Analysis of the impact of climatic parameters on agriculture in Algeria: Application of the ARDL Model with Error Correction Mechanism

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Received: 12/10/2021 Accepted: 01/11/2021 Publication: 01/12/2021

Abstract:

The purpose of this study is to analyze the impact of climatic factors on the evolution of agricultural added value in Algeria during the period from 1999 to 2020. The study is based on an ARDL (Autoregressive distributed lag) model where the agricultural value added is the endogenous variable and temperature and precipitation are exogenous variables of the model. This study is developed by respecting the different stages of econometric analysis, we studied the stationarity of the variables, determined the optimal number of lags, estimated an ARDL model, tested cointegration, estimated the long-term relationship, studied the robustness of the model through the different tests of the residuals and finally estimated an ECM model. We were able to deduce that the temperature influences the agricultural added value positively, while the precipitation affects it negatively.

Keywords: Agricultural added value, Temperature, Precipitation, ARDL.

Jel Classification Codes: Q51, O13.

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1. INTRODUCTION

At the start of the 21st century, climate change, or global warming, has been identified as one of the major problems for humanity. However, tackling the problems of natural or environmental resources is nothing new for the economy and for society as a whole. However, this may be the first time that a natural resource problem has reached a global scale in the modern era.

Climate change affects people and ecosystems around the world, and this climate change affects many sectors - health, economy, biodiversity, availability of natural resources, energy…etc.

All these climatic conditions exert a very strong influence on agricultural growth in Algeria. Inadequate and unevenly distributed precipitation and increasing temperatures hamper the adoption of intensive farming practices without artificial irrigation.

The purpose of this study is to analyze the vulnerability of agriculture to climatic factors. By responding to the following problem:

What are the effects of climatic parameters on agriculture in Algeria?

Based on the ARDL model, we defined agricultural value added as an endogenous variable and temperature and precipitation as exogenous variables of the model.

Using Eviews 9, we studied the stationarity of the variables, determined the number of optimal lags, estimated an ARDL model, tested cointegration, estimated the long-term relationship, studied the robustness of the model through the different tests of the residuals and finally estimated an ECM model.

2. AGRICULTURE AND CLIMATE CHANGE

2.1. Agriculture in Algeria

Algeria has faced a huge agricultural challenge, the nature of the land and the bioclimatic conditions are the main factors limiting agriculture in Algeria. Algeria is marked by the presence of two mountain ranges, the Tellian Atlas and the Saharan Atlas, stretching from the western border to the eastern border.

The agricultural relief produces climatic constraints: the Tellian Atlas is placed between the ocean and the interior space and prevents precipitation from the north or north-west. Therefore, Algeria is an arid country which is located in the arid and semi-arid triangle. This vast relief which is characterized by a dry and cold climate in winter and hot and dry in summer. If we compare the topography and the bioclimate, we can see that agriculture is severely restricted.

Drought and aridity are a constant threat, even in humid regions where the average annual rainfall appears high. FAO statistics indicate that the weighted rainfall index for agricultural land is 241.5 mm for Algeria, against 287.5 mm for Morocco, 190.32 mm for Mauritania and 326.1 mm for Tunisia (FAOSTAT).

Over the years (2000-2014), the percentage of agricultural gross domestic product (PIBA) in GDP increased from 8.3% in 2000 to 9.2% in 2010 and 11.2% in 2014. The increase is attributable to crop and animal production.

In the 2000s, the place of the agricultural sector in the GDP almost continued to increase, growing faster than the non-hydrocarbon industries, almost as much as the construction and public works sectors.

In addition to the sector's share in the formation of GDP, the agricultural sector has always been the engine of the country's economic growth, as its annual growth rate during the period 2004-2014 was 7.06%, so that the growth rate of the whole economy over the same period was only 2.72%.

2.2. Climate changes

2.2.1. Climate change around the world

Climate change is one of the main effects of the phenomenon called global warming. It is commonly used to describe the increase in the earth's average surface temperature, which has increased by nearly 1 degree Celsius over the past hundred years (IPCC, 2007).

The fourth report (IPCC, 2007) indicated that the temperature of the planet recorded an average increase of 0.6 ° C ± 0.2 ° C during the 20th century, and in 2100. According to the fifth report (IPCC 2014), each of the past three decades has been successively warmer on the earth's surface than all previous decades since 1850. 1983–2012 was the hottest 30-year period in the last 800 years in the Northern Hemisphere, even the hottest in the last 1,400 years.

