation in SSA and the variability of phonological indicators based on time series from 1982 to 2006, come to the results that high temporal variability occurs in semi-arid and sub-humid regions and that there is a wide range of positive rainfall trends between Senegal and Southern Sudan. Also find that, the diversity and trends observed in agricultural systems are dynamic. Jones, A D et al. [15], in their studies on the effects of agricultural diversity on household diets, used cross-sectional data from the Third Integrated Household Survey in Malawi. A nationally representative sample of farm households was implemented from March 2010 to March 2011 as part of the World Bank's Living Standards Measurement Study. The conclusion was that diversity in agricultural production was consistently associated with household dietary diversity. However, this relationship is complex and can be influenced by gender, wealth, control over household decisions, the relative market orientation of a household's agricultural production and the specific nature of agricultural diversity. Papaioannou, K and Haas M [16], examining the effects of climatic shocks on smallholder farmers in British colonial Africa, conclude that, at the district level, cash crop production causes less social stress in years of extreme rainfall variability. In the same perspective, Ochieng J, et al. [17], studying the effect of climate variability on the aggregate income of all crops on the one hand; maize and tea on the other hand, come to a first conclusion that climate variability affects all crops, but the effects differ from one crop to another; in a second step, temperature has a negative effect on maize, but a positive effect on tea. However, rainfall has a negative effect on tea. They deduce that temperature has a greater impact on production than rainfall. Michael C, and David T, [18], studying how alternative agricultural production systems, the efficiency of agricultural inputs, and the choice of food lead to environmental degradation, show that increasing the efficiency of agricultural inputs (the amount of food produced by the application of fertilizers or animal feed) would have beneficial effects on the environment for both crops and livestock. Moreover, for all the environmental indicators and nutrient units examined, feeds have the lowest environmental impacts, however, ruminant meat has 100 times higher impacts than plant-based feeds. In a similar vein to previous authors, Mall R. K. et al. [19], studying the relationship between crop production and climate change, conclude that crop production is vulnerable to climate variability and change through: temperature increases, CO_2 emissions, and changes in rainfall patterns. In the same year, Aslihan A, et al. [20], studying the impact of intercropping maize and leguminous crops, soil and water conservation practices, organic and inorganic fertilizers, concluded that crop production is vulnerable to climate variability and climate change through: increased temperatures, CO_2 emissions, and changing rainfall patterns.

Recent literature has also highlighted the potential impacts of climate change. A considerable amount of work that has discussed the potential impacts of climate change on agriculture has been available since the work of Callaway et al. [21]. Studies by Yates and Strzepek [22] found that, despite the increase in water availability in Egypt, production was still likely to be affected by climate change. Parry et al. [23] found that climate change is likely to lead to lower crop yields and increase disparities in cereal yields between developed and developing countries. Gregory et al. [24] believe that the potential impact of climate change on food security varies between regions, and between different social groups within a region. Kabubo Mariara [25] concluded that in the long term, climate change is likely to lead to increased poverty, vulnerability and loss of livelihoods.

In the majority of cases, rising temperatures will negatively affect agricultural yields. But what about adaptation?

2.2.2 Review on agricultural adaptation to climate change

Another key issue in the use of weather fluctuations is to assess the likelihood of adaptation. Economic historians have highlighted the ability of agricultural producers to adapt to changing climates. For example, in the North and West regions of the United States in the 19th century, wheat began to be grown in areas with variable climates (too dry or too cold), with the innovation of new cereal varieties (Olmstead and Rhode, [26]). The possibility of adaptation was a major argument for the approach of Mendel Sohn et al. [12]. However, in the American context, Hornbeck [27] finds limited evidence for adaptation through changes in land use. More recently, Burke and Emerick [28], justify adaptation in US agriculture. For them, estimates of production differences due to temperature change over the period between 1980 and 2000 appear to be statistically similar to the impact of annual temperature fluctuations.

Fishman [29] examines the potential of irrigation as a mitigation mechanism for climate change in the Indian context. He concludes that irrigation significantly mitigates this effect, although this mitigation has little impact when temperatures are very high. Travis J et al. [30], studying the effects of agricultural technologies in the face of climate change in developing countries, concludes that climate has obvious direct effects on agricultural production. The effective development and dissemination of new agricultural practices and technologies largely determine how and to what extent farmers mitigate and adapt to climate change.

