Assessing the Impact of Climate Change on Grain Yield in Algeria: An Econometric Study using Autoregressive Distributed Lag Model (ARDL)

Évaluer l'impact du changement climatique sur le rendement en grains en Algérie : une étude économétrique utilisant le modèle de décalage distribué autorégressif (ARDL)

Dr. IKHLEF Larbi University Mohamed-Cherif Messaadia Souk Ahras Algeria, Laboratory of Research and Economic Studies. Email: l.ikhlef@univ-soukahras.dz

Information sur l'article

Reçu le: 08 /7/2023
Accepté le:19/7/2023
Publié le: 15/9/2023

Mots clés:
Mot clé.1: Changement Climatique
Mot-clé.2 : CO2
Mot-clé.3 : Engrais
Mot-clé.4 : ARDL
Mot-clé.5 : Algérie
Codes de classification JEL:
H8 ,N5 ,Q 1

Résumé:

L'objectif principal de cette étude est d'étudier l'impact du changement climatique sur la production céréalière en Algérie. L'étude a utilisé des données annuelles collectées de 1961 à 2019 et a utilisé le modèle de décalage distribué autorégressif (ARDL) pour l'analyse des données. Les résultats de l'étude ont révélé la présence d'une relation d'équilibre à long et à court terme entre les variables explicatives, notamment la température et les émissions de dioxyde de carbone (kilotonnes), ainsi que les variables de contrôle, telles que la quantité d'engrais utilisée annuellement dans l'agriculture. et la superficie des terres utilisées pour la production céréalière en Algérie. Cependant, la variable des précipitations annuelles moyennes n'a pas montré d'effet significatif sur la production céréalière au cours de la période étudiée.

Keywords:
Keyword.1: Climate change
Keyword.2: CO2
Keyword.3: Fertilizer
Keyword.4: ARDL
Keyword.5: Algeria
JEL Clkassification Codes:
H8,N5 ,Q 1

Abstract:

The main objective of this study is to investigate the impact of climate change on grain production in Algeria. The study utilized annual data collected from 1961 to 2019 and employed the AutoRegressive Distributed Lag Model (ARDL) for data analysis. The findings of the study revealed the presence of a long- and short-term equilibrium relationship between the explanatory variables, including temperature and carbon dioxide emissions (kilotons), as well as the control variables, such as the amount of fertilizer used annually in agriculture and the area of land used for grain production in Algeria. However, the average annual precipitation variable did not show any significant effect on grain production during the studied period.

IKHLEF Larbi. Email: l.ikhlef@univ-soukahras.dz

1- Introduction

The agricultural sector plays a crucial role in the economic development of nations, contributing to growth, poverty reduction, and food security. However, this sector is highly vulnerable to the impacts of climate change, such as changes in temperature, precipitation, droughts, and floods. In the 21st century, climate change and its effects on agriculture have become a significant challenge for researchers and policymakers worldwide, with developing countries, including Algeria, being particularly affected. Algeria has experienced the repercussions of climate change, evident through recent wildfires and declining agricultural productivity, especially in grains like wheat and barley, due to drought and decreased precipitation. Researchers and practitioners believe that the negative impacts of climate change on agriculture, directly linked to food security and human livelihoods, have outweighed the positive effects in recent decades. Therefore, it is crucial to identify future abnormal climate events and develop adaptation measures to mitigate these impacts. The research problem addressed in this study is the impact of climate change on grain production in Algeria. The study aims to analyze the short-term and long-term associations between climate change and grain production using time series data for the period 1961-2019. The study will investigate the effects of annual rainfall rate, temperature, carbon dioxide emissions, fertilizer use, and land area on grain production, using the Auto-Regressive Distributed Lag (ARDL) model. The findings of this study are expected to provide valuable insights for decision-makers to formulate effective policies and strategies to mitigate the negative impacts of climate change on grain production and food security in Algeria