In North Africa, over the past decades, observed annual and seasonal trends in mean near-surface temperature indicate general warming well beyond the range of changes due to natural variability (Barkhordarian et al., 2012a). During the hot season (March to April to May, June to July to August), due to natural changes or natural forcing, the temperature near the surface of northern Algeria and Morocco is unlikely to increase.

Over the past 60 years, summer monsoon rainfall (June to September) has decreased in most parts of Africa. Areas with sufficient data include parts of western North Africa and parts of the eastern Sahel over the past century where annual rainfall is likely to decline, while parts of eastern and southern Africa are likely to increase annual precipitation. Over the past decades, the northern regions of North Africa (northern Atlas and Mediterranean coasts of Algeria and Tunisia) have experienced a sharp drop in winter and the onset of winter precipitation.

2.2.2. Climate change in Algeria

The analysis of climate change in the Maghreb, more precisely in Algeria, clearly shows that the impact of climate change is becoming more and more evident in the country. Recent climate changes in the Maghreb indicate that global warming is above the world average. Indeed, if on a global scale, the temperature increase in the 20th century was 0.74 ° C, then depending on the region, the temperature in the Maghreb rose between 1.5 and 2 ° C, i.e. more than double the increase. The world average, according to a report by the World Meteorological Organization (WMO), the decade 2000-2011 was one of the hottest decades ever observed in the Maghreb. There have also been many extreme weather and climatic events (floods, droughts, colds and heat waves) during this decade.

Between 1926 and 2006, the temperature increased by more than 1.5 ° C, and the average precipitation recorded a decrease of between 10 and 20% (TABET-AOUL, 2008).

The North-West and South-West regions of Algeria will be the most affected with both significant warming and reduced rainfall (AGENCE NATIONALE DES RESOURCES HYDRAULIQUES, 2009). The study of the change in the rainfall regime in North West Algeria showed a break in the 1970s (reduction in rainfall) for almost all of the stations studied (MEDDI-M., 2007). The climate in the Algerian steppe region has also undergone great changes, and rainfall has indeed decreased over the past century. Therefore, all studies confirm that Algeria will experience a severe increase in drought, which will make it more vulnerable to water scarcity and desertification. Algeria is also increasingly confronted with the return of extreme weather events (storms, floods, heat waves), which increases its vulnerability.

In Algeria, climate change, marked by an increase in average temperature and a decrease in precipitation, not only affects the quality and resilience of ecosystems, but also affects the availability and quality of natural resources necessary for economic and social conditions. In this sense, climate change and extreme weather events have endangered the country's agriculture, food security and socio-economic development.

3. STATISTICAL ANALYSIS OF VARIABLES

3.1. Agricultural value added VAA as a% of GDP

Fig.1 shows the evolution of agricultural value added in Algeria during the period from 1999 to 2020. We find that this variable is not stable over time. From 2000 to 2012, it did not exceed 9%, but from 2013, it noted a remarkable evolution.

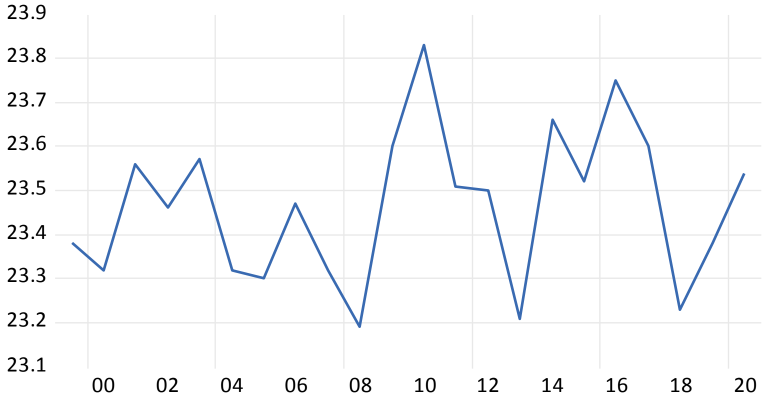
Fig.1. Graphic presentation of agricultural added value

Source: Prepared by researchers based on Eviews 9.

