

Achieving Sustainable Food Security in Algeria: An Econometric Study for the Period 1990-2023 Using the ARDL Model

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Abstract

Amid escalating global challenges, such as climate change, geopolitical tensions, and increasing reliance on food imports, food security emerges as a critical issue for achieving stability and sustainable development. This study aims to analyze the state of sustainable food security in Algeria during the period 1990–2023 using the Autoregressive Distributed Lag (ARDL) model. The findings reveal that agricultural GDP, governmental support, and agricultural exports positively contribute to improving food security, whereas climate change, food imports, and global food prices negatively impact it. Accordingly, the study recommends enhancing domestic production, optimizing resource management, and adopting adaptive policies to ensure food security in the face of ongoing challenges.

Key words: Sustainable food security, climate change, food imports, ARDL model, Algeria, sustainable development.

Jel Codes Classification : Q18, C32, O13, Q56.

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تحقيق الأمن الغذائي المستدام في الجزائر: دراسة قياسية للفترة 1990-2023 باستخدام نموذج ARDL

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ملخص

في ظل تنامي التحديات العالمية المتمثلة في التغيرات المناخية، التوترات الجيوسياسية، والاعتماد المتزايد على الواردات الغذائية، تبرز قضية الأمن الغذائي كواحدة من القضايا الأكثر إلحاحًا لتحقيق الاستقرار والتنمية المستدامة. تهدف هذه الدراسة إلى تحليل واقع الأمن الغذائي المستدام في الجزائر للفترة 1990-2023 باستخدام نموذج الانحدار الذاتي للفجوات الزمنية الموزعة (ARDL). تظهر النتائج أن الناتج المحلي الإجمالي الزراعي، الدعم الحكومي، والصادرات الزراعية تسهم إيجابيًا في تحسين الأمن الغذائي، في حين تؤثر التغيرات المناخية، الواردات الغذائية، وأسعار الغذاء العالمية سلبًا عليه. بناءً على ذلك، توصي الدراسة بتعزيز الإنتاج المحلي، تحسين إدارة الموارد، واعتماد سياسات تكيفية لضمان الأمن الغذائي في مواجهة التحديات الراهنة.

الكلمات المفتاحية: الأمن الغذائي المستدام، التغيرات المناخية، الواردات الغذائية، النموذج القياسي ARDL ، الجزائر، التنمية المستدامة.

التصنيف Jel : Q18 ، C32 ، O13 ، Q56.

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Introduction:

Food security represents a fundamental pillar for societal stability and socio-economic prosperity, directly impacting individual health and quality of life. Algeria, as a developing nation, faces persistent food security challenges due to insufficient domestic agricultural production and significant dependence on food imports to meet the population's essential needs. Between 2015 and 2021, Algeria's food imports increased by 25%, accounting for nearly 30% of the national external budget, thereby exacerbating economic burdens and hindering sustainable development efforts (Benkheznadji, 2024, p. 1236).

These challenges are intensified by global geopolitical disruptions, such as the Russian-Ukrainian conflict, which have led to supply chain interruptions and a 40% rise in food prices during the same period (Jagtap et al., 2022, p. 2099). Additionally, climate change plays a critical role in aggravating food security issues; droughts and rising temperatures have adversely affected agricultural output, resulting in reduced yields and increased food waste. These environmental, economic, and political factors further undermine Algeria's food security systems, presenting substantial challenges for agricultural and developmental policies.

The core research problem revolves around the extent to which Algeria has achieved sustainable food security objectives, considering both internal and external challenges. The study addresses the central research question: To what extent has Algeria achieved sustainable food security from 1990 to 2023, considering the domestic and global challenges faced?

To answer this question, the study posits three hypotheses: (1) Algeria has made significant progress toward sustainable food security during the target period through effective agricultural policies and continuous government support. (2) External challenges, such as geopolitical conflicts and climate change, have had a considerable negative impact on food security, necessitating innovative adaptive strategies. (3) Advancements in agricultural technology and the development of food infrastructure have positively contributed to increasing domestic production and reducing dependency on imports.