2 -Theoretical framework

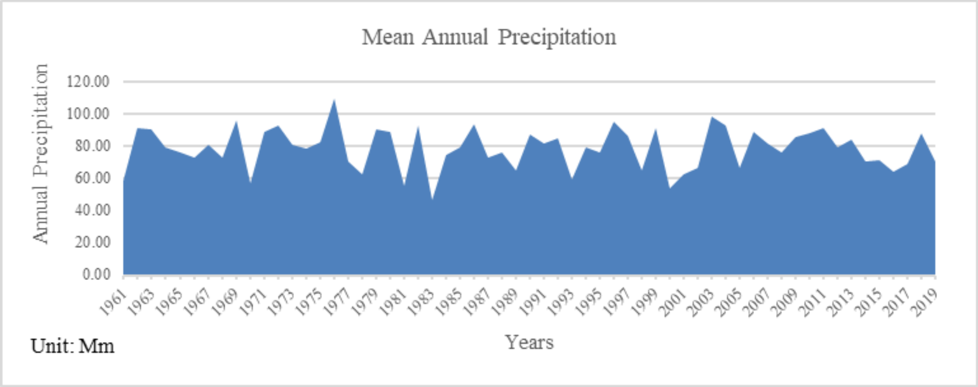
1.2 Climate Change in Algeria

Over the past decades, the world has witnessed a significant increase in anthropogenic greenhouse gas emissions, which led to a gradual rise in global warming, which in turn was cast by an increase in the average surface temperature of the Earth, melting of snow in countries as well as glaciers, and a rise in sea level. This also contributed to exacerbating the phenomenon of dehydration. All the aforementioned phenomena lead to major societal problems due to the economic and environmental damage left behind (Timmerman, 2016; Lee, Nadolnyak, & Hartarska, 2012), and on this basis, there is a broad consensus of climate scientists as well as countries' leaders, especially the major ones, to the necessity of adopting mechanisms that control the phenomenon of global warming at rates agreed upon by them.

In the Algerian context, climate change is considered one of the most critical challenges facing the government, especially in the last decade of the 21st century. Being part of the Mediterranean region, this reflects Algeria's severe vulnerability towards climate change, as specialists expect in the average term an increase in temperature by two degrees Celsius, a decrease in precipitation, and a more frequent annual increase in drought cases, which is directly mirrored in the increase in fires starting from 2021. The latter, according to the statistics of the National Aeronautics and Space Administration of the United State, devoured more than 62,000 thousand hectares of forests (Sahnoune, Belhamel, Zelmat, & Kerbachi, 2013; NASA, 2021).

Moreover, drought is a relative phenomenon that represents a deviation from normal hydro meteorological conditions. In this study, drought means a decrease in average annual precipitation and its fluctuation in Algeria rather than a scarcity of groundwater. Algeria has witnessed drought scenarios throughout the years, and considering long-term rainfall below the normal rate in a semi-arid climate will have devastating effects on Algerian agriculture. It is regarded as among the activities most directly affected by the decrease in the annual rate of rainfall (Habibi, midi, Torfs, & Remaoun, 2018; Rouabh, Adouane, & Felloussia, 2019). The following

Figure(01) shows the average rainfall in Algeria from 1961 to 2019:

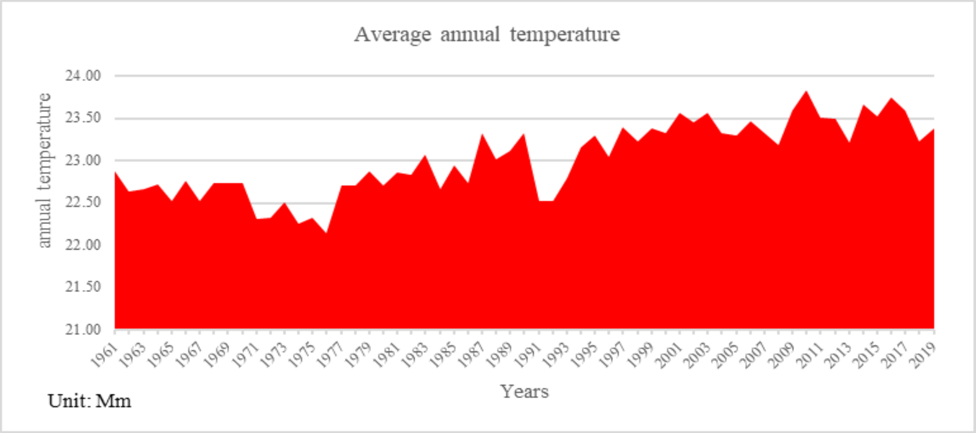


Source: Prepared by the researcher based on statistics from the Climate Change Knowledge Portal (CCKP) and the Climatic Research Unit of the University of East Anglia (CRU).

Climate change also affects temperatures through pressure on them. The average temperatures recorded in Algeria during summer were between 21° and 36° in different cities all over the country, whereas in the winter season, it decreased to an approximate of 8° to 12° (Boufekane, Busico, &

More, 2021). The annual average for all cities recorded rates ranging from 22° to about 24°, as shown in the following figure:

Figure2: Average annual temperature in Algeria during the period (1961-2019)



Source: Prepared by the researcher based on the statistics from the Climate Change Knowledge Portal (CCKP).

