Components of Algerian Sustainable Agricultural Development for Enhancing Food Security in Light of Climate Change.

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Abstract:

The study aimed to identify the most important capabilities that Algeria has to establish sustainable agriculture to achieve food security, especially with the rapid climate changes. The results showed that rainfall and temperature rates contribute to Algerian agricultural production by 0.33% and 2.5% in the short term only; this relationship is not achieved in the long term. Consequently, Algeria experienced a period of severe climate change due to the decline in rainfall. The best way to address these challenges to agricultural activity in Algeria is through sustainable agricultural development, which offers many effective solutions that can adapt to climate change and are not affected by the lack of rainfall. These solutions include aquaculture, renewable energies, attracting modern agricultural technical innovations, nanoclay liquid technology cultivation, and increasing the efficiency of Algerian water resources in the Sahara regions.

Keywords: Sustainable Agricultural; Development; Food Security; Climate Change.

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Introduction:

As population growth accelerates, the provision of food becomes increasingly important to states and governments worldwide. By monitoring and analyzing developments in food security, they can identify and address its indicators, informing decisions related to sectors impacting food security. This includes raising agricultural productive capacity, reducing malnutrition, and ensuring food availability to all segments of society, especially during crises such as climate change.

Climate change has underscored the significance of food security. Developed countries have initiated sustainable agricultural development through various systematic and institutional strategies, aiming to reconceptualize agricultural growth. Sustainable agricultural development leverages information and communication technologies, along with ecosystem data, to support and deliver timely information and services to farmers. This approach fosters the experimentation and expansion of innovative ideas with significant potential to impact food and agriculture. It also empowers rural families and inspires youth entrepreneurship in the food and agriculture sectors.

Recognizing the growing importance of sustainable agricultural development, the Algerian government is striving to strengthen its agricultural sector's capacity to ensure food security and maintain economic and social stability. This study examines the primary factors affecting agricultural production, addressing the following key issues:

What are the key determinants of agricultural production in Algeria? What fundamental pillars of sustainable agricultural development can ensure food security in Algeria amid climate change?

Research Hypotheses:

H0: Algeria possesses the necessary components for sustainable agricultural development to enhance food security.

H1: Algeria lacks the necessary components for sustainable agricultural development to enhance food security.

The remainder of this paper is organized as follows: Section 2 describes the theoretical framework, while Section 3 provides background information on Algerian agriculture. The pilot results are presented in Section 4, and the conclusions are contained in Section 5.

I. Theoretical framework

1. Dimensions of the food security problem

The term "food security" was first introduced in 1974 during the World Food Conference to underscore the importance of food supplies and to highlight the necessity of basic food availability and price stability as prerequisites for food security at both international and national levels. Accordingly, the Food and Agriculture Organization (FAO) defines food security as a situation in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2014).

Food security also reflects a society's ability to provide adequate food to its citizens in the long term, both quantitatively and qualitatively, at prices that are commensurate with their income. Ensuring food security requires action across multiple dimensions, including improving the governance of food systems, fostering inclusive and responsible investments in agriculture and rural areas, enhancing health and education, empowering small producers, and strengthening social protection mechanisms to reduce risk (FAO, 2014).

2. The concept of climate change

Climate change has emerged as one of the most significant and rapidly escalating threats to global populations and their food security. This phenomenon, driven by emissions of greenhouse gases from fuel combustion, deforestation, urbanization, and industrialization, results in variations in solar energy, temperature, and precipitation (Malla, 2008). Climate change poses a substantial threat to global ecosystems, profoundly affecting water resources, agriculture, coastal regions, freshwater habitats, vegetation and forests, snow cover, geological processes such as landslides, desertification, and floods. These impacts have long-term consequences for food security and human health.

The effects of climate change on agriculture and food security are considerable. Understanding the full spectrum of climate change impacts on food security necessitates an examination of its implications for prices, incomes, trade, and production. For instance, a decline in domestic food production can lead to rising food prices, thereby undermining access to food for individuals reliant on markets for their consumption needs. Moving beyond these generalities to a more nuanced understanding is challenging (Devereux & Edwards, 2004). Furthermore, the impacts of climate change will vary between countries due to differences in local resources (soil and water) and the nature of agriculture (modern and traditional).

3. Climate change impact on global food security

Climate change impacts food systems, which encompass the entire cycle of production, aggregation, processing, distribution, consumption, and disposal of food products, in multiple ways. Extreme weather events, such as hurricanes, floods, droughts, and wildfires, can destroy crops before they are harvested and damage essential infrastructure. Rising temperatures contribute to pollen sterility and water stress, resulting in decreased yields. Additionally, high temperatures suppress plants' immune responses, leading to increased vulnerability. Weeds also become more prolific, competing for resources with main crops and necessitating more intensive chemical or mechanical interventions (Hadley, 2023).

4. Sustainable agricultural development and its relationship to food security

Agricultural development plays a vital role in improving food security and nutrition by increasing the quantity and diversity of food, driving economic transformation, and serving as the main source of income for the majority of those living in extreme poverty. Sufficient income from agriculture is key for the 1.3 billion people working in the sector and directly determines their food security. Extensive experience across many countries over the years demonstrates that both agricultural development and economy-wide growth are necessary to improve food security and nutrition (FSN), with the former reinforcing the latter (HLPE Reports series, 2016).