This study aims to analyze the factors influencing sustainable food security in Algeria, including agricultural policies, government support, technological innovations, and the impact of global crises on food production and distribution. Additionally, it seeks to provide actionable recommendations for policymakers to enhance agricultural policies, support technological innovations, and develop food infrastructure in line with international best practices in food security. By bridging the gap between Algeria's vast agricultural potential and the practical realities of food security, the study considers the impacts of climate change and geopolitical challenges.

The study is organized as follows: an introduction, presenting the research problem and objectives, followed by a conceptual framework of the most important study terms. The empirical analysis discusses results, and the study concludes with key findings and recommendations.

- **Previous Studies**

A range of studies has explored food security in Algeria from different perspectives, offering valuable insights into its determinants, challenges, and prospects for improvement:

Benkheznadji (2024) focused on Algeria's standing within global food security indicators as defined by international organizations. It emphasized the country's efforts to mitigate economic dependency on food imports, particularly in the context of global economic transformations. The findings highlighted Algeria's attempts to align its agricultural strategies with international benchmarks to improve food security.

Lazereg et al. (2024) examined the state of food security in Algeria, with particular attention to the challenges posed by global economic shifts. It provided a diagnostic analysis of Algeria's food security performance based on global indicators, pointing to the urgent need

for comprehensive and sustainable policies to address vulnerabilities in the country's food systems.

Lynda and Houria (2024) analyzed the determinants of food security in Algeria over the long term. It revealed that variables such as agricultural GDP, the cultivated land area, and wheat production were positively correlated with food security, underscoring the importance of increasing domestic agricultural productivity to reduce reliance on imports.

Bouziane et al. (2024) explored the determinants of sustainable food security in Algeria, emphasizing the multifaceted impacts of external and internal factors. Key variables such as food imports, climate change, the performance of the agricultural sector, economic growth, and inflation were analyzed. The study found that these factors had varying effects on food security, with climate change and food imports being particularly detrimental.

Berbache et al. (2024) delved into Algeria's reliance on imported food to bridge the production gap, highlighting its implications for food security. The authors stressed the need for greater investment in the agricultural sector and policy reforms to promote self-sufficiency. The findings called for the establishment of a more integrated and resilient agricultural system capable of withstanding global shocks.

These studies collectively provide a rich foundation for understanding the complexities of food security in Algeria. However, the current study builds on these works by adopting a more comprehensive and dynamic approach, utilizing the Autoregressive Distributed Lag (ARDL) model to analyze the interplay between economic, climatic, and policy factors in achieving sustainable food security over an extended period (1990–2023).

I- Sustainable Food Security: A Conceptual framework

I-1- Definition of Sustainable Food Security:

Sustainability is a fundamental variable in the concept of food security. Reports from the Food and Agriculture Organization (FAO) indicate that since the 1970s, food production has caused significant environmental harm due to the excessive use of groundwater, fertilizers, and pesticides, leading to soil fertility degradation and the loss of natural components.

Sustainable food security is tied to a sustainable food system that ensures food security and nutrition for all without compromising the economic, social, and environmental foundations for future generations. This involves (2021, قادي, p. 567):

- Economic sustainability: Ensuring long-term profitability.
- Social sustainability: Delivering broad societal benefits.
- Environmental sustainability: Having a neutral or positive impact on natural ecosystems.

The American Public Health Association defines a sustainable food system as one that "provides healthy food to meet current needs while maintaining healthy ecosystems to provide for future generations with minimal negative environmental impact" (Johnston et al., 2014, p. 423). According to FAO, achieving sustainable food security requires (Berry et al., 2015, p. 2296):

- Providing balanced, nutritious food that meets everyone's needs.
- Ensuring agricultural production that preserves the environment, climate, soil, water, and biodiversity.
- Reducing energy consumption, greenhouse gas emissions, and waste.
- Engaging stakeholders (government, farmers, consumers, institutions) in crafting appropriate agricultural policies (2021, بوكير, p. 185).

Thus, sustainable food security can be defined as an approach ensuring the efficient use of resources to meet current and future food needs, either through domestic production or imports.