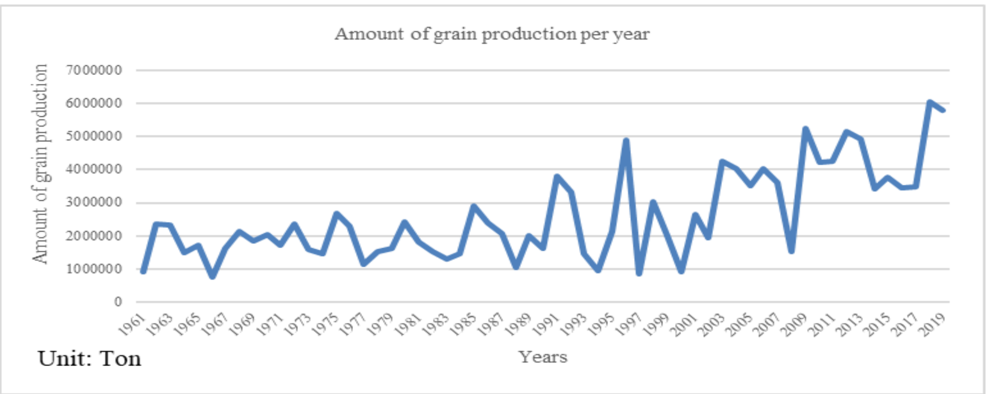
2.2 The Evolution of grain production and exploited areas in Algeria.

Winter grains such as wheat and barley are among the most widespread types of crops in the world. In Algeria, grain cultivation dominates the north. Wheat and barley are grown in autumn between mid-October and late November. The grain is harvested in spring and ends with the stage of ripening and filling the grain, after which the crop is harvested between late May and June (Chourghal, Lhomme, Huard, & Aidaoui, 2015; Rezzoug, Gabrielle, Suleiman, & Benabdeli, 2008). The agricultural productivity of grains, which included both hard and soft wheat, as well as barley, oats and alfalfa, fluctuated and decreased between the years 1961 and 2019, especially between 1995 and 2009, as shown in the following figure:

The area of land exploited for the production of winter grains fluctuated between high and low during the period from 1961 to 2019, and the most important grains adopted in this study are hard and soft wheat, as well as barley, oatmeal and alfalfa. In general, the total exploited area decreased from 27086.32 km 2 (That is, more than 2,708,623 hectares) in 1961 to 31,873.98 km2 (that is, more than 3,187,398 hectares) in 2019, as shown in the following figure:

Overall, agricultural production depends on fertilization to preserve soil fertility, as well as to confront pests that cause damage to plants.

The increased demand for food in Algeria as a result of increased population growth has led to the intensification of agricultural operations, and thus an increase in the use of chemical fertilizers, which come in handy with negative effects in the long run. These negative effects can be perceived in soil degradation, groundwater pollution, and greenhouse gas emissions. The intensive use of these chemicals leads to exacerbation and the increase of health and environmental damages. On this basis, most countries of the world, including Algeria, managed to replace fertilizers with organic ones (cattle manure, etc.) as a reliable and sustainable alternative to soil composting (Ibrahim, Bazri, & Trigo, 2020; Ghemam, et al., 2020). This study relied on the total fertilizers used in agriculture as a whole due to the lack of reliable statistics on grain production. The use of fertilizers increased from 1961 with an estimated amount of 1776.57 kg per 1 km 2 to 2074.61 kg per 1 km 2 (note: 1 km 2 = 100 hectares), in proportion to the land used for agriculture (World Bank), and the following figure shows the development of fertilizer use in Algeria:



2.3 Climate change impact on agricultural production

Researchers, as well as practitioners and experts, believe that climate changes affect agriculture mainly through changes in temperature, precipitation, carbon dioxide concentration, and the frequency of extreme weather events that cause different effects on agriculture in different regions, and the degree of vulnerability depends on the sensitivity and adaptive capacity of the region. With climate change, researchers in this field also believe that regions located in tropical and subtropical climates are more vulnerable to the negative effects of climate change, and that these effects will damage the climate-sensitive agriculture sector. Accordingly, climate changes act as a direct influence on agricultural production along with other factors such as land, water, fertilizers, etc. Nonetheless, others see that the impact of climate change becomes greater on agriculture in regions where agriculture is primitive and does not depend much on technology (Ju et al, 2013; Mishra, Sahu, & Sahoo, 2015).

Meanwhile Ayinde, Muchie, and Olatunji (2011) argue that the risks of climate change on agricultural production do not affect grains only, but this also includes livestock as many farmers depend on animal resources for income as well as food and animal products. Thus, the climate can have a direct and indirect influence on livestock through climate changes, namely; air, temperature, humidity, wind speed… etc.. These climatic factors affect animal performance such as growth, milk production, wool production and reproduction, in addition to the quantity and quality of fodder and grain, and consequently, increasing the incidence and severity of diseases in livestock.