Sustainable agriculture refers to the practice of producing food, fiber, and other agricultural products in a manner that promotes environmental stewardship, economic viability, and social well-being. It involves balancing the needs of food production with the preservation and enhancement of ecosystems, natural resources, and rural livelihoods. Key aspects of sustainable agriculture include :

- Preserving natural resources and managing water for future generations.
- Promoting biodiversity and protecting the environment.
- Addressing the challenges of climate change.

Sustainable agriculture acknowledges the interconnectedness of ecological, economic, and social aspects of food production. It aims to ensure long-term food security, protect the environment, support rural communities, and promote healthy and resilient food systems. Transitioning towards sustainable agriculture requires collaboration, innovation, and the integration of traditional knowledge with scientific advancements (HLPE Reports series, 2016).

5. Overview of the agricultural sector in Algeria

The agricultural sector contributes to stimulating growth in many countries, and in providing employment and raw materials to the various relevant productive sectors.

5.1 Agricultural development plans in Algeria

Algeria has many development plans for the development of the agricultural sector to stimulate and strengthen investors and farmers to achieve effective economic growth in the agricultural sector, which reduce food imports and increase the possibility of food security. These plans are as follows:

5.1.1 National Agricultural Development Programme

The programme of the National Agricultural Development Plan launched in the second six months of 2000 to achieve the following objectives:

- To support the adaptation of production systems.
- Development of national production and agricultural productivity.
- Support and rehabilitation of land through concession contracts.
- Support for the national afforestation programme.
- Support for land rehabilitation in the South .

However, this programme has had a range of challenges: The State shall bear all expenditures for subsidized projects And Lack of access to support for good farmers and poor results from the support policy. In 2005, the Government introduced a new scheme to try to give more rigorous and easier access to support by determining the proportion of support in the cost of each project.

5.1.2 Agricultural and rural renewal programme

The agricultural and rural renewal policy aims to achieve sustainable national food security by examining significant changes and impacts in the infrastructure that supports food security. This policy also establishes a public-private partnership and involves all actors in the development process, leading to new governance models for farming and rural areas. The government has allocated 1,000 billion Algerian dinars to this public expenditure program.

5.1.3 Plan of Action for Agriculture 2015-2019

The Plan of Action for Agriculture 2015-2019 is structured around three principal pillars. The first pillar focuses on the transformation of the agricultural and livestock sectors by modernizing and restructuring the industry. This includes enhancing the competencies of agricultural professionals, and providing monitoring and support for agricultural entrepreneurs. The second pillar emphasizes the significance of forest production and the promotion of ecotourism. The third pillar prioritizes investment in the fishing and aquaculture sectors, aiming to increase fish exports while ensuring the protection and sustainability of fishing grounds.

Overall, the Plan of Action for Agriculture seeks to achieve an average sectoral growth rate of 5%. It targets a production value of approximately 4,300 billion Algerian dinars, aims to reduce imports by $2 billion, and projects export revenues of $1.1 billion. Additionally, the plan anticipates the creation of 1.5 million jobs within the agricultural sector.

5.1.4 Agricultural model 2020-2024 oriented towards sustainable development

The agricultural sector of Algeria is incorporated into the Government's programs for 2020-2024, with a particular emphasis on advancing desert agriculture. This includes the establishment of the Office for the Development of Industrial Agriculture in the Sahara, designed to support entrepreneurs in the southern regions and facilitate their access to the benefits provided by relevant legislation. The 2020-2024 agricultural policy framework also aims to (Bouchenafa, 2019):

- Enhance the green economy by optimizing natural resource management through the implementation of spraying and drip irrigation systems across approximately 939,200 hectares, representing 64% of the total irrigable area of 1,473,919 hectares.
- Since 2020, the policy has promoted the integration of renewable energy sources in agricultural investments located in the highlands and southern regions.
- The new strategy also targets the Forestry Sector, with objectives to diversify the economy and improve rural incomes by creating green jobs.
- Additionally, the sector plans to leverage university partnerships to advance innovation and research in areas such as fertilizers, environmentally friendly pesticides, and cutting-edge technological solutions.

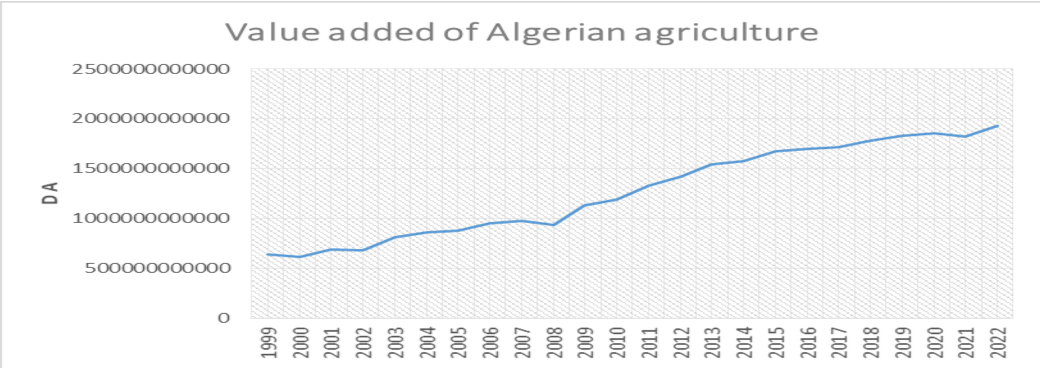
This strategy enabled the export of about 50,000 tons of agricultural products during the first quarter of 2021, and exports of more than 100,000 tons of vegetables and fruits in 2020.