3.2. The annual mean temperature (C °)

Fig.2 shows us the evolution of the annual average temperature in Algeria during the period from 1999 to 2020. We note that this variable is unstable, the lowest temperatures are recorded in 2008, 2013 and in 2018 with a value of 23.19, 23.21 and 23.23 respectively. The highest are felt in 2010 and 2016 with 23.83 and 23.75 respectively.

Fig.2. Graphical presentation of the annual mean temperature

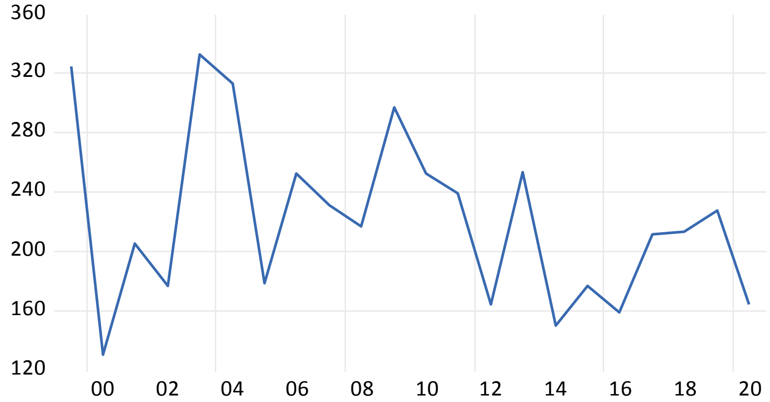


Source: Prepared by researchers based on Eviews 9.

3.3. Average annual precipitation (mm)

Fig.3 shows us the evolution of annual average precipitation in Algeria during the period from 1999 to 2020. We note that this curve is irregular, the peak is recorded in 2003 with a value of 332.93 mm and the minimum value is in 2000 with a value of 130.56 mm.

Fig.3. Graphical presentation of annual mean precipitation



Source: Prepared by researchers based on Eviews 9.

4. ECONOMETRIC MODELING WITH ARDL

4.1. Study of stationarity

To test the stationarity of our time series we used the Augmented Dicky Fullar test (ADF) which is generally used in stationarity tests.

4.1.1. The agricultural value added VAA

According to Table 1, we note that the value of the ADF statistic obtained for the variable VAA (-3.66) is lower than the critical value at the critical threshold of 5%, therefore it is stationary in level. This is compatible with the adoption of the ARDL model.

Table 1. ADF stationarity test

Null Hypothesis: VAA has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.662003	0.0484
Test critical values:	1% level	-4.467895	
	5% level	-3.644963	
	10% level	-3.261452	

*MacKinnon (1996) one-sided p-values.

Source: Prepared by researchers based on Eviews 9.

4.1.2. The annual mean temperature

From Table 2, we find that the value of the ADF statistic obtained for the TEMPERATURE variable (-3.93) is less than the critical value at the critical threshold of 5%, and its associated probability is 0.02 which is less than 5 %, so it is stationary in level.

Table 2. ADF stationarity test

Null Hypothesis: TEMPERATURE has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.930281	0.0290
Test critical values:	1% level	-4.467895	
	5% level	-3.644963	
	10% level	-3.261452	

*MacKinnon (1996) one-sided p-values.

Source: Prepared by researchers based on Eviews 9.

4.1.3. Average annual precipitation

From Table 3, we note that the value of the ADF statistic obtained for the PRECIPITATION variable (-4.96) is lower than the critical value at the critical threshold of 5%, and its associated probability is 0.0037 which is much lower than 5%, so it is stationary in level.

Table 3. ADF stationarity test

Null Hypothesis: PRECIPITATION has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.964242	0.0037
Test critical values:	1% level	-4.467895	
	5% level	-3.644963	
	10% level	-3.261452	

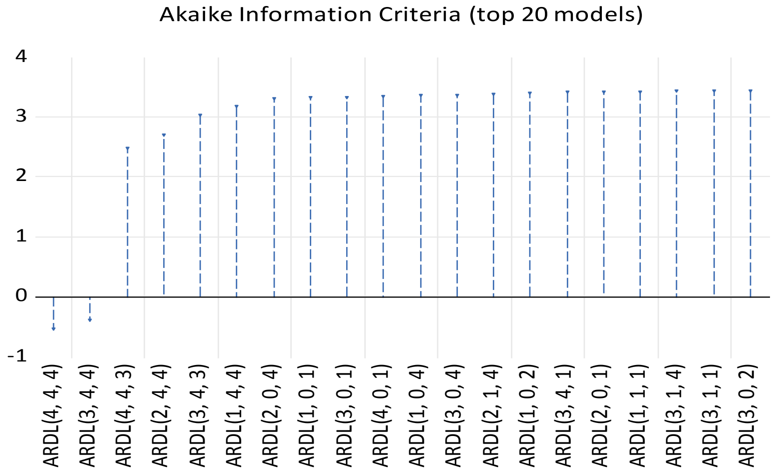
*MacKinnon (1996) one-sided p-values.