In a same vein, Fischer, Shah, and Velthuizen (2002) believe that the agricultural sector is affected by many factors, including land degradation, water scarcity, and the biodiversity threat... etc., and climate change can cause damage to the ecosystems of lands and waters which negatively affect agricultural productivity. They also argue that the prosperity of the agricultural sector depends on its ability to deal with climate change consequences, as developing countries in these cases are less adaptable to climate change damages, just as they are vulnerable to social, environmental and economic pressures. For that reason, the researchers suggest that the impact of climate change inclusion in the design and implementation of national development plans of countries can reduce vulnerability to climate change.

3 - Research design

3.1 Study model and variables

Through this study, we will try to determine the extent to which climate change affected grain production in Algeria during the period (1961-2019). The study's variables were set and their data was gathered relying on numerous electronic sources, as well as an attempt to address previously used variables on this subject. As a result, the time period was set at 58 years, from 1961 to 2019, due to the lack of data on grain production and exploited land for the years 2020-2021 at the level National Bureau of Statistics. Based on economic theory and previous empirical studies, the following model will be estimated:

$$AGPR= f(APR, ATM, FR, LER, CO2)$$

The following table shows the definition of the variables included in the study model:

Table 1: Study variables

Previous studies	Data source	Variable Name	Variable symbol
(Makougoum, 2018)	*(ONS)*	The amount of winter grain production per year	AGPR
(Mishra et al, 2015; (Makougoum, 2018)	*(CCKP; CRU)*	Annual precipitation rate	APR
(Chandio et al, 2020; Ayinde et al, 2011)	*(CCKP; CRU)*	Annual temperature	ATM
(Makougoum, 2018; Chandio, et al, 2020)	*(World Bank)*	The amount of fertilizer used annually in agriculture	FR
(Makougoum, 2018; Chandio, et al, 2020)	*(ONS)*	The area of land used for grain production	LER
(Chandio et al, 2020; Ayinde et al, 2011)	*(World Bank)*	CO2 emissions (kt)	CO2

To determine the impact of climate change on grain production in Algeria during the period (1961-2019), the Autoregressive Distributed Lag deceleration (ARDL) method will be used, according to the following mathematical formula:

$$\begin{aligned}\Delta LAGPR_t = \beta_0 &+ \sum_{t=1}^{p} \beta_{1t}\Delta LAGPR_{t-i} + \sum_{t=1}^{q1} \beta_{2t}\Delta LAPR_{t-i} + \sum_{t=1}^{q2} \beta_{3t}\Delta LATM_{t-i} \\ &+ \sum_{t=1}^{q3} \beta_{4t}\Delta LFR_{t-i} + \sum_{t=1}^{q4} \beta_{5t}\Delta LLER_{t-i} + \sum_{t=1}^{q5} \beta_{6t}\Delta LCO2_{t-i} \\ &+ \alpha_1 LAGPR_{t-1} + \alpha_2 LAPR_{t-1} + \alpha_3 LATM_{t-1} + \alpha_4 LFR_{t-1} \\ &+ \alpha_5 LLER_{t-1} \\ &+ \alpha_6 LCO2_{t-1} \\ &+ \varepsilon_t \dots\dots\dots\dots\dots\dots \qquad \dots.(02)\end{aligned}$$

Δ: It indicates first-order differences, 0β: fixed limit, p,q1,q2,… q5: high Limit for time delay, t: time, 6β…β1,β2: Short term relationship transactions, 6α1… α2,α Long term relationship transactions, εt: random error limit.

3.2 Standard analysis using ARDL

3.2.1 Unit root tests for the study variables:

Testing the stability of the time series and determining the degree of their integration is considered a necessary condition of co-integration, and in order to apply the ARDL model correctly, all study variables must be integrated of the order I (0) or I (1), that is, there are no integrated variables of the order I (0) or I (1) in higher ranks. And to study the stability of the time series of the variables under study and to determine the degree of their integration, we will rely on the Augmented Dickey Fuller test (ADF). The results of this test are shown in the following table:

Table 2: The results of the unit root test for the variables of the study using the ADF test

UNIT ROOT TEST RESULTS TABLE (ADF)							
Null Hypothesis: the variable has a unit root							
	At Level						
		LAGPR	*LAPR*	*LATM*	*LFR*	*LLER*	*LCO2*
With Constant	*t-Statistic*	*-1.9679*	*-9.1737*	*-1.5697*	*-3.3128*	*-6.9645*	*-2.1751*
	Prob.	*0.3440*	*0.0000*	*0.4913*	*0.0187*	*0.0000*	*0.2174*
		n0	*****	*n0*	****	*****	*n0*
With Constant & Trend	*t-Statistic*	*-2.1155*	*-9.1401*	*-5.1489*	*-3.2622*	*-6.9716*	*-1.6341*
	Prob.	*0.2331*	*0.0000*	*0.0005*	*0.0829*	*0.0000*	*0.7671*
		n0	*****	*****	***	*****	*n0*
Without Constant & Trend	*t-Statistic*	*1.6188*	*-0.2345*	*0.4708*	*-0.0448*	*0.1366*	*2.6080*
	Prob.	*0.9729*	*0.5972*	*0.8134*	*0.6637*	*0.7216*	*0.9975*
		n0	*n0*	*n0*	*n0*	*n0*	*n0*
	At First Difference						
		d(LAGPR)	*d(LAPR)*	*d(LATM)*	*d(LFR)*	*d(LLER)*	*d(LCO2)*
With Constant	*t-Statistic*	*-7.6448*	*-7.7929*	*-11.4811*	*-7.2731*	*-11.1155*	*-7.6895*
	Prob.	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.000*	*0.0000*