Numerous contemporary analyses link economic success to temperate climate through beneficial agricultural technologies (Jones, [31]; Crosby, [32]; Diamond, [33]).

Nazan K et al. [34], studying the importance of goat breeding in climate change mitigation and adaptation, conclude that goats have many advantages, allowing them to maintain production under extreme climatic conditions. Mainly, goats have a higher capacity than other ruminants in terms of converting certain feed sources to milk and meat. In addition, goats emit less methane than other domestic ruminants. Based on these advantages, goat keeping will play an important role in climate change mitigation and adaptation in difficult climatic regions.

The scientific literature has also examined the role of forests in the process of adaptation to climate change. Forests have an important regulatory role, as they play an important role in the global carbon balance, and preserve biodiversity. Van M et al. [35], studying the effects of deforestation on the climate in the western United States of America, conclude that deforestation increases warming and reduces precipitation. Using longitudinal data, Carnicer et al. [36], also showed that deforestation leads to a decrease in rainfall in the Iberian Peninsula. Related work has also shown that global warming reduces the resistance of trees (Adams et al. [37]). Westerling et al. [38], using panel data, show that the increase in forest fires in the western subregions of the United States is closely related to changes in temperature and local precipitation.

In summary, the estimates show that high temperatures negatively and significantly affect agricultural production. These impacts are pronounced when temperatures rise above a specific threshold. It appears that, in rich countries such as the United States, Canada and Europe, the effects of climate change have been mitigated through adaptation techniques. However, in developing countries the phenomenon remains a major concern, as in these countries agriculture accounts for a significant proportion of global production.

However, an econometric evaluation will enable us to assess the specific case of Cameroon based on econometric regressions.

3. EVALUATION METHODOLOGY

The evaluation methodology adopted focuses first on the nature and source of the data (3.1), then on the choice and justification of the variables (3.2), and finally on the econometric regression model (3.3).

3.1 Nature and Source of Data

The data used are inherently secondary in nature. They are extracted from: The World Bank's World Development Indicators (WDI) database and National Aeronautics and Space Administration (NASA) weather stations. The variables are quantitative and therefore measurable. The period of the study is from 1980 to 2016. This study period is due to the availability of data. For example, the temperature data from the NASA base stopped in 2016.

3.2 Selection and Justification of Variables

In this paragraph, two types of variables are distinguished in order to verify the relationship between rising temperatures and cereal production in Cameroun. These are the explained variable and the explanatory or independent variables.

3.2.1 The dependent variable: cereal production

Cereal production is our dependent variable, it characterizes the availability of food. The data available for this study are the cereal yields (Rcer), they are expressed in kilograms per hectare of land harvested, and they include: wheat, rice, corn, barley, oats, rye, millet, sorghum, buckwheat and mixed grains. These data relate to dry grain crops only. Several authors have used it in their work (Adams et al. [11,9]).

3.2.2 Independent variables

The temperature variable (Temp), it represents the variable of interest. It is measured by the evolution of average temperatures over the course of a year. The unit of measurement is the degree Celsius (°C). Previous studies have shown that global warming is expected to have adverse effects on agricultural productivity in Africa (Deschenes and Greenston, [7]; Schlenker and Lobell, [3]; Feng et al. [8]).

The cereal land variable (Terre cer), refers to the area harvested, although some countries report only the area sown or cultivated. It is measured in hectares. This variable was used by Deschênes and Greenstone [7]. These authors believe that soil quality, especially the percentage of sand and clay, has very little effect on agricultural production.

The Population Density (Dpop) variable is measured by the number of people per square kilometre of land. It is obtained by the mid-year population density divided by the area of land in square kilometres. The population is made up of all residents regardless of their legal status or citizenship, with the exception of refugees who do not permanently reside on the national territory. The literature suggests that population density is an indicator of agricultural adaptation options. Population density is also an indicator of the availability of agricultural labour.

The variable carbon dioxide (CO_2) emissions is composed of carbon dioxide emissions produced during the consumption of solid, liquid and gaseous fuels. FAO experts (1997) believe that the increase in CO_2 would have positive effects on crop production.