Source: Prepared by researchers based on Eviews 9.

4.2. Determination of the optimal delay number

The validation of this model is also judged by the graphical presentation (Fig.4) which makes it possible to visualize the Akaike values of the 20 optimal ARDL models estimated by the Eviews software.

Fig.4. Akaike values of the 20 optimal models



Source: Prepared by researchers based on Eviews 9.

After having determined the number of delays on Eviews, the estimation of the model makes it possible to retain ARDL (4, 4, 4) as the optimal model according to the Akaike Information Criteria (AIC) criterion because it corresponds to the minimum value of the information criterion AIC.

4.3. Estimation of an ARDL model

According to Table 4, all the coefficients are significant because their associated probabilities are less than the critical value 0.05, with the exception of the agricultural value added delayed by three years and the temperature.

Table 4. ARDL estimation results (4.4.4)

ARDL Long Run Form and Bounds Test
Dependent Variable: D(VAA)
Selected Model: ARDL(4, 4, 4)
Case 3: Unrestricted Constant and No Trend
Date: 10/10/21 Time: 18:59
Sample: 1999 2020
Included observations: 18

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-342.8161	31.07918	-11.03041	0.0016
VAA(-1)*	-1.822469	0.108829	-16.74610	0.0005
TEMPERATURE(-1)	16.25398	1.355323	11.99270	0.0012
PRECIPITATION(-1)	-0.091934	0.006479	-14.18970	0.0008
D(VAA(-1))	0.529684	0.083388	6.352050	0.0079
D(VAA(-2))	-0.554292	0.062137	-8.920518	0.0030
D(VAA(-3))	0.054821	0.058825	0.931932	0.4201
D(TEMPERATURE)	1.080903	0.427702	2.527236	0.0856
D(TEMPERATURE(-1))	-10.28234	0.845807	-12.15684	0.0012
D(TEMPERATURE(-2))	-10.50110	0.720500	-14.57474	0.0007
D(TEMPERATURE(-3))	-6.557850	0.476464	-13.76357	0.0008
D(PRECIPITATION)	-0.012283	0.001841	-6.670871	0.0069
D(PRECIPITATION(-1))	0.050253	0.004019	12.50367	0.0011
D(PRECIPITATION(-2))	0.044187	0.003144	14.05573	0.0008
D(PRECIPITATION(-3))	0.015372	0.001914	8.029451	0.0040

* p-value incompatible with t-Bounds distribution.

Source: Prepared by researchers based on Eviews 9.

4.4. Cointegration test

The f-bounds test is used to determine the presence of cointegration between the variables; it is based on the comparison of the Fisher statistic with the Fisher critical value of the two bounds for each significance level.

If the calculated F statistic is greater than the upper critical value, the null hypothesis of no cointegration will be rejected. If the calculated F statistic is less than the lower critical value, the null hypothesis of no cointegration will be accepted. However, if the calculated F-statistic is between the lower and upper critical values, the result is inconclusive.

Table 5. Cointegration test (Bounds test)

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	101.1143	10%	3.17	4.14
k	2	5%	3.79	4.85
		2.5%	4.41	5.52
		1%	5.15	6.36

Source: Prepared by researchers based on Eviews 9.

The result of the cointegration test (Table 5) shows that the Fisher statistic (101.11) is much higher than the upper limit of the critical values for all the significance levels 1%, 2.5%, 5%, and 10%. So we reject the null hypothesis and we accept the alternative. This result confirms the cointegration of the time series and therefore the existence of a short and long term relationship between the explanatory variables and the variables to be explained. We can then estimate the long-term effects between the variables.

4.5. Estimation of the long-term relationship

From Table 6, both variables have a significant impact. The temperature and precipitation variables are statistically significant (prob <5%) and the model is generally good (Prob-Fisher <5%).