I-2- Dimensions of Sustainable Food Security:

The dimensions of sustainable food are (Guiné et al., 2021, p. 2736):

- a) **Availability:** Ensuring sufficient national food supplies to meet growing demand while stabilizing quantities and prices to meet minimum needs.
- b) **Accessibility:** Following historical famines in Africa and Asia, despite food availability, the concept of food security evolved to focus on meeting food demand at all levels—national, regional, household, and individual.
- c) **Environmental sustainability:** Meeting food needs by utilizing renewable resources while protecting the environment is a cornerstone for long-term food security.
- d) **Safety:** Protecting food supplies from disasters and economic fluctuations that impact prices or production. Since the 1990s, this concept has expanded to include food quality and safety concerning nutritional elements and standards throughout production, storage, and distribution processes.

II - The Current State of Sustainable Food Security in Algeria:

This section focuses on evaluating the state of sustainable food security in Algeria by examining various indicators. Some of these indicators are part of the global Sustainable Development Goals (SDG) framework for 2030, such as the prevalence of undernourishment, food insecurity, and malnutrition. Others are widely recognized by researchers and specialists, including job creation in the agricultural sector and the contribution of agricultural GDP to the total national economy.

II -1- Analysis of Food Sustainability in Algeria:

Food systems are integral to achieving the United Nations' 17 Sustainable Development Goals. To track countries' progress, the Economist Impact, in collaboration with the Barilla Center for Food and Nutrition, developed the Food Sustainability Index (FSI). The FSI was first introduced in 2016, ranking food sustainability in 25 countries (Béné et al., 2022, p. 4). It expanded to 34 countries in 2017, 67 in 2018, and 78 countries in 2021. The index evaluates food systems across three key pillars: food loss and waste, sustainable agriculture, and nutritional challenges. It includes 38 indicators and 95 sub-indicators, with scores ranging from 0 to 100, where 100 represents the highest sustainability level (Poczta-Wajda & Poczta, 2024, p. 11).

Table n°1: Food Sustainability in Algeria (2021)

Indicator	Food Sustainability	Food Loss and Waste	Sustainable Agriculture	Nutritional Challenges
Score	51	31	55	66
Global Rank	73	78	76	36

Source: Economist Impact - Food Sustainability Index.

The table n°1 highlights Algeria's food sustainability indicators in 2021. The overall food sustainability score of 51 ranked Algeria 73rd globally, indicating a moderate level. The food loss and waste score of 31 and rank of 78 reflect significant challenges in managing food resources effectively. On the other hand, sustainable agriculture scored relatively better at 55 and ranked 76th, signaling tangible efforts that require further enhancement. Nutritional challenges recorded a higher score of 66, ranking Algeria 36th globally, emphasizing the need for urgent improvements to ensure sustainable food security.

II -2- Analysis of Sustainable Food Security Indicators in Algeria:

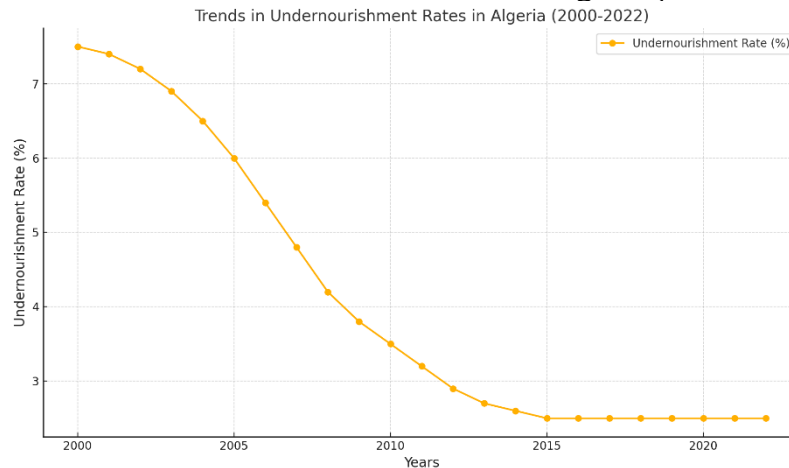
This section examines key sustainable food security indicators based on statistics from the Food and Agriculture Organization (FAO):

a) Prevalence of Undernourishment

Undernourishment arises from limited access to food, inability to prepare meals, or health conditions that inhibit nutrient absorption. It can also result from increased caloric demands unmet by current food intake. This indicator is included in the SDG framework to evaluate progress toward ending poverty and hunger (Diaz- Sarachaga et al., 2018, p. 666).