						0	
		***	***	***	***	**	***
With Constant & Trend	*t-Statistic*	*-7.5963*	*-7.7145*	*-11.3758*	*-7.2369*	*-6.3499*	*-8.0920*
	Prob.	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
		***	***	***	***	**	***
Without Constant & Trend	*t-Statistic*	*-6.8263*	*-7.8645*	*-11.5528*	*-7.3134*	*-11.2159*	*-6.7765*
	Prob.	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
		***	***	***	***	**	***
Notes:							
a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant							

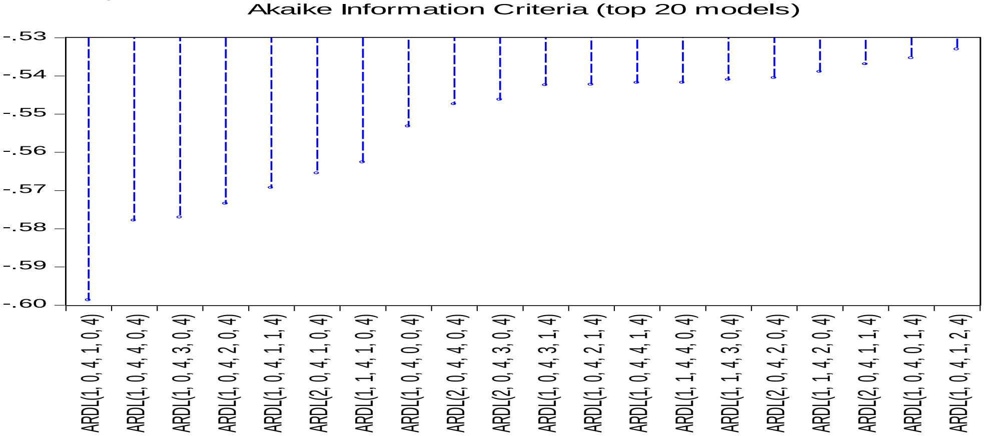
According to the results of the Augmented Dickie Fuller test (ADF) for the unit root shown in the table above and by comparing the calculated values with the tabulated values at the levels of significance 1% = α, 5% = α and 10% = α, it is clear that the dependent variable (AGPR) and the independent variable (ATM) and (CO2) under study are not stable at the level, while the rest of the independent variables are stable at the level. After conducting first-degree differences on these variables and re-taking the ADF test, they all became stable, and therefore all study variables (LAGPR) , LATM, LCO2) are integrated at the first degree, i.e. from Figure I (1). Hence, in the next step, a co-integration test can be performed using the Bounding Test method to test the extent to which there is a long-term equilibrium relationship between climate change and grain production in Algeria during the study period.

3.2.2 Cointegration test using Bounds Test

In order to test the cointegration relationship between the variables of the study, the ARDL model must be estimated. In this regard, we relied on the AIC criterion to determine the optimal time delays, so that the appropriate model is the one through which the lowest value of this criterion is obtained.

The model chosen in this study according to Figure No. (01) is from Figure ARDL (1,0,4, 1,0,4).

Fig. 6: Determining the number of delays in the ARDL model



Testing the cointegration relationship between the study variables within the framework of the Unrestricted Error Correction Model (UECM), where the null hypothesis states that there is no cointegration (a long-term equilibrium relationship) between the variables will be tested as follows:

$$H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0$$

As opposed to the alternative hypothesis that there is a cointegration relationship in the long run:

$$H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq 0$$

Table (03) shows the results of the ARDL Bounds Test, where it is clear that the statistical value (F-statistic) is equal to 7.0699, which is greater than the critical value of the upper limit at all levels of significance 1%, 5% and 10%. Thus, there is a long-term equilibrium relationship between climate change and grain production in Algeria during the study period.

Table 3: ARDL Bounds Tests results.

ARDL Bounds Test		
Null Hypothesis: No long-run relationships exist		
Test statistic	*value*	*k*
F-statistic	*7.0699*	*5*
Critical Value Bounds		
Significance	*I0 Bound*	*I1 Bound*

10%	*2.26*	*3.35*
5%	*2.62*	*3.79*
1%	*3.41*	*4.68*

3.2.3 Diagnostic tests for the model:

In order to verify the existence of standard problems that affect the strength and validity of the estimated model, a set of diagnostic tests will be performed, and the following table shows the results of the most important of these tests.

