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DETERMINANTS OF FOOD SECURITY IN ALGERIA IN LIGHT OF CLIMATE CHANGE-ANALYTICAL ECONOMETRIC STUDY FOR THE PERIOD 1990-2021

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ABSTRACT:
This study aimed to identify the most important factors and variables that affect food security in Algeria in light of climate changes. The study approach includes econometric analysis based on the bound testing approach (ARDL) regarding the period of 1990-2021. The empirical study showed that rainfall does not contribute to increasing agricultural production in the long term, but rather the contribution is limited to the short term only. Therefore, enhancing and sustaining Algerian food security in light of the decline in rainfall requires ensuring water security by enhancing investments to benefit from underground and surface water. Desalinating seawater and directing it to agriculture; Strengthening national governance of food security and nutrition through a clear and shared vision of goals and means of action; Support sustainable agri-food sectors to create decent job opportunities in rural areas.

Keywords: Food security, climate changes, water, agriculture sector.

INTRODUCTION
Over the years, the demand for food in Algeria has been on an upward trend due to the increase in the Algerian population, reaching approximately 45 million in the year 2023. This presents a challenge to food security. The evolution of food imports confirms that the food gap still exists, adding further pressure on developmental tasks entrusted to the Algerian government to ensure food security for the society. The upcoming period imposes an economic reality full of complexities that require strategic preparedness, especially in light of frequent developments in global food conditions and the unique circumstances such as climate change.

The ongoing climate changes pose a global environmental issue that has impacted various sectors, including the economic aspect. Climate changes, accompanied by rising temperatures, have affected precipitation levels, resulting in a depletion of water resources. This necessitates the need to explore new conditions for effective water resource management and agricultural production elements to achieve agricultural development amidst these climate changes. Consequently, this contributes to achieving food security in Algeria. Therefore, this study aims to address the following main question: **What is the impact of climate change on food security in Algeria?**

SIGNIFICANCE OF STUDY

This study has been conducted to attempt to identify the most significant factors and variables influencing food security in Algeria. Notably, it addresses the issue of climate change and its accompanying effects on agricultural production. Considering that the latter is one of the primary means to achieve food security, it is crucial for us to diagnose the reality of climate change in Algeria and assess its impact on agricultural production to enhance the agricultural sector and subsequently achieve food security.

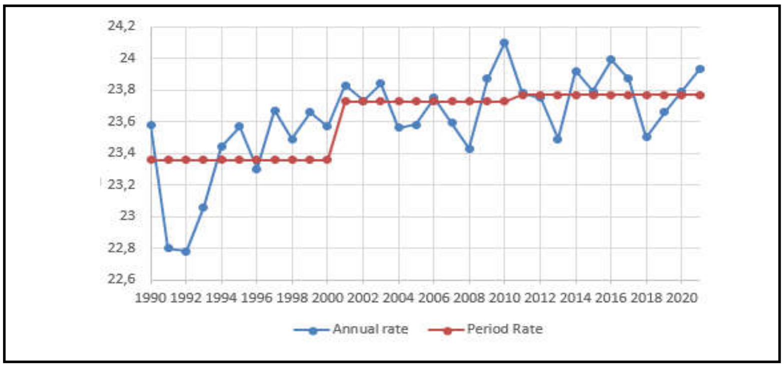
Climate change indicators in Algeria during the period 1990-2021

There are several indicators of climate change, and the most important of these indicators are temperature averages and rainfall rates.

- **Temperature rates:**

Figure 1 shows the evolution of average temperatures in Algeria during the period 1990-2021.

Fig.1 Evolution of average temperatures in Algeria for the period 1990-2021



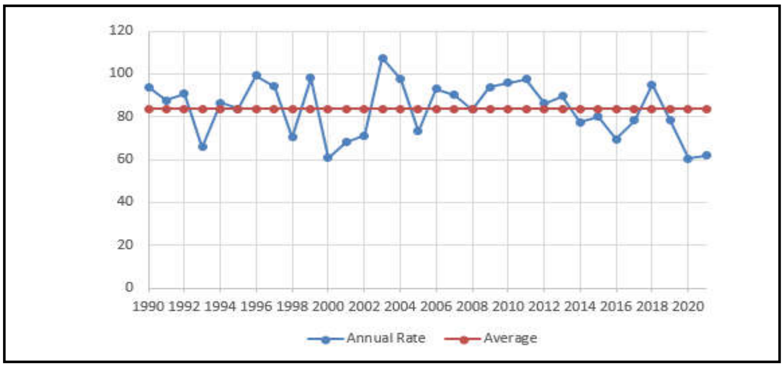
Source: Prepared by authors based on: (The World Bank, 2023)