6. Fact of agricultural production and associated variables in Algeria

6.2 Evolution of local agricultural production in Algeria

Supplement No. (01) reveals a notable upward trend in the monetary value added by Algerian agriculture, increasing from 640.63 billion DA in 1999 to 972.42 billion DA in 2007, a change attributed to the Algerian Government's agricultural policies. However, in 2008, there was a 3.8% decline in this value. With the implementation of the Agricultural and Rural Renewal Program in 2009, the value added of Algerian agriculture rose to 1.19 trillion DA by 2010. This positive trajectory continued, reaching 1.93 trillion DA by 2022. The accompanying figure illustrates the evolution of the value added by Algerian agriculture over the period from 1999 to 2022.

Figure (1): Evolution of the value added of Algerian agriculture (1999-2022)

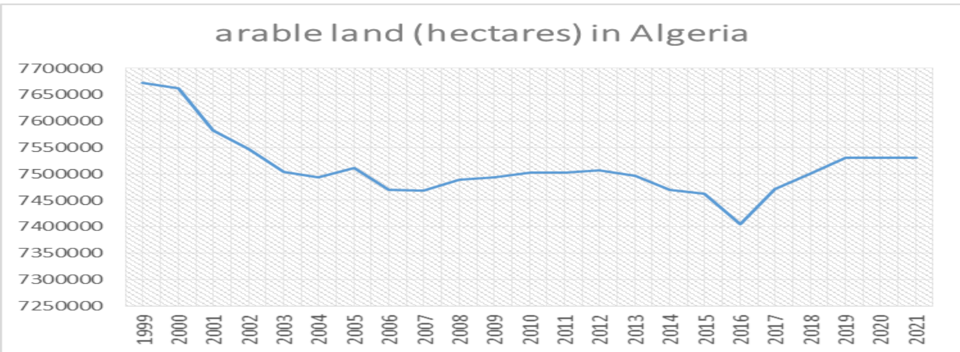


Source: The World Bank. https://data.worldbank.org/indicator/NV.AGR.TOTL.KN?locations=DZ.

6.2 Development of arable area in Algeria

The supply of food is influenced by the availability, quality, and production capacity of agricultural land. Between 2000 and 2007, Algeria experienced a reduction in arable land by 204,000 hectares. By 2012, the arable area had increased to 756,500 hectares, supported by the rehabilitation of 7,745 agricultural investors and the development of over 865 desertification control programs. However, by 2016, the arable land decreased to 7,404,200 hectares due to climatic changes and the limited effectiveness of desertification control initiatives. As of 2021, Algeria's arable land is estimated to be 7,530,600 hectares. The accompanying figure illustrates the changes in arable land in Algeria from 1999 to 2021.

Figure (2): Evolution of arable area in Algeria (1999-2021)



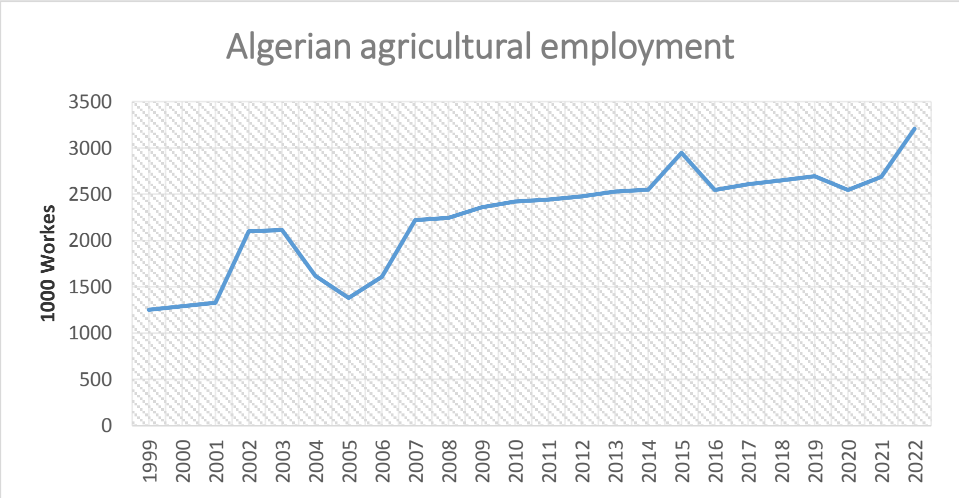
Source: The World Bank. https://data.worldbank.org/indicator/AG.LND.ARBL.HA?locations=DZ.

6.3 Position of employment in the Algerian agricultural sector

During the 1990s, Algeria faced a complex security situation that significantly impacted the labor force within the agricultural sector. In 1999, the sector employed approximately 1,250,000 workers. This number increased at a gradual pace, reaching 1,609,630 by 2006, partly due to rural exodus and the migration of labor to other sectors.

As the security situation improved, coupled with increased government focus on the agricultural sector, various development programs were implemented to restore and stabilize rural communities. Efforts to mitigate rural displacement included the establishment of numerous local development projects. Consequently, the labor force in the Algerian agricultural sector grew from 2,220,120 in 2007 to 2,650,000 in 2021. The accompanying figure illustrates this trend.