Table 4: Diagnostic Tests' Results

Statistical test	calculated value	probability value	Decision
Serial Correlation (LM test)	5.1186	0.0774	Hypothesis H0 accepted: no autocorrelation problem
Heteroskedasticity (Breusch-Pagan-Godfrey)	16.9420	0.3223	H0 hypothesis accepted: no variance problem exists
Normality (Jarque-Bera)	1.4013	0.4962	H0 hypothesis is accepted: the residuals are normally distributed
Ramsey RESET Test	1.6605	0.2053	H0 Hypothesis accepted: The model does not suffer from the problem of indeterminacy

Based on the results of the LM test shown in the table above, it is clear that the probability value corresponding to this test Prob = 0.0774 is greater than 0.05. Therefore, the alternative hypothesis will be rejected and the null hypothesis (H0) will be accepted, which states that there is no autocorrelation between the remainder, and this means that the estimated model does not suffer from the autocorrelation problem.

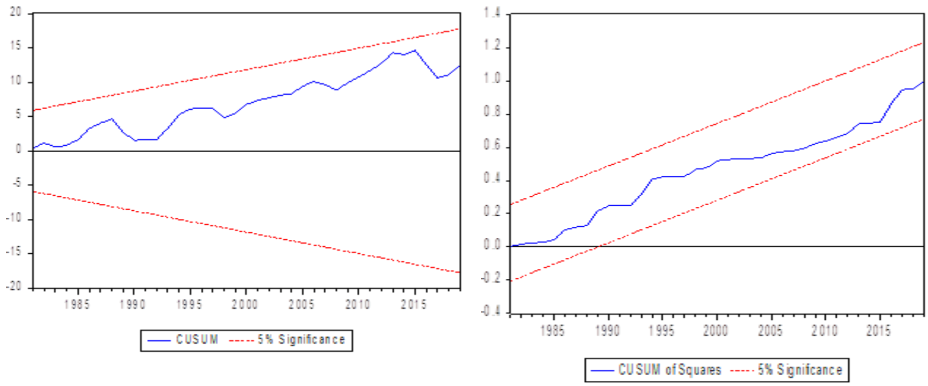
The results of the Breusch-Pagan-Godfrey test also indicate that the probability value corresponding to this test Prob = 0.3223 is greater than 0.05. Therefore, we reject the alternative hypothesis and accept the null hypothesis (H0), which states that the model does not suffer from the difference of variance problem, and this means that the estimated model does not suffer from the problem of instability of contrast smoothing.

It is also noted from table 4 that the probability value corresponding to the Jarque-Bera test for a normal distribution reached 0.4962, which is greater than 0.05, and so we accept the null hypothesis (H0), which states that the residuals are normally distributed.

As for the Ramsey RESET test, the results shown indicate the validity of the function (linear) form used in the model Prob = 0.2053 (greater than 0.05) for the null hypothesis (H0) "the function does not suffer from the problem of indeterminacy").

To test the structural stability of the estimated model parameters, the cumulative sum of residuals test (CUSUM) and the cumulative sum of squares test (CUSUMSQ) will be used. It is clear from the graph that the model is located within the critical limits in both tests at a significant level of 5%, thus accepting the null hypothesis and therefore in which there is a structural stability of the model.

Fig. 7: The results of the structural stability test of the model according to SUSUMSQ and CUSUM



Source: Outputs from Eviews.9 program

3.2.4 Error Correction Formula Estimation of Model (ARDL-ECM):

The short-term relationship is represented in estimating the error correction model, which represents the expression of the variables used in the study model in the formula of differences, in addition to the error correction limit with a slowdown of one time CointEq(-1) as an explanatory variable, where the error correction limit measures the speed of adjusting the imbalance in the short term to balance in the long term. If the value of the parameter of the error correction limit is negative and significant, this indicates the existence of a long-term relationship between the variables. Table No. (04) shows the results of estimating the study model in the short term.