3.3 Econometric Regression

The Ricardian approach is introduced into the study of the impacts of climate change by Mendelson et al. [12], in response to the limitations of the production function approach. It attempts to directly assess the effect of climate change on land and agricultural yields. By looking at the price of agricultural land in different environments, this approach implicitly considers the full range of possible adaptation strategies available to farmers.

The basic formulation of our econometric model is a modified, simplified and adapted version of its basic model, and is as follows:

$$Y_t = \beta i\, Z_t + \varepsilon_t \quad (1)$$

Where: Yt is the dependent variable, in the context of our study it represents cereal yields; Zt is the vector of independent variables that are perceived as determinants of agricultural production (temperature, population density, land used for cereal production, CO_2 emissions); βi is the coefficient matrix of the independent variables and εt is the error term.

If a cointegrating relationship exists, then the long-run model, the short-run model and the error-correction version of the ARDL model to be estimated can be formulated as follows:

$$\ln Rcer_t = \alpha_0 + \sum \beta_{1i} \ln Rcer_{t-i} + \sum \beta_{2i} \ln Dpop_{t-i} + \sum \beta_{3i} \ln Terre\_cer_{t-i} + \sum \beta_{4i} CO_{2t-i} + \sum \beta_{5i} \ln temp_{t-i} + u_t \quad (2)$$

$$\Delta \ln Rcer_t = \alpha_0 + \sum \beta_{1i} \Delta \ln Rcer_{t-i} + \sum \beta_{2i}\, \Delta \ln Dpop_{t-i} + \sum \beta_{3i}\, \Delta \ln Terre\_cer_{t-i} + \sum \beta_{4i} \Delta \ln\, CO_{2t-i} + \sum \beta_{5i} \Delta \ln Temp_{t-i} + \delta(ECM_{t-1)} + \varepsilon_t. \quad (3)$$

With

$$ECM_{t-1} = \ln Rcer_{t-1} - \alpha_0 + \sum \beta_{1i} \ln Rcer_{t-i} + \sum \beta_{2i} \ln Dpop_{t-i} + \sum \beta_{3i} \ln Terre\_cer_{t-i} + \sum \beta_{4i} \ln\, CO2_{t-i} + \sum \beta_{5i} \ln temp_{t-i} \quad (4)$$

Avec: $-1 \leq ECM_{t-1} \leq 0$ et $\delta<0$.

The absolute value of δ determines how quickly equilibrium will be established. With: Rcer: Cereal yields (Kg per hectare); Temp: Temperature (°C); Dpop: Population density (people per Km_2 of land); Terre-cer: Land used for cereal production (Hectare); CO_2: Carbon dioxide emission (Metric ton per capita).

4. RESULTS OF ESTIMATES AND INTERPRETATIONS

In this section, we will present: the descriptive analysis and the Correlation table (Table 2); the results of the preliminary tests (4.2); the cointegration results (4.3); the results of the ARDL test (4.4), and finally the results of the robustness tests (4.5).

4.1 Descriptive Analysis and Correlation Table

This paragraph summarizes the results of the descriptive analysis (4.1.1) and the Correlation table (Table 2) of this study.

4.1.1 Descriptive analysis

In this sub-section, it is important to look at the descriptive analysis of the natural behaviour of the data available to us. At first glance, we can see that some variables are of high value compared to others, which widens the gap between them. In order to overcome these discrepancies, we use a logarithmic transformation, as shown in the Table 1.

According to the Table 1 it can be seen that over the period 1980-2016, the average cereal yields in (kg/ha) are estimated at 7.2178, with a maximum of 7.5462 and a minimum of 6.7619; the average temperature, evaluated in degrees Celsius (°C), at an average of 26. 1096, a maximum of 27,600 and a minimum of 23,300. The average CO_2 over the same period, evaluated in metric tons per capita, has a maximum of 0.67443, an average of 0.31228, and a minimum of 0.08938. The average Dpop evaluated in person per Km^2 of land, over the same period has an average rate of 32.886, limited to a maximum of 50.5084, and a minimum of 18.8955; finally the average cereal land, measured in Ha, is in the range 14.4894 and 13.2744, with an average of 13.8705, over the 36 years of study.