Figure (3): Evolution of Algerian agricultural employment (1999-2021)

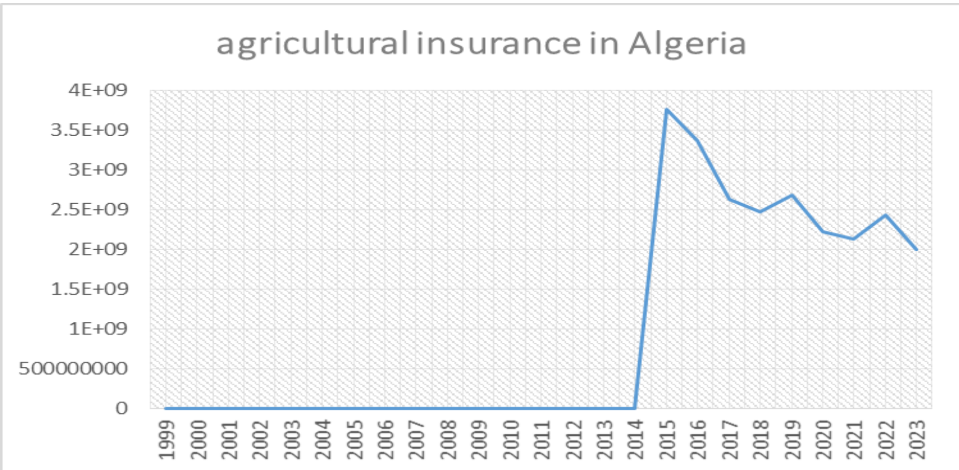


Source: National Office of Statistics: https://www.ons.dz/spip.php?rubrique327

6.4 Fact of agricultural insurance in Algeria

The agricultural sector faces numerous risks, including the potential for declining production due to uncontrollable factors such as climatic conditions and the risk of falling prices resulting from high supply levels. To mitigate these risks, agricultural insurance becomes crucial for safeguarding investments. To assess the evolution of farm insurance businesses in Algeria, we analyze the following data:

Figure (4): Evolution of agricultural insurance in Algeria (2000-2022)



Source: National Council of Insurance (2018, 2019, 2020, 2021, 2022). Market Situation Report, Fourth Quarter. https://cna.dz/notes-de-conjoncture/.

Supplement No. (01) indicates a decline in Algerian agricultural insurance from DA 1,431,013 in 2001 to DA 993,563 in 2004. However, by 2011, the value of agricultural insurance had risen to DA 1,620,553, and by 2022, it reached DA 2,408,135,968. This increase is attributed to the rise in agricultural production, growing agricultural risks associated with climate change, and the evolving nature of commercial agriculture. Agricultural insurance is increasingly recognized as an essential risk management tool, offering a relatively low-cost solution compared to potential risk losses.

II. Material and methods

1. Analysis of climate change indicators in Algeria

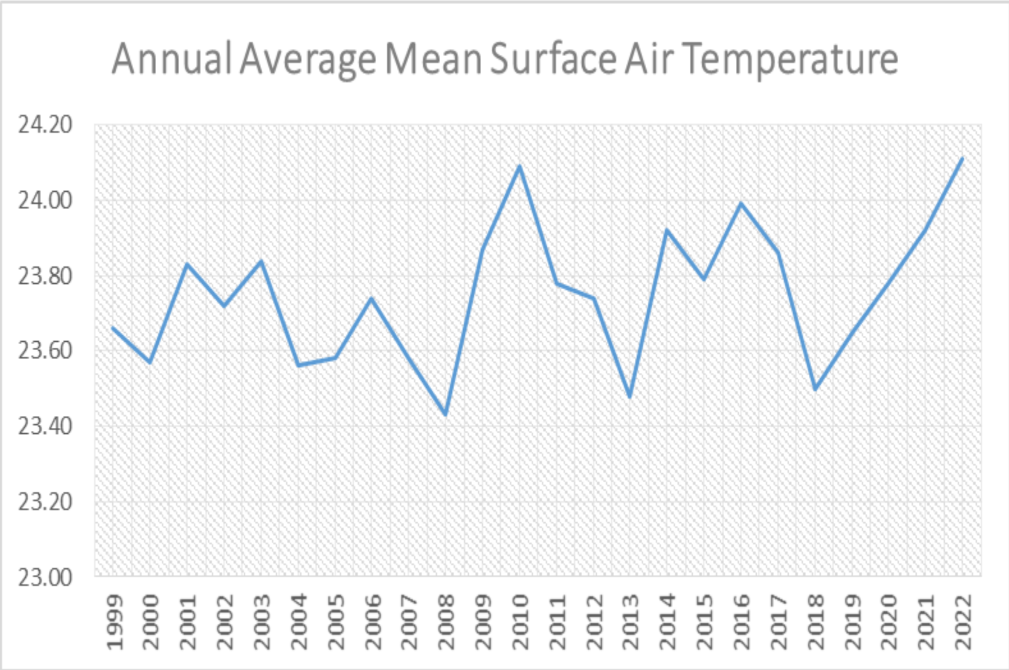
Understanding climate trends—past, present, and future—requires contextualizing them within the framework of natural variability. Climate variability refers to the fluctuations in climate conditions, such as temperature and precipitation, from year to year within their typical range of variability. In Algeria, temperature and rainfall patterns have undergone significant changes, which are elucidated in the following points:

1.1 Temperature rates

The average annual temperature in Algeria was approximately 23.77°C during the period from 1999 to 2009, and it increased to about 24.10°C in the subsequent years (2010-2022). This represents an increase of approximately 0.33°C over less than 23 years. Climate projections suggest that temperatures could rise by an additional 1°C by 2050.