From the above figure, it can be observed that the average temperatures in Algeria during the period 1990-2021 witnessed varying fluctuations. In the period 1990-2000, the average was 23.35 degrees Celsius, increasing to approximately 23.73 degrees during the period 2001-2010, representing an increase of nearly half a degree Celsius. Subsequently, it continued to rise in the period 2011-2021, but by a marginal amount of 0.05 degrees Celsius. Additionally, the lowest annual average temperature was recorded at 22.78 in the year 1992, while in the period 2001-2021, the lowest annual average reached 23.43, compared to a maximum of 24.1 degrees Celsius. Observing the temperature trends in Algeria, it is evident that they are on a continuous rise. Climate scientists project that by the year 2050, temperatures will increase by 1 degree Celsius.

- **Rainfall rate:**

With the increase in temperatures and the associated climate changes, the agricultural GDP in Algeria, especially that relying on seasonal agriculture, is experiencing a continuous decline due to the fluctuations in rainfall rates. The following figure illustrates the evolution of rainfall rates during the period 1990-2021.

Fig.2 Evolution of rainfall in Algeria for the period 1990-2021



Source: Prepared by authors based (The World Bank, 2023)

Through Figure 2, we observe that during the period 1990-2021, the average rainfall was 83.74 mm. Additionally, the annual precipitation rates exhibited varying fluctuations, ranging from a minimum of 60.59 mm to a maximum of 107.6 mm.

-The empirical study

In this section of the study, we will estimate a model to assess the impact of climate change on food security in Algeria during the period 1994-2021. This will be done using the Autoregressive Distributed Lag (ARDL) model for cointegration, and the estimation will follow the following steps:

-Model specification:

The formulation of the model is the following function:

$$Pagr = f(RPre; RTem; PES)$$

Where :

Pagr : The volume of agricultural production in Algeria, adopted as an indicator to express food security (in US dollars, base year 2015).

RPre: rainfall rate (mm).

RTem: Average temperature (°C).

Pes: Amount of pesticides (in tons).

For studying the proposed model, annual data for the period (1994-2021) was used for all study variables, and it was transformed using the decimal logarithm.

-Unit root test:

In order to investigate the stationarity properties of the data, a univariate analysis of each of the three time series (GDP, exports, and imports) was carried out by testing for the presence of a unit root. The time series behavior of each of the series using the Augmented Dickey-Fuller (ADF) test are presented in table 1.

Table 1 Results of ADF test

	Unit Root Test (ADF)						Variables
	1^{er} différences			Level			
	None	Trend & Constant	Constant	None	Trend & Constant	Constant	
I(1)	5.440 - 0.000) (	-6.772 (0.000)	-6.880 (0.000)	2.498 0.995) (	-2.701 (0.243)	-0.992 (0.741)	PAgr
I(0)	–	–	–	–	-3.781 (0.0336)	-3.628 (0.011)	RPre
I(0)	–	–	–	–	-4.598 (0.006)	-3.978 (0.005)	Rtem
I(1)	-5.595 0.000) (	-5.338 (0.001)	-5.532 (0.000)	–	-5.543 (0.000)	–	Pes

Source: Prepared by authors based on Eviews 12.