4.1.2 Correlation table

As a reminder, the Correlation Table presents the correlation between two or more random variables, i.e. studies the strength of the link between the variables.

The Table 2 shows a positive and significant correlation between Grain Yields and variables such as: population density, grain land and temperature. There is also a negative and positive correlation between Grain Yields and carbon dioxide.

4.2 Preliminary test Results

Preliminary tests are tests that analyse the feasibility of the studied model. The results of the unit root test (4.2.1), and the determination of the number of delays (4.2.2), will form the backbone of this part.

4.2.1 Results of the unit root test

The results of the unit root test allow us to celebrate the level of stationarity of the variables and to choose the econometric analysis model.

Table 1. Descriptive analysis

Vbles	Mean	Max	Min	Std.Dev.
LnRcer	7.21	7.54	6.76	0.24
Temp	26.1	27.6	23.3	1.14
$C0_2$	0.31	0.67	0.08	0.15
Dpop	32.8	50.5	18.8	9.49
LnTerrecer	13.8	14.4	13.2	0.36

Source: Author, based on WDI data (2018)

Table 2. Correlation table

Vbles	CO_2	Dpop	LNRcer	LNTerrecer	Temp
CO_2	1				
Dpop	-0.42**	1			
LNRcer	-0.5***	0.8***	1		
LNTerrecer	-0.054	0.8***	0.39**	1	
Temp	-0.5***	0.5***	0.5***	0.257	1

Source: Author, based on WDI data (2018)

Table 3. Unit root test results

Variables	0-order integration, « I(0) »			order 1 integration, « I(1) »		
	DFA cal	Proba	Decision	DFA cal	Proba	Decision
Temp	-2.250	0.193	N.S	-7.356	0.000	S
CO_2	-3.148	0.031	S			
R.cer	-1.824	0.363	N.S	-5.464	0.0001	S
Dpop	-2.235	0.1983	N.S	-2.897	0.0894	S
Terre-cer	-0.800	0.806	N.S	-7.285	0.000	S

From the results presented in the Table 3, it follows that, with the exception of the CO_2 variable, which is integrated at level or integrated of order 0, the rest of the variables such as: cereal yields, population density, cereal land, and temperature are integrated of order 1.

In conclusion, although all these variables are not stationary at level, they all become stationary in first difference. It can therefore be deduced that the cointegration approach by Boound testing is the most appropriate.

4.2.2 Determination of the number of lags

The Fig 1 shows the twenty best models according to the Schwarz information criteria. The ARDL model (1, 1, 2, 1, 0, 1) corresponds to the lowest SIC value.

4.3 Cointegration Results: Bound Testing Approach

As a reminder, the Bound test approach was used to assess the presence of cointegration between series. The test procedure is based on common F-statistics. If the calculated F-statistic is greater than the upper critical value, regardless of the level of integration, the null hypothesis, which is illustrated by the absence of cointegration, can be rejected. Also, if the calculated F-statistic is below the lower critical value, the null hypothesis can also be rejected. However, if the calculated F-statistic falls between the lower and upper critical values, the result is inconclusive. This result is summarized in the Table 4.

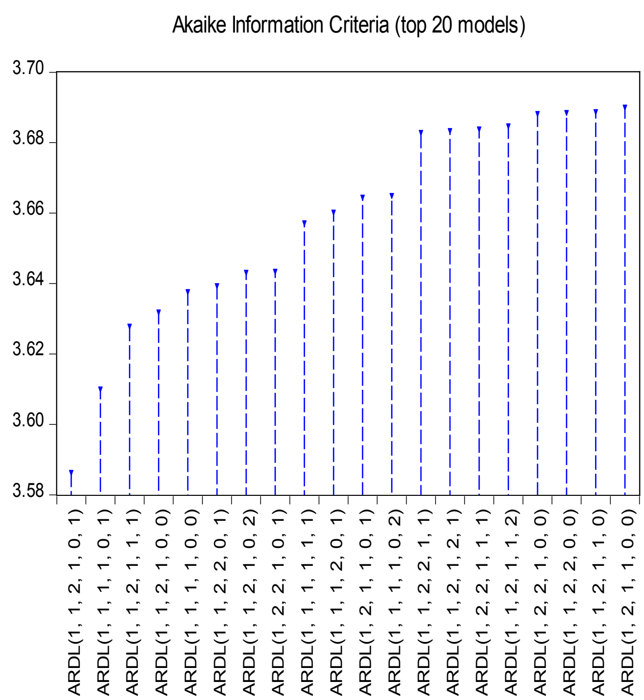


Fig. 1. The number of lags
Source: Author, based on WDI data (2018)