This upward trend in temperatures is indicative of climate change and is likely to impact rainfall patterns (which will be discussed in the following section) and pose a risk to food security. For a clearer understanding of the evolution of average temperatures in Algeria, refer to the following figure:

Figure (5): Evolution of Temperature rates in Algeria (1999-2022)

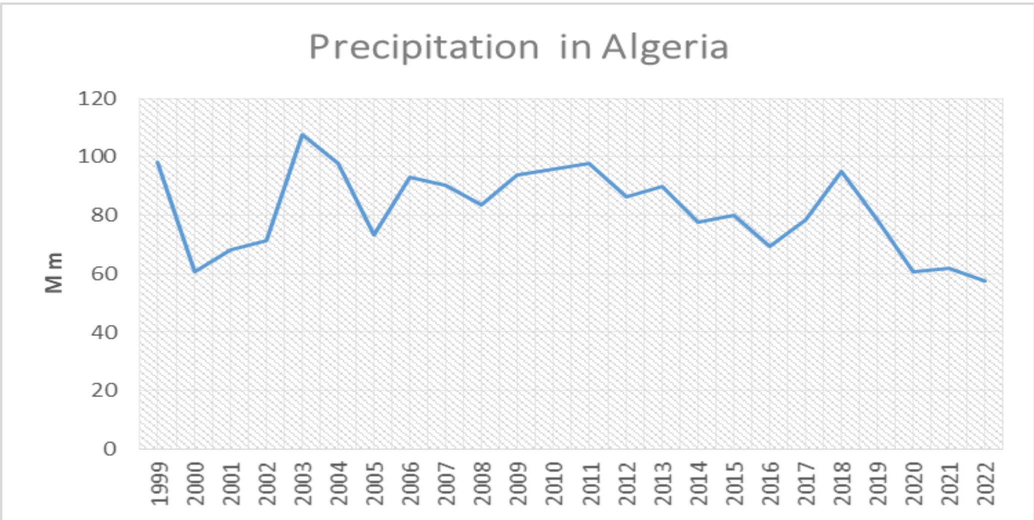


Source: The World Bank. https://climateknowledgeportal.worldbank.org/

1.2 Rainfall rate

Rainwater serves as the primary source for most agricultural crops in Algeria, although non-seasonal crops may rely on irrigation and adapted agricultural practices, such as plastic greenhouses (Bouarab, 2022). The increase in temperature and associated climate changes have adversely affected agricultural GDP, particularly for sectors reliant on seasonal agriculture. This decline is attributed to fluctuations in rainfall rates. The following figure illustrates the evolution of rainfall rates in Algeria from 1999 to 2022.

Figure (6): Evolution of Precipitation in Algeria (1999-2022)



Source: The World Bank. **https://climateknowledgeportal.worldbank.org/country/algeria**

Annual rainfall in Algeria is generally low, exceeding 100 mm only once in 2003. Moreover, rainfall has been steadily decreasing, reaching 57.61 mm in 2022. This trend indicates that Algeria is experiencing significant climatic changes, including rising temperatures and declining rainfall. These changes pose serious challenges for future food provision in Algeria and threaten social security by compromising food security.

2. Methodology for estimating impact of climate change on agriculture production in Algeria

2.1 Study model

The Autoregressive Distributed Lag (ARDL) model, also known as the bounds test for cointegration, was first developed by Pesaran and Shin (Pesaran & Shin, 1995) and has been utilized in previous crop-climate studies (Ramandeep, 2023). The ARDL model is preferred over other econometric models due to its ability to produce consistent and efficient results even with small sample sizes. Additionally, it is robust against endogeneity, a common issue in crop and climate datasets where predictor variables may be correlated with error terms (Ramandeep et al., 2023).

A key advantage of the ARDL model is its capacity to simultaneously assess both short-run and long-run effects of independent variables on dependent variables. Furthermore, it is applicable when variables are integrated of either order zero or one, and it addresses endogeneity concerns present in the data (Peng et al., 2022). The general formulation of the proposed study model is as follows:

$$\begin{aligned}\Delta Pr_{\mathrm{t}} = \alpha_{00} + \sum_{i=1}^{n} \alpha_{0i}\,\Delta \mathrm{Aa}_{t-i} + \sum_{i=0}^{n} \alpha_{1i}\,\Delta \mathrm{L}_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\,\Delta \mathrm{In}_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\,\Delta \mathrm{Te}_{t-i} \\ + \sum_{i=0}^{n} \alpha_{4i}\,\Delta \mathrm{Ra} + +\lambda_0 \mathrm{Pr}_{t-1} + \lambda_1 \mathrm{Ar}_{t-1} + \lambda_2 \mathrm{L}_{t-1} + \lambda_3 \mathrm{In}_{t-1} + \lambda_4 \mathrm{Te}_{t-1} \\ + \lambda_4 \mathrm{Ra}_{t-1} \varepsilon_t\end{aligned}$$

The long-term relationship can also extracted from the proposed model as follows:

$$\mathrm{P}r_{\mathrm{t}} = \mathrm{a}_0 + \mathrm{a}_1 \mathrm{Aa}_{\mathrm{t}} + \alpha_2 \mathrm{L}_{\mathrm{t}} + \mathrm{a}_3 \mathrm{In}_{\mathrm{t}} + \mathrm{a}_4 \mathrm{Te}_{\mathrm{t}} + a_5 Ru_t$$

Also:

$$\mathrm{a}_0 = -\left(\frac{\alpha_{00}}{\lambda_0}\right), \mathrm{a}_1 = -\left(\frac{\lambda_1}{\lambda_0}\right), \mathrm{a}_2 = -\left(\frac{\lambda_2}{\lambda_0}\right), \mathrm{a}_3 = -\left(\frac{\lambda_3}{\lambda_0}\right), \mathrm{a}_4 = -\left(\frac{\lambda_4}{\lambda_0}\right), a_5 = -\left(\frac{\lambda_5}{\lambda_0}\right)$$

Where:

Pr**:** local agricultural production in Algeria.
Aa: arable area in Algeria.
L**:** Algerian agricultural employment**.**
In**:** agricultural insurance in Algeria**.**
Te**:** Temperature rates in Algeria**.**
Ra**:** rainfall rates in Algeria.