The temperature variable has a positive effect on agricultural value added, while precipitation affects it negatively.

An increase in precipitation (mm) of 1% lowers agricultural value added by 0.05%, while an increase in temperature (C °) of 1% increases it by 8.91%.

Table 6. The estimate of the long-term relationship

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TEMPERATURE	8.918659	0.685597	13.00859	0.0010
PRECIPITATION	-0.050445	0.001502	-33.59618	0.0001

EC = VAA - (8.9187*TEMPERATURE -0.0504*PRECIPITATION)

Source: Prepared by researchers based on Eviews 9.

4.6. Model validation

Before proceeding to the economic reading of the results, it is necessary to check whether the ARDL model fulfills the conditions and assumptions of normal distribution, of non-autocorrelation of errors, of homogeneity of the variance of errors, of specification of the model and of its stability using Eviews 9.

4.6.1. Auto-correlation test

The hypothesis of the test is as follows:

$$\begin{cases} H_0\text{: uncorrelated errors.} \\ H_1\text{: correlated errors.} \end{cases}$$

We use the autocorrelation test (Breusch-Godfrey) to check if the errors are not auto-correlated. The probability associated with the F-statistic is 0.5282, it is well over 5%, so we accept the null hypothesis that there is no autocorrelation of errors.

Table 7. Auto-correlation test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.291895	Prob. F(2,1)	0.5282
Obs*R-squared	12.97739	Prob. Chi-Square(2)	0.0015

Source: Prepared by researchers based on Eviews 9.

4.6.2. Heteroscedasticity (ARCH)

The hypothesis of the test is as follows:

$$\begin{cases} H_0\text{: homoscedastic errors.} \\ H_1\text{: heteroscedastic errors.} \end{cases}$$

We use the heteroskedasticity test (ARCH) to check if the errors are homoscedastic. The probability associated with the F-statistic is 0.0651, it is slightly above the critical value 5%, so we accept the null hypothesis, so the residuals are homoscedastic.

Table 8. Heteroscedasticity test (ARCH)

Heteroskedasticity Test: ARCH

F-statistic	3.961874	Prob. F(1,15)	0.0651
Obs*R-squared	3.551962	Prob. Chi-Square(1)	0.0595

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 10/11/21 Time: 01:42
Sample (adjusted): 2004 2020
Included observations: 17 after adjustments

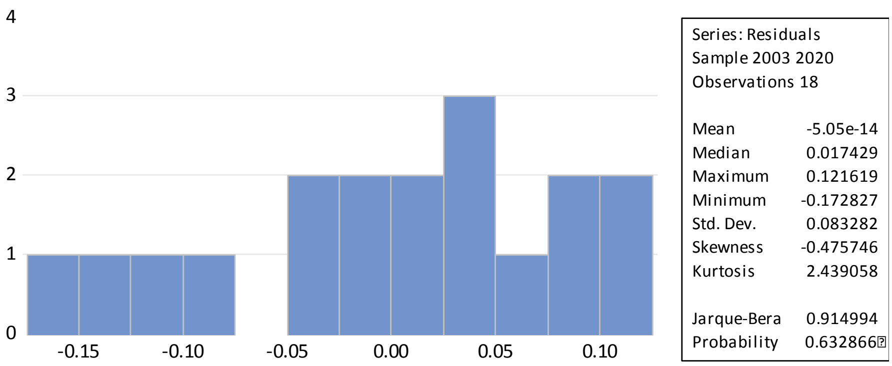
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003947	0.002349	1.680507	0.1136
RESID^2(-1)	0.450280	0.226221	1.990446	0.0651

Source: Prepared by researchers based on Eviews 9.

4.6.3. Normality test

The Jarque-Bera test allows us to better appreciate the normality of the residuals. The probability associated with the Jarque-Bera statistic is 0.6328, it is much greater than the critical value 0.05, which verifies the assumption of normality of the residuals.

Fig.5. Normality test



Source: Prepared by researchers based on Eviews 9.

4.6.4. Specification Test

The ARDL model contains shifted variables, the Ramsey test allows us to know if the model is well specified or not.

The hypothesis of the test is as follows:

H_0: the model is well specified.

H_1: the model is incorrectly specified.

We accept H0 if the probabilities are greater than 5%.