Algeria, like other nations, is striving to ensure adequate and nutritious food to address undernourishment, particularly in rural and remote areas. Analysis of these indicators demonstrates Algeria's progress in addressing specific challenges but also underscores the need for robust policies to overcome structural and environmental hurdles.

Figure n°1: Trends in Undernourishment Rates in Algeria (2000-2022) - Unit (%)



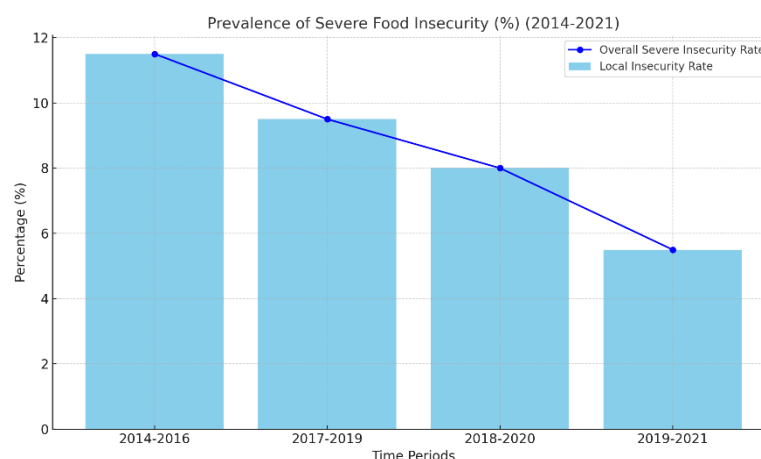
Source: Prepared by the authors using Python 3.13.0, based on data from the Food and Agriculture Organization of the United Nations (FAO).

The Figure n°1 illustrates the trend in undernourishment rates in Algeria from 2000 to 2022, measured as a percentage. It shows a significant decline in undernourishment rates, starting from approximately 7.5% in 2000 and reaching a stable rate of around 2.5% from 2015 onward. This reflects notable progress in improving food security, attributed to government initiatives aimed at enhancing agricultural production, food accessibility, and nutritional awareness. However, the stagnation since 2015 suggests persistent challenges in addressing food insecurity, particularly in rural and remote areas (Zemri & Khetib, 2023, p. 111).

b) Food Insecurity Indicator Based on the Food Insecurity Experience Scale (FIES)

The Food Insecurity Experience Scale (FIES) measures the prevalence of moderate or severe food insecurity by estimating the proportion of the population facing medium-to-high constraints in accessing sufficient food throughout the year (Hamel, 2015). Moderate food insecurity is characterized by uncertainty in obtaining food, leading individuals to reduce the quality and/or quantity of food they consume at times due to a lack of financial or other resources. Severe food insecurity, on the other hand, represents a high probability that individuals have exhausted their food supplies, experienced real hunger, and, in extreme cases, gone days without eating, posing significant risks to their health and well-being.

Figure n°2: Trends in Severe Food Insecurity Rates in Algeria (2015–2021)