III. Result and discussion

This section details the results obtained from estimating the study model and testing for cointegration using the Autoregressive Distributed Lag (ARDL) model. The lag length for the model variables was selected based on the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC), with the EViews 12 software automatically determining the appropriate lags.

Additionally, the stability of the time series for the model variables was assessed using the Augmented Dickey-Fuller (ADF) test. The results indicated that the time series are stationary at both levels (0) and first differences (1), which validates the application of the ARDL methodology.

1. **Estimation results of the study model**

The results of the estimate were as follows:

Table (01): Results of the short-term assessment of the study model

ARDL Long Run Form and Bounds Test
Dependent Variable: D(PR)
Selected Model: ARDL(2, 1, 2, 0, 0, 1)
Case 2: Restricted Constant and No Trend
Date: 05/12/24 Time: 17:03
Sample: 1 24
Included observations: 22

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-28.63999	10.73046	-2.669036	0.0235
PR(-1)*	-0.148639	0.066706	-2.228266	0.0500
AA(-1)	3.762258	1.476748	2.547664	0.0290
L(-1)	0.253062	0.100174	2.526233	0.0301
IN**	0.001017	0.003476	0.292539	0.7759
TE**	2.258984	1.066939	2.117256	0.0603
RA(-1)	0.337083	0.087765	3.840758	0.0033
D(PR(-1))	-0.633047	0.125069	-5.061568	0.0005
D(AA)	-3.266300	2.192281	-1.489909	0.1671
D(L)	0.107376	0.065713	1.634022	0.1333
D(L(-1))	-0.204783	0.072034	-2.842881	0.0175
D(RA)	0.229965	0.054006	4.258172	0.0017

Source: Prepared by the researcher based on Eviews 12.

The general statistical analysis of the model reveals that most of the short-term coefficients are statistically significant at the 10% level, as determined by the student's t-test, with the exception of agricultural insurance. Specifically, a one-unit increase in labor results in a 3% increase in agricultural production, while an additional hectare of arable land leads to a 5% increase in production. Conversely, a one-degree rise in temperature results in a 6% increase in agricultural production. Rainfall has a relatively minor effect on agricultural production, contributing only 0.33%.

The Fisher test indicates that the model is statistically significant, and the Adjusted R-squared value shows that the variables included in the model explain 99.74% of the variation in agricultural production in Algeria for the period from 1999 to 2022.

Furthermore, the F-Bounds test for cointegration, as shown in Table 01 of the annex, yielded a value of 17.73, which exceeds the upper limit at the 5% significance level. Additionally, the error correction term for the model, at a 1% significance level and equal to -0.1486, confirms the existence of a long-term relationship between the dependent variable and the explanatory variables. This suggests that a long-term relationship should be explored further, as detailed in the subsequent table.

Table (2): Results of the long-term assessment of the study model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AA	25.31140	16.55101	1.529296	0.1572
L	1.702528	0.398691	4.270294	0.0016
IN	0.006841	0.022382	0.305671	0.7661
TE	15.19780	11.47584	1.324330	0.2149
RA	2.267800	1.274369	1.779547	0.1055
C	-192.6817	127.7745	-1.507982	0.1625

Source: Prepared by the researcher based on Eviews 12.

According to the results presented in Table 2, the labor variable is the only factor that significantly affects Algerian agricultural production in the long term, with an impact of 1.70%. In contrast, rainfall rates do not significantly influence agricultural production in Algeria for the period from 1999 to 2022. This finding suggests that new production mechanisms should be explored to enhance food security and mitigate the limited impact of rainfall on agricultural output.

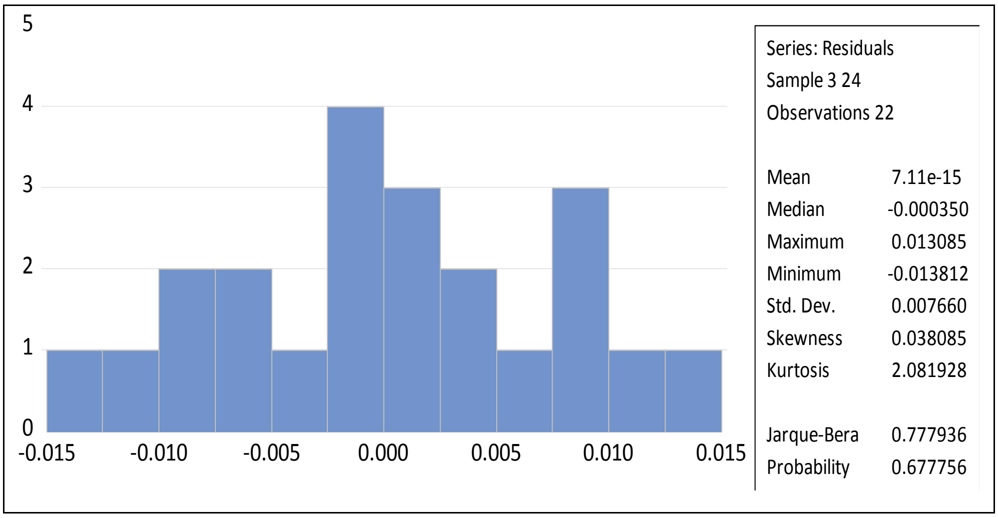
2. Diagnostic tests for the estimated study model