Referring to the above Table 4, it can be seen that, whatever the degree of integration, the value of the calculated statistic (4.39) is higher than the upper critical value (4.37). We can therefore reject the null hypothesis (H0= no long-term relationship), and conclude that there is a long-term relationship between the different variables.

4.4 Estimation Results Translated by ARDL

The results of the estimates translated by the ARDL can be seen in the short term (4.4.1) as well as in the long term (4.4.2).

4.4.1 Result of the short-term dynamics

The results of the short-term dynamics are summarized in the Table 5.

As a reminder, D denotes the first difference of the variables used. The term CointEq (-1) corresponds to the lagged residual from the long-term equilibrium equation. Our results are estimated at -0.586, negative and largely significant at the rate of 1%, confirming the existence of an error correction mechanism. This coefficient expresses the degree to which the dependent variable (cereal yield), will be recalled towards the long term target.

The short-term results show that temperature does not affect cereal yields in Cameroon. This can be explained by the ingenuity and renewed capacity to adapt to farming techniques transmitted from generation to generation such as: watering, irrigation, cultivation of very short crops.

The population density at the date (t-2) negatively affects cereal yields. This can be justified by the fact that a large part of the population is not interested in agriculture, and even when this is the case, it is interested in growing products other than cereals. This result is contrary to that of Kabubo-Mariara [25].

Cereal land at dates (t), (t-1), and (t-2), negatively affects cereal production. This can be explained by the law of diminishing yields. That is to say, the more the land is exploited, the more it deteriorates and the yields become increasingly decreasing.

Carbon dioxide also affects cereal yields in the short term. This result is contrary to that of the FAO, which believes that the increase in CO_2 would have positive effects on crop production.

While population density at (t) and (t-1), does not seem to affect grain yields.

Table 4. Bound testing approach

	F-statistic	Seuil	Confidence interval		Decision
			I_0	I_1	
Cointegration Test	4.399	10%	2.2	3.09	There is a cointegration relationship at the threshold of 1%.
		5%	2.56	3.49	
		2,5%	2.88	3.87	
		1%	3.29	4.37	

Source: Author, based on WDI data (2018)

Table 5. Short-term results

Variables	Coefficient	Prob.
D(Temp)	-0.005	0.710
D(LNTerrecer)	-0.374	0.000
D(LNTerrecer(-1))	-0.127	0.048
D(LNTerrecer(-2))	-0.234	0.001
D(Dpop)	1.035	0.283
D(Dpop(-1))	0.730	0.610
D(Dpop(-2))	-3.776	0.003
D(CO_2)	-0.214	0.003
CointEq(-1)*	-0.586	0.000

Source: Author, based on WDI data (2018)

Beyond the short-term results, the ARDL model also integrates long-term dynamics.

4.4.2 Result of the long-term dynamics

In order to complement the short-term outcomes, the long-term outcomes, as elaborated in the Table 6, will be addressed.

Long-term results show that in Cameroon the temperature does not affect cereal yields. Two explanations can be attributed to adaptation and the agro-ecological diversity that abounds in the country. As in the short term, farmers manage to resist the vagaries of the climate through renewed ingenuity in the ancestral cultivation techniques that they apply from generation to generation. Several studies have found similar results, although the contexts were different (Deschênes and Greenstone, [7]; Mendelsohn, Nordhaus and Shaw, [12]). Also, Cameroon has a very varied agro-ecological diversity, and of the 10 regions that make up the country, only two seem to be affected by desertification. The other eight really do not seem to be affected. In short, crops are adapted to each agro-ecology.

As for population density, it positively affects agricultural production. That is to say, the more the population grows, the higher the agricultural yields. Population density means an abundance of labour. The more it grows, the more labour is available, and the higher the agricultural yields. Similar results have been found by (Kabubo-Mariara, [25]) who finds that, labour endowment contributes to an increase in net agricultural incomes.