We use the Specification Test (Ramsey Rest) to verify the specification of this model. The probability associated with the F-statistic is 0.7226, it is greater than the critical value 5%, so we accept the null hypothesis, so the model is specified.

Table 9. Specification test

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: VAA VAA(-1) VAA(-2) VAA(-3) VAA(-4) TEMPERATURE TEMPERATURE(-1) TEMPERATURE(-2) TEMPERATURE(-3) TEMPERATURE(-4) PRECIPITATION PRECIPITATION(-1) PRECIPITATION(-2) PRECIPITATION(-3) PRECIPITATION(-4) C

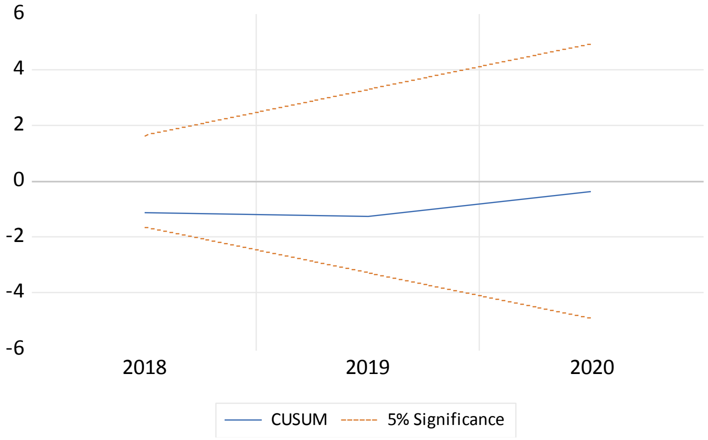
	Value	df	Probability
t-statistic	0.408250	2	0.7226
F-statistic	0.166668	(1, 2)	0.7226
Likelihood ratio	1.440782	1	0.2300

Source: Prepared by researchers based on Eviews 9.

4.6.5. Stability test

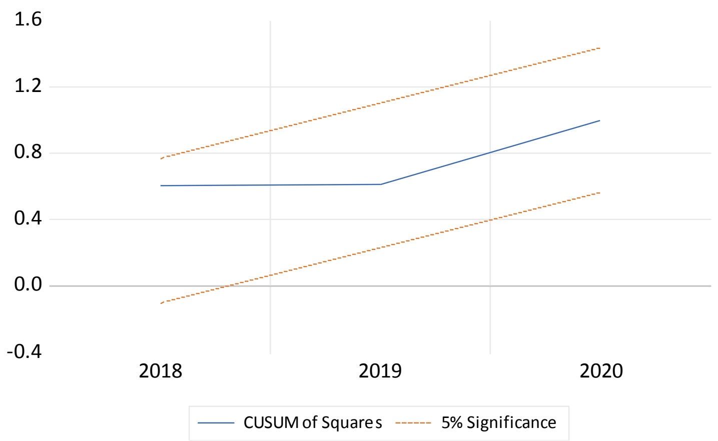
After confirming the existence of a long-term relationship between the exogenous variable and the endogenous variables, we move on to checking the stability of the model. For the estimation coefficients of the ARDL model to be structurally stable, the curve of the CUSUM and CUSUMSQ statistic must be between the critical limits at a significant level of 5%, otherwise the model is not stable.

Fig.6. Model stability test (CUSUM Test)



Source: Prepared by researchers based on Eviews 9.

Fig.7. Model stability test (CUSUMSQ Test)



Source: Prepared by researchers based on Eviews 9.

According to Fig.6 and Fig.7, the results show that the graphs of the statistics of CUSUM and CUSUMSQ remain within the interval of the critical values at the threshold of 5%, which implies that the coefficients of the model are structurally stable during the period 1999-2020.

In general, the probabilities of the four tests are greater than 5%. This allows us to accept the null hypothesis H0 for each test. The errors of our ARDL model are not auto-correlated and are normally distributed, their variances are constant and the model is well specified so the model is overall good.

4.7. Estimation of an ECM model

From Table 10, we note that both variables are significant because their statistics are greater than the Student's table value at the 5% level. The term of CointEqt-1 (-1.82, t-stat = -2.48), it is negative and largely significant, thus confirming the existence of an error correction mechanism. The estimated value is -1.82, it gives us the speed of the VAA_t, $TEMPERATURE_t$ and $PRECIPITATION_t$ processes to align with equilibrium after a shock produced in the short term. 182% of short-term errors can be corrected in the first year to return to equilibrium over the long term.