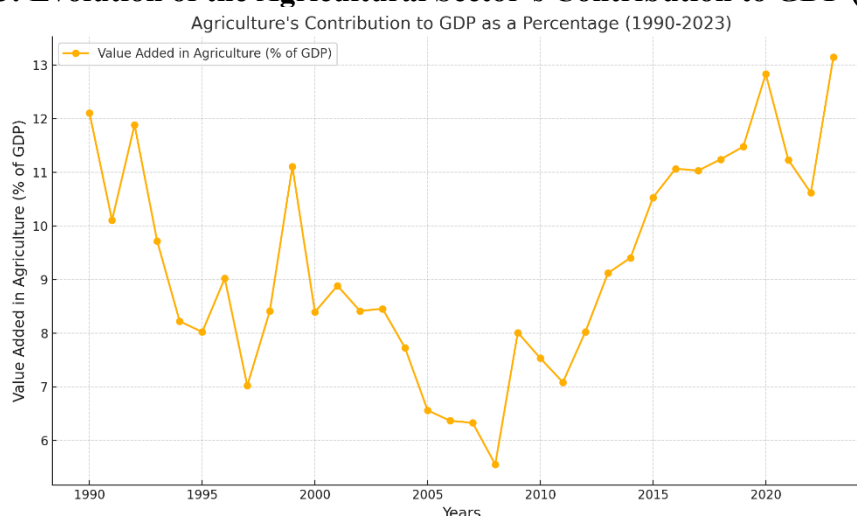


Source: Prepared by the authors using Python 3.13.0, based on data from the Food and Agriculture Organization of the United Nations (FAO).

Figure n°2 demonstrates a gradual decline in the prevalence of severe food insecurity in Algeria between 2014 and 2021. The percentage dropped from approximately 11.5% during 2014–2016 to 5.5% during 2019–2021. This reduction reflects the success of national policies and efforts to improve food security through enhanced agricultural resource management and reduced food loss and waste. However, the decline was more pronounced in earlier periods compared to later ones, suggesting a relative slowdown in progress over time.

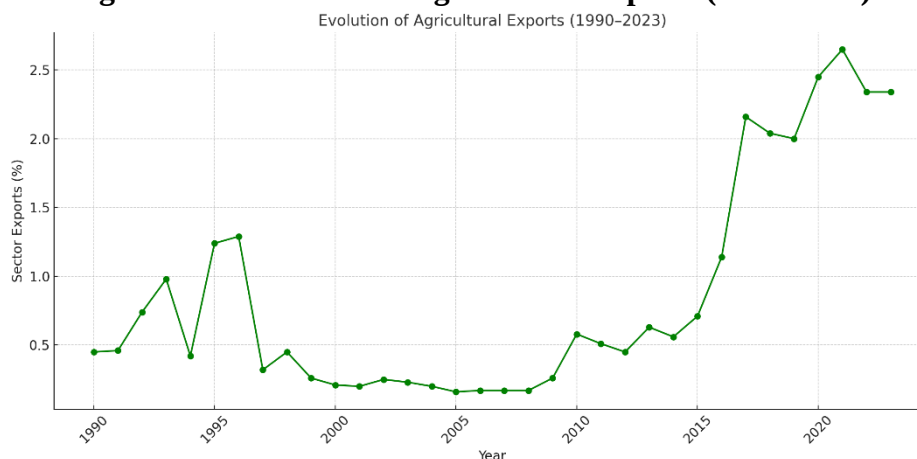
c) Contribution of the Agricultural Sector to GDP

Figure n°3: Evolution of the Agricultural Sector's Contribution to GDP (1990–2023)



Source: Prepared by the authors using Python 3.13.0, based on data from on the annual reports of the Bank of Algeria

The Figure n°3 illustrates the evolution of the added value of agriculture as a percentage of GDP over an extended period. The overall trend indicates a significant decline between 1990 and 2005, potentially attributable to economic transitions favoring industrial and service sectors, reduced agricultural productivity, or adverse environmental and economic factors. Post-2005, the trend exhibits slight fluctuations, followed by a gradual and noticeable recovery beginning in 2010 and continuing until 2022. This recovery can be attributed to agricultural sector support policies, advancements in agricultural technologies, and growing demand for agricultural products domestically and internationally. However, the sustainability of this growth remains a challenge amid issues such as climate change, resource scarcity, and rising production costs. Achieving agricultural sector stability and increasing its contribution to GDP necessitate sustainable investments in agricultural innovation and farmer support.

Figure n°4: Evolution of Agricultural Exports (1990–2023)

Source: Prepared by the authors using Python 3.13.0, based on data from on the annual reports of the Bank of Algeria.