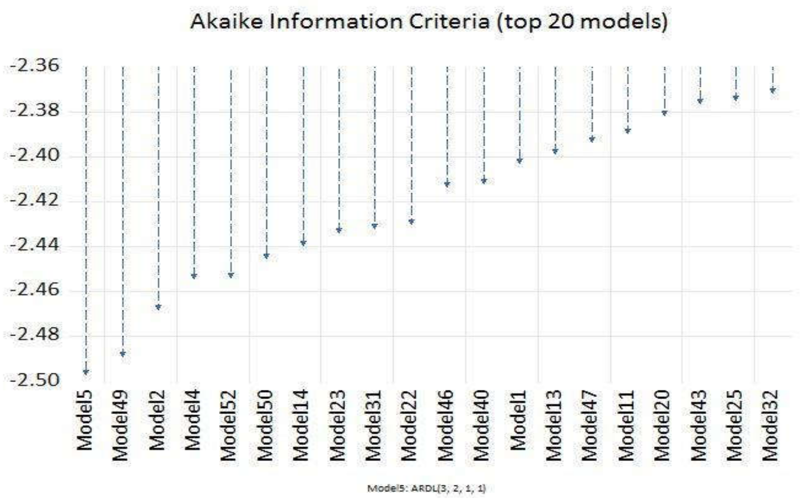
Through Table (01), it is observed that both series (RPre, RTem) are stationary at level I(0). The other variables (PAgr and Pes), are integrated of order one I(1) under 5% Confidence level. The time series in the study location is integrated of order 0 and 1;

this implies the possibility of applying the bounds testing approach to investigate the existence of a long-term equilibrium relationship between the study variables and, consequently, the ability to estimate the Autoregressive Distributed Lag (ARDL) model.

-Autoregressive Distributed Lag Estimates:

After confirming that the study variables are integrated of order zero and one, the determination of the optimal number of lags for the model will rely on the Akaike Information Criterion (AIC), with the results illustrated in the following figure.

Fig.3 determine optimal lag length



Source: Prepared by authors based on Eviews 12.

Based on Figure 3 and by choosing the minimum value of the Akaike Information Criterion (AIC), the optimal lag length for the model is ARDL(3,2,1,1).

-Co-integration Test :

There are various techniques for conducting the co-integration test. The popular approaches are: the well-known residual based approach proposed by Engle and Granger (1987) and the maximum likelihood-based approach proposed by Johansen and Julius (1990) and Johansen (1992). When there are more than two I (1) variables in the system, the maximum likelihood approach of Johansen and Julius has the advantage over residual-based approach of Engle and Granger; however, both of the approaches require that the variables have the same order of integration. This requirement often causes difficulty to the researchers when the system contains the variables with different orders of integration. To overcome this problem, Pesaran et al. (1996, 2001) proposed a new approach known as Autoregressive Distributed Lag (ARDL) for co-integration test that does not require the classification of variables into

I(0) or I(1). The main advantage of this procedure (ARDL) is that it can be applied regardless of the stationary properties of the variables in the sample and allows for inferences on long-run estimates, which is not possible under alternative co-integration procedures. In other words, this strategy may be applied irrespective of whether the series are I (0) or I (1) (Samreth, 2008, p. 5). Moreover, the bound testing procedure of co-integration is more appropriate for a small sample size [Pessaran et all (2001); Tang (2001); Tang (2002)] An ARDL representation of equation (1) is formulated as:

$$\Delta LnPagr=\beta_0+\beta_1 LnPagr_{t-1}+\beta_2 LnRPre_{t-1}+B_3 LnRTem_{t-1}+ B_4 LnPES_{t-1} +\sum^{k}_{i=1}\beta_5\Delta LnPagr_{t-1} +\sum^{k}_{i=1}\beta_6\Delta LnRPre_{t-1}+\sum^{k}_{i=1}\beta_7\Delta LnRTem_{t-1}++\sum^{k}_{i=1}\beta_8\Delta LnPES_{t-1}+\varepsilon_t \quad (1)$$

Where β_0 is an intercept, Δ is difference operator, ε_t random terms. In equation (1), all variables are expressed in logarithmic form.

As stated in Pesaran and Pesaran (Pesaran, 1997, p. 304), the ARDL procedure contains two steps. First, the existence of the long-run relation between the variables in the system is tested. In other words, the null hypothesis of no co-integration or no long-run relationship defined by H_0: $\lambda 1 = \lambda 2 = \lambda 3 = \lambda 4 = 0$ is tested against its alternative H_1: $\lambda 1 \neq 0$, $\lambda 2 \neq 0$, $\lambda 3 \neq 0$, $\lambda 4 \neq 0$ by computing the F-statistics. The distribution of this F-statistics is nonstandard irrespective of whether the variables in the system are I (0) or I (1). The critical values of the F statistics in this test are available in Pesaran and Pesaran (1997) and Pesaran et al. (2001). Table 2 shows the results of this test:

Table 2. F-statistics of Bound Tests

F-stat = 4.505283		
lower bound	**upper bound**	**significance levels**
2.72	3.77	10%
3.23	4.35	5%
3.69	4.89	2.5%
4.29	5.61	1%

Source: Prepared by authors based on Eviews 12.