Table 5: The results of estimating a short-term relationship for the ARDL model (1,0,4, 1,0,4)

Cointegrating Form

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
D(LAPR)	*0.222217*	*0.160427*	*1.385155*	*0.1739*
D(LATM)	*-2.833962*	*2.624359*	*-1.079868*	*0.2868*
D(LATM(-1))	*-5.148437*	*2.601664*	*-1.978902*	*0.0549*
D(LATM(-2))	*-0.909188*	*2.868582*	*-0.316947*	*0.7530*
D(LATM(-3))	*-6.843002*	*2.422056*	*-2.825287*	*0.0074*
D(LFR)	*-0.135181*	*0.069031*	*-1.958278*	*0.0574*
D(LLER)	*0.275887*	*0.090845*	*3.036881*	*0.0042*
D(LCO2)	*0.323557*	*0.174394*	*1.855319*	*0.0711*
D(LCO2(-1))	*-0.461713*	*0.215225*	*-2.145259*	*0.0382*
D(LCO2(-2))	*-0.064591*	*0.216611*	*-0.298189*	*0.7671*
D(LCO2(-3))	*0.420848*	*0.161065*	*2.612913*	*0.0127*
CointEq(-1)	*-0.872563*	*0.123891*	*-7.042972*	*0.0000*

*Cointeq = LAGPR - (0.2547*LAPR + 13.4016*LATM -0.3116*LFR + 0.3162*LLER + 0.2464*LCO2 -42.8953)*

It is noted that the CointEq error correction coefficient (-1) was negative and significant, with a value of (-0.8725), which confirms the existence of a long-term equilibrium relationship between the variables of the study. The value of the error correction parameter shows that about 87% of the short-term imbalance in grain production in the previous period can be corrected in the current period towards the long-term relationship when any change or shock occurs in the explanatory variables. For grain production (LLER), it is negatively affected by an increase in both temperatures (LATM) and carbon dioxide (LCO2) emissions.

3.2.5 Estimation of Cointegration Relationship in the Long Run:

The previous results confirmed the existence of a long-term equilibrium relationship between the explanatory variables included in the study model and grain production in Algeria during the period (1961-2019), and at this stage the long-term coefficients of the ARDL model (1,0,4, 1,0,4) will be estimated.

Table 6: Results of estimating the long-run coefficients of the ARDL model (1,0,4, 1,0,4)

Long Run Coefficients				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
LAPR	*0.254671*	*0.175052*	*1.454834*	*0.1537*
LATM	*13.401609*	*2.871478*	*4.667146*	*0.0000*
LFR	*-0.311578*	*0.094877*	*-3.284019*	*0.0022*
LLER	*0.316179*	*0.118359*	*2.671353*	*0.0110*
LCO2	*0.246376*	*0.069134*	*3.563769*	*0.0010*
C	*-42.895268*	*8.681035*	*-4.941262*	*0.0000*

The estimation results represented in Table (06) show that the estimated value of the variable coefficient of the logarithm of the annual rainfall rate (LAPR) is statistically insignificant at the level of 5%, and therefore the rainfall rate has no effect on grain production in the long term.

The results shown in the table above also indicate that the logarithm annual temperature (LATM) has a positive and statistically significant effect at the level of 5%, as an increase in annual temperatures by 1% will lead to an increase in grain production in the long run by 13%.

The variable logarithm of fertilizer’s amount used annually in agriculture (LFR) has a negative and statistically significant effect at the level of 5%, as an increase in the amount of fertilizer used annually in agriculture by 1% will lead to a decrease in grain production in the long run by 0.31%.

The variable logarithm of carbon dioxide emissions (LCO2) has a positive and statistically significant effect at the level of 5%, as an increase in carbon dioxide emissions by 1% will lead to an increase in grain production in the long run by 0.24%.

On that account and based on the previously obtained results, the hypothesis that there is a statistically significant effect of climate change on grain production in Algeria is proven.

5. Conclusion

Using the Autoregressive Distributed Lag (ARDL) model, this study aimed to investigate the influence of climate change on grain production in Algeria between 1961 and 2019. The study revealed several key findings. Firstly, there exists a significant long-term equilibrium relationship between the explanatory variables in the model and grain production during the study period. Secondly, annual rainfall rates were found to be statistically insignificant at the 5% level, suggesting that they do not have a significant impact on grain production in the long run. On the other hand, annual temperatures were positively and significantly correlated with grain production, with a 1% increase in temperatures leading to a 13% increase in grain production in the long term. In contrast, the amount of fertilizer used annually in agriculture had a statistically significant negative effect at the 5% level, with a 1% increase in fertilizer use resulting in a 0.31% decrease in grain production in the long run. Additionally, the area of land used for grain production had a positive and statistically significant effect at the 5% level, with a 1% increase in land area leading to a 0.31% increase in grain production in the long run. Finally, carbon dioxide emissions were positively and significantly correlated with grain production, with a 1% increase in emissions resulting in a 0.24% increase in grain production in the long run.