Cereal land, for its part, negatively affects cereal yields. This can be explained, on the one hand, by the fact that land degrades as it is farmed. This reduces cereal yields in the long term; and on the other hand, the composition of the soil, which can be poor in fertilizers. This affects cereal yields. Deschênes and Greenstone [7], also believe that the quality of the soil, rich in sand and clay, affects agricultural production.

Carbon dioxide does not seem to affect cereal yields.

4.5 Robustness Test

The robustness test allows us to appreciate the authenticity of our results. Thus, the diagnostic tests (3.5.1), and the "CUSUM" test and "CUSUMQ" tests (3.5.2) will allow us to confirm the robustness of our model.

4.5.1 Results of the diagnostic tests

Also known as post-estimation tests, diagnostic tests were performed to assess the robustness of our model. These tests include: the Lagrange multiplier test for the autocorrelation of residuals; the Ramsey functional form test (RESET) for the omission of a variable; the JarqueBera test for the normality of residuals; and the Breusch-Pagan-Godfrey heteroscedasticity test for heteroskedasticity. The results of these tests are summarized in the Table 7.

Looking at the Table 7, we can see that the variables are normally distributed, the absence of autocorrelation of the residuals, the absence of heteroskedasticity, and the absence of omission of a variable. The results of these few tests show that the residuals have all the properties we are looking for. This really confirms that our model is robust.

4.5.2 Results of the "CUSUM" and "CUSUMQ" tests

In this study, the results of the "CUSUM" and "CUSUMQ" tests are applied to the residuals of the econometric model. The CUSUM and CUSUMQ tests are based on the sum of the residuals. They represent the curve of the cumulative sum of residuals, with 5% of the critical lines. The model parameters are unstable if the curve is outside the critical area, and stable if the curve is between the two critical lines. The results of our estimates are presented in the Fig. 2.

Table 6. Long-term outcome

Variables	Coefficient	Prob.
Temp	0.056	0.155
CO_2	-0.107	0.711
LNTerrecer	-0.397	0.049
DPop	0.099	0.004
C	10.90	0.0006

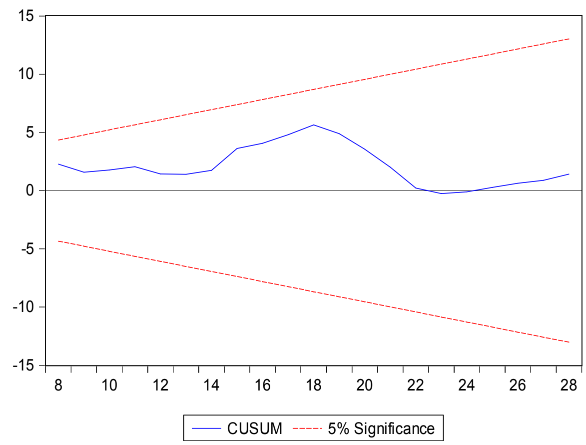
Source: Author, based on WDI data (2018)

Table 7. Diagnostic test results

Tests	V. cal	Prob	Decision
Normality	0,692	0,707	Presence
Autocorrelation	1,404	0,271	Absence
heteroskedasticity	1,974	0,083	Absence
omission of a variable	3,048	0,097	Absence

Source: Author, based on WDI data (2018)

CUSUM Test



CUSUMQ Test

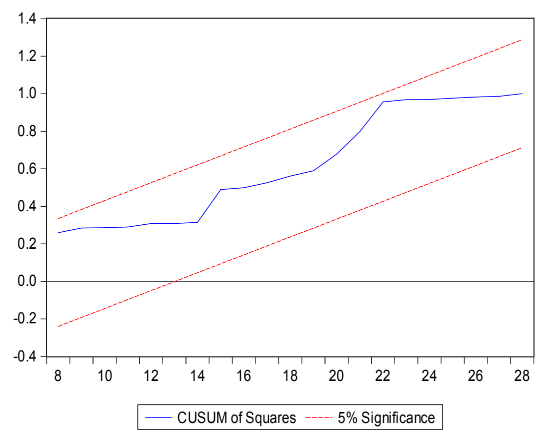


Fig. 2. Results of the "CUSUM" test and the "CUSUMQ" test
Source: Author, based on WDI data (2018)

After analysis, it is also found that the model parameters are stable, as the curves lie between the two critical lines. So our model is robust.