To assess the criterion validity of the estimated study model, we conducted the following diagnostic tests:

2.1 **Error Autocorrelation Test**: The Durbin-Watson (DW) statistic yielded a value of 2.08, indicating that there is no first-degree autocorrelation among the residuals of the estimated model.

2.2 **Test of Normal Distribution of Residuals (Jarque-Bera Test)**: To evaluate the normal distribution of residuals, we employed the Jarque-Bera (JB) test. The results of this test are illustrated in the following figure:

Table (3): Results of the normal distribution test for the residuals

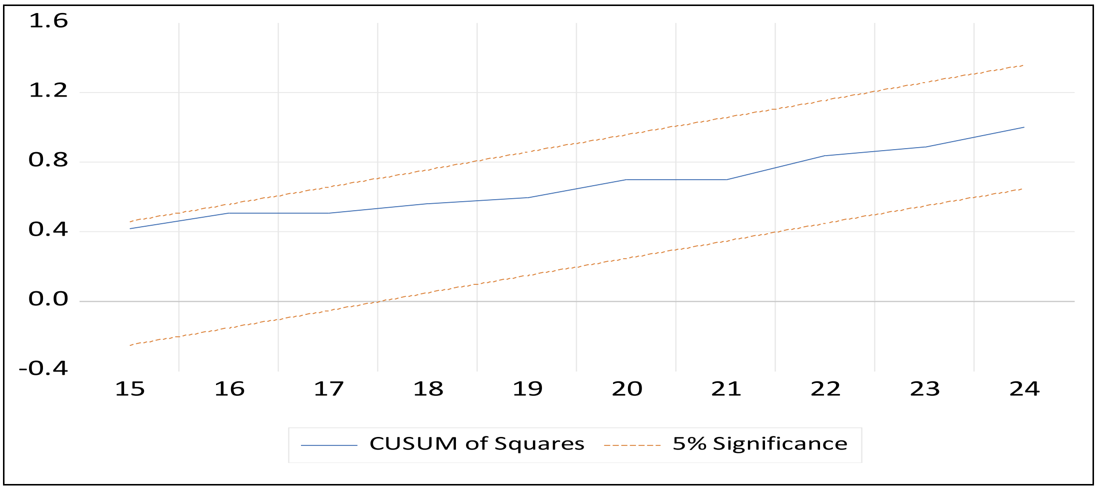


Source: Prepared by the researcher based on Eviews 12.

Table (3) indicates that the normal distribution of the residuals achieved through the Jarque-Bera test, with a value of 0.77 and a probability of 0.67.

2.1 Testing the structural stability of the model coefficients: To ensure that the data used in the estimated study model are free of any structural changes, we use the C.U.S.U.M S. Q test, and the following figure shows the results:

Figure (7): C.U.S.U.M.S.Q. Study Model Test



Source: Prepared by the researcher based on Eviews 12.

From the figure, we notice that the C.U.S.U.M.S.Q test for the estimated study model is within the limits of the critical region, indicating stability in the model at a 5% significance level.

IV. Conclusions

Promoting food security necessitates the implementation of a comprehensive range of policies. Algeria has pursued this through various agricultural development programs, with the most recent being the 2020-2024 agricultural model aimed at fostering sustainable development. This model has yielded encouraging results compared to previous periods. However, the sustainability of its implementation is uncertain when considering the significant impacts of climate change on Algerian food security. Climate change adversely affects agricultural resources and production branches, leading to a decline in agricultural output.

The declining rainfall in Algeria, combined with inadequate water resource management and concerns over the exploitation of shale gas in the southern regions, is expected to negatively impact agricultural production and, consequently, food security.

To address these challenges, sustainable agricultural development offers effective solutions that can adapt to climate change and mitigate the effects of reduced rainfall. Key strategies include :

1. Aquaculture in the Algerian

Aquaculture involves the cultivation of marine and freshwater organisms in controlled environments, with production influenced by economic, technological, biological, and environmental factors (Jang & Yamazaki, 2020; Kaleem & Sabi, 2021). Since 1980, aquaculture has been the fastest-growing global food-producing sector, expanding at an annual rate of 8.6% (Oyebola & Olutande, 2019), with Africa demonstrating the highest regional growth rate of 7% (Nadarajah & Flaaten, 2017). Aquaculture is notable for its efficient water use, which contributes to resource and energy conservation, making it a sustainable solution for enhancing food production and addressing the needs of a growing population.

In Algeria, aquaculture remains underdeveloped and is primarily practiced by smallholders, impacting both food security and ecosystem services, while also serving as an indirect economic driver. Various aquaculture methods are employed in Algeria, with the choice of method depending on factors such as water availability, resources, and climatic conditions. These methods include:

- **Hydrodistillation Agriculture (Fog Harvesting)**: This method extracts water from fog in desert regions. Fog is captured through specialized networks or nets, collected, and then directed to irrigation systems for vegetation.