Based on the F statistic, the null hypothesis of no long-run relationship is rejected at the 5 percent and 10 percent levels of significance, because the computed Fstatic (4.51) is greater than the upper bound of the critical value (i.e. 4.35 and 3.77) of standard significant levels provided by Pesaran et all (2001). These values support the existence of co-integration or long-run relationship between variables in the equation.

-Estimate the long and short run relationship

The results of long-run representations of our analysis are presented in Table 3.

Table 3. Results of estimating the long-run relationship of the model ARDL (3, 2, 1, 1)

Variables	Coefficient	Std.Error	t-stat	Prob
RPRE	2.554290	1.238809	2.061891	0.0583
RTEM	51.74292	18.31866	2.824601	0.0135
PES	0.690471	0.151176	4.567323	0.0004

Source: Prepared by authors based on Eviews 12.

Table 3 indicates that the p-value for the pesticide variable (PES) is less than 5%, indicating its significance. The results also show that the elasticity of the temperature rate is equal to 0.69, meaning that if it changes by 1%, agricultural production will change by 69% in an inverse relationship. On the other hand, the temperature rate is significant at 5%, while the parameter for the rainfall rate is not significant because its p-value is greater than 5%.

-Error correction model

After running co-integration test, ECM estimation can be done. The error correction is mechanism which describes the speed of adjustment of the variable to return to the equilibrium when a shock occurs in the evolution of the variable i.e. error correction models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable - Y - returns to equilibrium after a change in an independent variable - X. ECMs are useful models when dealing with integrated data, but can also be used with stationary data. ECMs are useful for estimating both short-term and long-term effects of one time series on another (Chen Jen Eam, 2004). The basic structure of an ECM is:

$$\Delta Y_t = \alpha + \beta \Delta X_{t-1} - \beta EC_{t-1} + \varepsilon_t$$

Where EC is the error correction component of the model and measures the speed at which prior deviation from equilibrium are corrected, it must be negative.

In table 4, we provide the results of error correction representations of estimated ARDL model. From the table, it is clear that the error correction term (ECt−1) has the right sign (negative) and is statistically significant at 1 percent. This result provides the evidence of co-integration among variables in the model. Specifically, the estimated value of ECt−1 is − 0.186576, means that it is correcting the disequilibrium under rate of 18.66% annually, so the PAGR and the independent variables have equilibrium long-run relationship.

Table 4. The Error Correction Representation for the Selected ARDL model

Variables	Coefficient	Std.Error	t-stat	Prob
C	-30.56444	6.546112	-4.669099	0.0004
D(PAGR(-1))	-0.729323	0.179538	-4.062227	0.0012
D(PAGR(-2))	-0.729323	0.189477	-2.005170	0.0647

D(RPRE)	0.212473	0.071015	2.991937	0.0097
D(RPRE(-1))	-0.134250	0.078408	-1.712205	0.1089
D(RTEM)	4.439256	1.890554	2.348125	0.0341
D(PES)	0.026263	0.035533	0.739120	0.4720
CointEq(-1)*	-0.186576	0.039885	-4.677906	0.0004

Source: Prepared by authors based on Eviews 12.

The results from the above table indicate that the rainfall rate variable (RPre) is not significant in the previous period (t-1). However, in the current period, it is statistically significant at 5%, with a value equal to 0.2124. This means that if the latter changes by 1%, agricultural production will change by 0.2124% in a short-term positive relationship.

As for the temperature rate variable (RTem), it is statistically significant at 5% level. It also affects agricultural production in a short-term positive relationship, where 1% change leads to 4.4392% change in agricultural production. Regarding the significance of the pesticide quantity coefficient, we note that its p-value is greater than 5%, indicating insignificance.