5. CONCLUSION

The objective of this paper was to examine the effect of rising temperatures on cereal production in Cameroon over the period 1980-2016. The method of analysis used was the staggered delay cointegration test or Auto Regressive Distributed Lags (ARDL) combined with the CUSUM and CUSUMQ tests. The results show that temperature does not affect cereal production in Cameroon in the short and long term. This can be justified by adaptation measures. Farmers manage to resist the vagaries of the climate by renewing the ingenuity of ancestral cultivation techniques that they pass on from generation to generation. Also, Cameroon has a very varied agro-ecological diversity, and of the 10 regions it has, only two seem to be affected by desertification. The other eight really don't seem to be affected at all.

Like any human work, this article cannot be perfect. It does not claim to have addressed all the issues on climate change. Moreover, the economics of climate change is still a vast field of research where several ideas remain to be explored. It would be possible to extend this work using climate projection data through simulations in order to better appreciate the effect of rising temperatures on cereal yields in Cameroon. Likewise, this work would also have been better if this study had been carried out on all agricultural products by subdividing the country into agro-ecological zones.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. GIEC. Impacts, adaptations and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Parry ML, Canziani OF, Palutikof JP, van der Linden PJ et Hanson, C. E. (ed.). Cambridge University Press, Cambridge, Royaume-Uni. 2007;1000.
2. Barrios Salvador, Bazoumana Ouattara, Eric Strobl. The impact of climatic change on agricultural production: Is it different for Africa? Food Policy. 2008;33(4):287-298. Available:https://doi.org/10.1016/j.foodpol.2008.01.003
3. Schlenker W, Lobell DB. Robust negative impacts of climate change on African agriculture. Environmental Research Letters. 2010;5(1):1–8.
4. Rowhani P, Lobell DB, Linderman M, Ramankutty N. Climate variability and crop production in Tanzania. Agric. For. Meteorol. 2011;151:449–460.
5. Lobell DB, Bänziger M, Magorokosho C, Vivek B. Non linear heat effects on African maize as evidenced by historical yield trials. Nat. Clim. Chang. 2011;1:42–45.
6. Blanc Elodie. The impact of climate change on crop yields in Sub-saharan Africa. American Journal of Climate Change. 2012;1:1-13.
7. Deschenes O, Greenstone M. The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. American Economic Review. 2007;97:354-385.
8. Feng Shuaizhang, Alan B. Krueger, Oppenheimer M. Linkages among climate change, crop yields and Mexico–US cross-border migration. Proceedings of the National Academy of Sciences. 2010;107(32):14257–62.
9. Adams R. Global climate change and US Agriculture Nature. 1990;345:219-224.
10. Kaiser HM, Riha SJ, Wilks DS, Rossiter DG, Sampath R. A farmle velanalysis of economic and agronomic impacts of gradual warming. American Journal of Agricultural Economics. 1993;75:387-398.
11. Adams RM, Fleming R, Chang C, McCarl B, Rosenzweig C. A reassessment of the economic effects of global climate change in U.S. Agriculture. Climatic Change. 1995;30(2):147167. Available:www.springerlink.com/index/N201G122L0PW77M2.pdf
12. Mendelsohn R, Nordhaus WD, Shaw D. The impact of global warming on agriculture: A Ricardian analysis. The American Economic Review. 1994;4(84): 755-771.
13. Fischer G, Shah MM, van Velthuizen HT. Climate change and agricultural vulnerability. IIASA, Laxenburg, Austria; 2002.
14. Anton Vrieling, Author Kirsten, de Beurs Molly M, Brown E. Variability of African farming systems from phenological analysis of NDVI time series. Climatic Change. 2011;109(3-4):455–477.
15. Jones AD, Shrinivas A, Bezner-Kerr R. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. Food Policy. 2014;46: 1-12. Available:https://doi.org/10.1016/j.foodpol.2014.02.001
16. Papaioannou Kostadis, de Haas Michiel. Climate shocks cash crops and resilience:

Evidence from Colonial Tropical Africa; 2015.
Available:https://ssrn.com/abstract=2679299
http://dx.doi.org/10.2139/ssrn.2679299

17. Ochieng J, Kirimi L, Mathenge M. Effects of climate variability and change onagricultural production: The case of small scale farmers in Kenya. NJAS – Wageningen Journal of Life Sciences. 2016;77:71-78.
Available:https://doi.org/10.1016/j.njas.2016.03.005
18. Michael Clark, David Tilman. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency and food choice. Environ. Res. Lett. 2017;12: 064016.
19. Mall RK, Gupta A, Sonkar G. Effect of climate change on agricultural crops, current developments in biotechnology and bio engineering crop modification, nutrition and food production. Crop Modification, Nutrition and Food Production. 2017;23-46.
Available:https://doi.org/10.1016/B978-0-444-63661-4.00002-5
20. Aslihan Arslan, Federico Belotti, Leslie Lipper. Smallholder productivity and weather shocks: Adoption and impact of widely promoted agricultural practices in Tanzania. Food Policy. 2017;69:68-8.
21. Callaway, John M. Adaptation benefits and costs: Are they important in the global policy picture and how can we estimate them? Global Environmental Change. 2004;14:273-282.
22. Yates DN, Strzepek KM. An assessment of integrated climate change impactson the agricultural economy of Egypt. Climatic Change. 1998;38:261-287.
23. Parry ML, Rosenzweig C, Iglesias A, Livermore M, Fischer G. Effects of climate change on global food production under sres emissions and socioeconomic scenarios. Global Environmental Change. 2004;14:53-67.
24. Gregory PJ, Ingram, MJSI. Brklacich. Climate change and food security. Phil. Trans. R. Soc. B. 2005;360:2139-2148.
25. Kabubo-Mariara J. Global warming and livestock husbandry in Kenya: Impacts and adaptations. Ecological Economics. 2009;68:1915-1924.
26. Olmstead Alan L, Paul W. Rhode. Adapting North American wheat production to climatic challenges, 1839–2009. Proceedings of the National Academy of Sciences. 2011;108(2):480–85.
27. Hornbeck R. The enduring impact of the American dust bowl: Short- and long-run adjustments to environmental catastrophe. American Economic Review. 2012;102(4): 1477–1507.
28. Burke M, Emerick K. Adaptation to climate change: Evidence from US Agriculture; 2013.
Available:http://www.ocf.berkeley.edu/~kemerick/Burke_ Emerick_2013.pdf
29. Fishman R. Climate change, rainfall variability and adaptation through irrigation: Evidence from Indian Agriculture. Unpublished; 2011.
30. Travis J, Lybbert Daniel A. Sumner. agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. Food Policy. 2012;37(1):114-123.
Available:https://doi.org/10.1016/j.foodpol.2011.11.001
31. Jones E. The European miracle: Environments, economies and geopolitics in the history of Europe and Asia. Cambridge and New York: Cambridge University Press; 1981.
32. Crosby Alfred W. Ecological imperialism: The biological expansion of Europe, 9001900. Cambridge and New York: Cambridge University Press; 1986.
33. Diamond J. Guns, germs and steel: The fates of human societies. New York: W. W.Norton; 1997.
34. Nazan Koluman Darcan, Nissim Silanikove. The advantages of goats for future adaptation to climate change: A conceptual overview. Small Ruminant Research. 2018;163:34-38.
Available:https://doi.org/10.1016/j.smallrumres.2017.04.013
35. Van Mantgem, Phillip J, et al. Widespread increase of tree mortality rates in the Western United States. Science. 2009;323(5913):521–24.
36. Carnicer J, Coll M, Ninyerola M, Pons X, Sanchez G, Penuelas J. Widespread crown condition decline, food web disruption and amplified tree mortality with increased climate change-type drought. Proceedings of the National Academy of Sciences. 2011;108(4):1474–78.
37. Adams Henry D, et al. Temperature sensitivity of drought-induced tree mortality

portends increased regional die-off under global-change- type drought. Proceedings of the National Academy of Sciences. 2009;106(17):7063–66.

38. Westerling AL, Hidalgo HG, Cayan DR, Swetnam TW. Warming and earlier spring increase western U.S. Forest Wild Fire Activity; 2006.

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