Table 10. Estimation of an ECM model

ARDL Error Correction Regression
Dependent Variable: D(VAA)
Selected Model: ARDL(4, 4, 4)
Case 3: Unrestricted Constant and No Trend
Date: 10/10/21 Time: 19:03
Sample: 1999 2020
Included observations: 18

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-342.8161	15.25881	-22.46676	0.0002
D(VAA(-1))	0.529684	0.052330	10.12200	0.0021
D(VAA(-2))	-0.554292	0.041743	-13.27879	0.0009
D(VAA(-3))	0.054821	0.040022	1.369781	0.2643
D(TEMPERATURE)	1.080903	0.234218	4.614940	0.0191
D(TEMPERATURE(-1))	-10.28234	0.477047	-21.55414	0.0002
D(TEMPERATURE(-2))	-10.50110	0.456522	-23.00242	0.0002
D(TEMPERATURE(-3))	-6.557850	0.338585	-19.36841	0.0003
D(PRECIPITATION)	-0.012283	0.001282	-9.578534	0.0024
D(PRECIPITATION(-1))	0.050253	0.002733	18.38836	0.0004
D(PRECIPITATION(-2))	0.044187	0.002157	20.48523	0.0003
D(PRECIPITATION(-3))	0.015372	0.001220	12.59833	0.0011
CointEq(-1)*	-1.822469	0.081053	-22.48492	0.0002

R-squared	0.997122	Mean dependent var	0.222389
Adjusted R-squared	0.990213	S.D. dependent var	1.552275
S.E. of regression	0.153564	Akaike info criterion	-0.745888
Sum squared resid	0.117910	Schwarz criterion	-0.102841
Log likelihood	19.71299	Hannan-Quinn criter.	-0.657220
F-statistic	144.3357	Durbin-Watson stat	3.074606
Prob(F-statistic)	0.000015		

* p-value incompatible with t-Bounds distribution.

Source: Prepared by researchers based on Eviews 9.

The error correction formula for the ARDL model is given by:

$$\mathbf{\Delta VAA = -342.81 + 0.52\Delta VAA_{t-1} - 0.55\Delta VAA_{t-2} + 1.08\Delta TEMPERATURE - 10.28\Delta TEMPERATURE_{t-1} - 10.50\Delta TEMPERATURE_{t-2} - 6.55\Delta TEMPERATURE_{t-3} - 0.01\Delta PRECIPITATION + 0.05\Delta PRECIPITATION_{t-1} + 0.04\Delta PRECIPITATION_{t-2} + 0.01\Delta PRECIPITATION_{t-3} - 1.82CointEq_{t-1}}$$

The quality of adjustment of this model is more than 99%, that is to say the exogenous variables namely TEMPERATURE and PRECIPITATION explain to more than 99% the agricultural value added in Algeria during the period 1999-2020. This implies that only 1% remains which is explained by other phenomena.

5. CONCLUSION

The purpose of this study is to econometrically analyze the impact of climatic parameters on agriculture in Algeria during the period from 1999 to 2020. Using the Eviews 9, we based ourselves on the ARDL (Autoregressive distributed lag) model. Which allowed us to study the existing relationship between the endogenous variable (agricultural value added) and the exogenous variables (temperature and precipitation) in the short and long term and to detect the cointegration relationship.

This analysis allows us to retain the following results:

- The three variables are stationary in level.

- The existence of a short and long term relationship between agricultural added value and temperature and precipitation.

- The coefficients of the estimate are very significant.

- An increase in precipitation (mm) by 1% lowers agricultural added value by 0.05%, and an increase in temperature (C °) by 1% increases it by 8.91%.

- According to the Autocorrelation, Normality, Heteroscedasticity (ARCH) and Specification test, the errors of our ARDL model are not auto-correlated and are normally distributed, their variances are constant and the model is well specified.

- The results of the Stability test show that the model coefficients are structurally stable during 1999-2020.

- The coefficient CointEqt-1 (-1.82) is negative so there is indeed an error correction mechanism.

- In the long term, agricultural added value, temperature and precipitation evolve in a similar way.

- 182% of short-term errors can be corrected in the first year to return to equilibrium over the long term.

We can conclude that temperatures affect agricultural value added positively, while the precipitation affects it negatively.

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- Reports:

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