Based on these findings, several recommendations can be made. Decision makers in Algeria should consider implementing mechanisms to increase grain production to stimulate economic growth and development, particularly given the Covid-19 pandemic and global supply disruptions. Efforts should also be made to reduce dependence on imported grain products, which can negatively impact overall growth and development, especially with increasing population growth. Infrastructure for agricultural production should be prioritized, along with simplification of regulations in the agricultural sector to promote growth and development. The government should also engage all stakeholders in planning and implementation phases to address the challenges posed by climate change in the agricultural sector. Ensuring the availability of water during times of absence of expected rainy seasons and investing in reliable weather forecasting technology can help mitigate the impact of drought or extreme weather events, such as floods. Finally, developing new crop varieties that can adapt to high temperatures and harsh drought conditions, introducing innovative agricultural methods, and supporting institutional research can contribute to building resilience against climate change impacts on grain production in Algeria.

6− References

Ayinde, O., Muchie, M., & Olatunji, G. (2011). Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach. Journal of Human Ecology, 35(03), 189-194. doi:10.1080/09709274.2011.11906406

Boufekane, A., Busico, G., & Maizi, D. (2021). Effects of temperature and relative humidity on the COVID-19 pandemic in different climates: a study across some regions in Algeria (North Africa). Environmental Science and Pollution Research, 29, 18077–18102.

Chourghal, N., Lhomme, J. P., Huard, F., & Aidaoui, A. (2015). Climate change in Algeria and its impact on durum wheat. Regional Environmental Change, 16, 1623–1634. doi:10.1007/s10113-015-0889-8

Fischer, G., Shah, M., & Velthuizen, H. v. (2002). Climate Change and Agricultural Vulnerability. Johannesburg. IIASA.

Ghemam, A. D., Kherraz, K., Alia, Z., Chamsa, A. K., Hacene, L., & Senoussi, M. M. (2020). The Effects of the Fertil Verde Fertilizer on the Growth and Yield of Chili Pepper (Capsicum annuum L) in Southern Algeria. Algerian Journal of Biosciences, 01(01), 18-23. Retrieved from https://www.asjp.cerist.dz/en/article/149979

Habibi, B., Meddi, M., Torfs, P., & Remaoun, M. (2018). Characterisation and prediction of meteorological drought using stochastic models in the semi-arid Chéliff–Zahrez basin (Algeria). Journal of Hydrology: Regional Studies, 16. doi:10.1016/j.ejrh.2018.02.005

Ibrahim, K., Bazri, K., & Trigo, D. (2020). The influence of ramial fragmented wood and manure on some Physicochemical Parameters of a sandy loam soil Constantine (Algeria). Journal of Fundamental and Applied Sciences, 13(01), 40-57. doi:10.4314/jfas.v13i1.3

Ju, H., Velde, M., Lin, E., Xiong, W., & Li, Y. (2013). The impacts of climate change on agricultural production systems in China. Climatic Change Journal, 120, 313-324. doi:10.1007/s10584-013-0803-7

Lee, J., Nadolnyak, D., & Hartarska, V. (2012). Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study. Annual Meeting, Birmingham: Southern Agricultural Economics Association. Retrieved February 4-7, 2012

Makougoum, C. F. (2018). Changement climatique au Mali : impact de la secheresse sur l'agriculture et stratégies d'adaptation (PhD Thesis). Clermont-Ferrand: Ecole Doctorale des Sciences Economiques, Juridiques, Politiques et de gestion, Université Clermont Auvergne.

Mishra, D., Sahu, N. C., & Sahoo, D. (2015). Impact of climate change on agricultural production of Odisha (India): a Ricardian analysis. Regional Environmental Change, 16, 575-584. doi:10.1007/s10113-015-0774-5

NASA. (2021). Retrieved 02 26, 2022, from https://earthobservatory.nasa.gov/images/148687/fire-outbreak-in-algeria.

ONS. Récupéré sur https://www.ons.dz/spip.php?rubrique379.

Rezzoug, W., Gabrielle, B., Suleiman, A., & Benabdeli, K. (2008). Application and evaluation of the DSSAT-wheat in the Tiaret region of Algeria. African Journal of Agricultural Research, 03(04), 284-296. Retrieved from www.researchgate.net.

Rouabh, A., Adouane, C., & Felloussia, A. L. (2019). Assessment of Climate Change and its Effects on Cereal Production by 2070 in North Algeria. Revue Agriculture, 10(02). Retrieved from https://revue-agro.univ-setif.dz/documents-agri/Volume10N2-2019/Rouabhi-al.pdf.

Sahnoune, F., Belhamel, M., Zelmat, M., & Kerbachi, R. (2013). Climate Change in Algeria: Vulnerability and Strategy of Mitigation and Adaptation. Energy Procedia, 36. doi:10.1016/j.egypro.2013.07.145

Timmerman, J. (2016). Development of a Techno-Economic Energy Model for Low Carbon Business Parks (PhD Thesis). Ghent: Faculty of Engineering and Architecture Department of Civil Engineering, University of Ghent.

World Bank. (n.d.). Retrieved 03 01, 2022, from WorldBank: https://data.worldbank.org/country/algeria.