- **Hydroponics Agriculture**: This technique involves cultivating plants without soil, using nutrient-rich solutions instead. The water solution in hydroponics systems is recycled and reused, promoting efficient water use.

- **Semi-Floating System Agriculture**: Plants are placed on floating boards that rest on the water's surface. Nutrients are supplied through the purification of surrounding water, enhancing plant growth and improving water utilization.

- **Urban Spraying Agriculture (Aeroponics)**: In this method, plant roots are sprayed with a nutrient solution. This technique is efficient in water usage and supports uniform and rapid plant growth.

2. Renewable energies: alternative security for agricultural activity in the Algeria

To mitigate the adverse effects of shale gas on agricultural development in the Algerian Sahara, it is crucial to leverage renewable energy sources to promote sustainable agricultural practices. Solar energy, in particular, represents a vital renewable resource for Algeria. The country possesses significant solar energy potential, estimated to be equivalent to four times the total global energy consumption, approximately 37,000 billion cubic meters of gas annually.

Algeria has pioneered the establishment of a hybrid solar power plant, the world’s first of its kind, which utilizes both gas and solar energy. This plant has a production capacity of up to 150 megawatts, with an additional facility operating at 1.1 megawatts. The deployment of solar energy in the Algerian Sahara offers several benefits, including mitigating climate change by reducing greenhouse gas emissions and providing essential energy resources for desert agriculture.

Solar energy can be utilized in various agricultural applications in the Algerian desert. It facilitates the drying of crops, heating of greenhouses, barns, and other agricultural structures, and provides hot water for processing and operational needs. Additionally, solar power can drive agricultural machinery and water pumps, enhancing the efficiency and sustainability of farming activities in the region (United Nations, ESCWA, 2019).

3. Attracting modern agricultural technical innovations

Among the modern farming techniques suitable for the Sahara environment is the use of biochar, also known as biocoal. Biochar is a carbon-rich material produced through the thermal transformation of organic matter at temperatures exceeding 400 degrees Celsius in the absence of oxygen. This process stabilizes the carbon present in the organic material, effectively preventing its release into the atmosphere.

Biochar offers several benefits for agriculture, particularly in arid environments like the Sahara. It enhances soil fertility, improves the physical properties of soil, increases agricultural production, and helps protect plants from certain soil-borne diseases. Additionally, biochar's carbon-rich composition allows it to remain in the soil for thousands of years, making it a potent tool for carbon sequestration. This contributes to mitigating global warming and climate change by reducing the amount of carbon dioxide in the atmosphere.

4. **Nanoclay liquid technology cultivation**

Nanoclay is innovation produced by the emerging Norwegian company Desert Control. Nanoklay is liquid consists of water and mud only, and the company designed it to be sprayed on sand or sandy soil.

5. **Increasing the efficiency of Algerian water resources in the Sahara regions**

To enhance the efficiency of water resources in Algeria's Sahara, the following actions are recommended:

- **Expansion of Water Dams**: Increasing the number of water dams to improve water storage and distribution.
- **Augmentation of Desalination Plants**: Expanding the capacity of desalination plants in the Sahara to address the region's water scarcity.
- **Targeted Research on Desalination**: Directing research efforts towards desalination technologies to benefit southern areas suffering from severe rainfall deficits and limited water resources, ensuring these solutions align with sustainable agricultural development goals.

Suggestions for Future Action :

- **Promote Sustainable Agricultural Development**: Advocate for both political and individual efforts to support sustainable agricultural practices that address the challenges posed by climate change.
- **Invest in Research Centers**: Increase investments in scientific research centers focused on sustainable agricultural development to create agricultural practices suited to the desert environment of Algeria.
- **Explore Regional Clusters**: Conduct research on regional clusters dedicated to agricultural activities in the Algerian Sahara, prioritizing sustainable agricultural development within these areas.

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VI. Appendix:

Appendix (1): Results of the study model

Dependent Variable: PR
Method: ARDL
Date: 05/12/24 Time: 21:59
Sample (adjusted): 3 24
Included observations: 22 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): AA L IN TE RA
Fixed regressors: C
Number of models evaluated: 486
Selected Model: ARDL(2, 1, 2, 0, 0, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
PR(-1)	0.218314	0.143832	1.517841	0.1600
PR(-2)	0.633047	0.125069	5.061568	0.0005
AA	-3.266300	2.192281	-1.489909	0.1671
AA(-1)	7.028558	2.023261	3.473875	0.0060
L	0.107376	0.065713	1.634022	0.1333
L(-1)	-0.059098	0.066832	-0.884273	0.3973
L(-2)	0.204783	0.072034	2.842881	0.0175
IN	0.001017	0.003476	0.292539	0.7759
TE	2.258984	1.066939	2.117256	0.0603
RA	0.229965	0.054006	4.258172	0.0017
RA(-1)	0.107118	0.072558	1.476314	0.1706
C	-28.63999	10.73046	-2.669036	0.0235

R-squared	0.997449	Mean dependent var	12.09999
Adjusted R-squared	0.994643	S.D. dependent var	0.151659
S.E. of regression	0.011100	Akaike info criterion	-5.861311
Sum squared resid	0.001232	Schwarz criterion	-5.266197
Log likelihood	76.47442	Hannan-Quinn criter.	-5.721120
F-statistic	355.4792	Durbin-Watson stat	2.803505
Prob(F-statistic)	0.000000		

Source: Prepared by the researcher based on Eviews 12.