- Diagnost Test

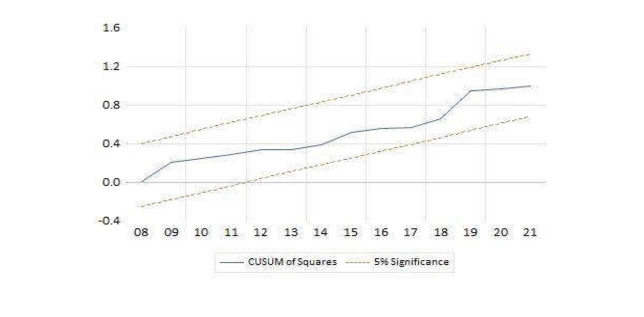
The diagnostic tests for the estimated model indicated the presence of autocorrelation in errors based on the Breusch-Godfrey test, as the p-value for the Lagrange Multiplier test was 0.29, which is greater than 0.05. On the other hand, the Jarque-Bera test revealed that the residuals follow a normal distribution. Additionally, the ARCH test showed that the p-value for the Chi-squared test statistic was 0.3222, greater than 0.05, indicating homoscedasticity of the errors.

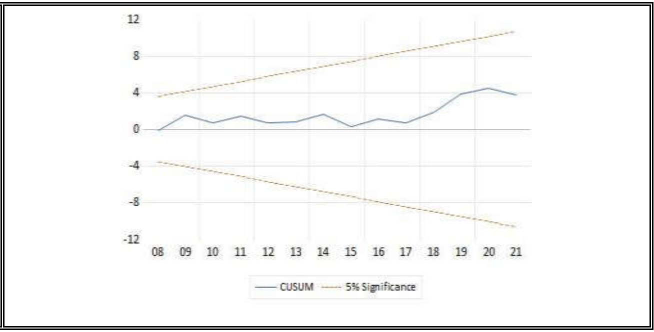
To confirm the stability of the estimated model, the tests of CUSUM and CUSUMSQ are employed in this study.

In this study the stability tests, namely, CUSUM (Cumulative Sum) and CUSUMSQ (CUSUM of Squares) of recursive residuals, are conducted. These tests are originally proposed by Brown et al. (1975). The two tests; cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test the null hypothesis are that the coefficient vector is the same in every period; the alternative is simply that it is not (Hisashi Tanizaki, 1995). Fig 2 provides the graphs of CUSUM and CUSUMSQ tests.

Fig.4 CUSUM and CUSUM Q Tests

(CUSUM Q) Test	(CUSUM) Test





Source: Prepared by authors based on Eviews 12.

Figure 4 indicate that the plot of CUSUM and CUSMSQ are completely stable within 5% of critical bands. This implies that the estimated parameters are stable over the time. Thus judging from this, we can argue that the estimated model is stable.

CONCLUSION

Enhancing food security requires the implementation of a set of policies, which Algeria has actively pursued through various development programs in the agricultural sector. The latest of these is the Agricultural Model 2020-2024, oriented towards sustainable development, and it has yielded promising results in previous time periods. However, the continuity of achieving such results is uncertain, considering the climatic changes that significantly impact Algerian food security through negative repercussions on various agricultural resources and different branches of agricultural production, leading to a decline in agricultural output. The climate changes experienced by Algeria in general are characterized by a decline in the average rainfall rate. In the period 1990-2021, the average rainfall was 83.74 mm, showing variations in different periods. This has had a clear impact on Algerian agricultural production, consequently increasing the pressure on Algerian food security.

In this context, the empirical study has clarified that rainfall does not contribute significantly to the increase in agricultural production over the long term. The contribution is limited to the short term only, which aligns perfectly with reality. Algerian agriculture is largely traditional, relying heavily on rain-fed agriculture for grain production. Therefore, during seasons of low rainfall, grain production is significantly reduced.

These results call for us to explore the best ways to enhance Algerian agricultural production for the promotion and sustainability of Algerian food security in light of the declining rainfall rates. This can be achieved through a set of proposals, including the following:

- Ensuring water security by enhancing investments to utilize groundwater and surface water, as well as adopting desalination of seawater for agricultural purposes.

- Adopting sustainable agricultural development to address the challenges of climate change.
- Strengthening national governance for food security and nutrition by defining a clear and shared vision for goals and actions.
- Supporting sustainable agricultural food sectors to create decent employment opportunities in rural areas.

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