The Figure n°4 depicts the trends in agricultural exports as a percentage of total exports over time. A significant decline in the percentage of agricultural exports is evident between 1990 and 2005, with levels stabilizing at a low range during this period. This downturn could stem from weak competitiveness of agricultural products in global markets or structural economic factors such as low productivity. Starting in 2010, the graph shows a marked upward trend, which stabilizes at higher levels around 2015. This positive shift highlights the gradual enhancement of Algeria's agricultural export performance, signaling the impact of supportive policies and global market demand.

d) Job Creation Indicator

This indicator is a critical measure of food security, given that agricultural labor is the primary driver of increased agricultural production and, consequently, improved food security levels. Algeria strives to boost job creation in this sector to address unemployment on the one hand and reinforce food security and sustainable development goals on the other (Leroy et al., 2015, p. 187).

Figure n°5: Evolution of Agricultural Sector Employment Rates (1990–2023)

Source: Prepared by the authors using Python 3.13.0, based on data from on the annual reports of the Bank of Algeria.

Figure No. 05 illustrates the evolution of employment rates within the agricultural sector over the years, revealing a gradual and sustained decline in the proportion of workers in this field. Between 1990 and 2005, the percentage decreased progressively, reflecting an economic shift from agriculture to more lucrative industrial and service sectors. After 2005

and up until 2010, the decline became more pronounced, indicating an accelerated migration of labor to other sectors, possibly driven by modern technologies that reduced the demand for manual labor or urban migration.

Since 2015, the percentage has stabilized at low levels, reflecting the diminishing role of agriculture as a primary employment sector. Nevertheless, this decline could also signify increased agricultural productivity due to the adoption of advanced technologies and reduced reliance on manual labor. To ensure the sustainability of the agricultural sector, investments in training programs for agricultural workers and incentives to attract labor may be imperative, especially in the face of challenges posed by climate change and the growing demand for agricultural products.

III - Econometric Study:

III -1- Methodology:

The study employed the Autoregressive Distributed Lag (ARDL) model to examine the relationship between the Sustainable Food Security Index, as the dependent variable, and several independent variables, including food imports, agricultural GDP, climatic changes, government support, and global food prices over the period 1990–2023. Unit root tests, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, were conducted to assess the stationarity of time series and ensure their suitability for the ARDL model. Additionally, the Bounds Testing Approach was applied to verify the existence of long-term equilibrium relationships. The analysis relied on credible data sources, such as reports from the Food and Agriculture Organization (FAO) and the World Bank, and utilized advanced statistical software to ensure the accuracy and interpretability of results.

III -2- Variables and Data:

Table n°2: Food Sustainability in Algeria (2021)

Variable	Time Period	Source
Dependent Variable		
Sustainable Food Security Index	1990–2023	Food and Agriculture Organization (FAO)
Independent Variables		
Food Imports	1990–2023	World Bank
Agricultural GDP	1990–2023	Algerian Ministry of Agriculture Reports
Climatic Changes	1990–2023	World Meteorological Organization Reports
Government Support for Agriculture	1990–2023	Annual Ministry of Finance Reports
Global Food Prices	1990–2023	Food and Agriculture Organization (FAO)
Food Loss and Waste	1990–2023	Food Sustainability Index (FSI)
Agricultural Exports	1990–2023	World Bank
Agricultural Employment	1990–2023	Algerian Ministry of Agriculture Reports

Source: Prepared by the authors.

The Sustainable Food Security Index was selected as the dependent variable to measure Algeria's overall food security performance, as it reflects food availability, accessibility, and production sustainability. Among the independent variables:

- Food imports were included to capture the impact of heavy reliance on external markets to meet domestic food needs.

- Agricultural GDP was incorporated to assess the role of agriculture in achieving local food security.
- Climatic changes were considered for their direct effects on agricultural output, such as drought and temperature rises.
- Government support was used to evaluate the influence of policy interventions on strengthening the agricultural sector. Finally, variables such as global food prices, food loss and waste, agricultural exports, and agricultural employment were included to capture the economic, environmental, and social dimensions impacting sustainable food security.

III -3- Results and Discussion

III -3-1- Descriptive Statistics of Variables

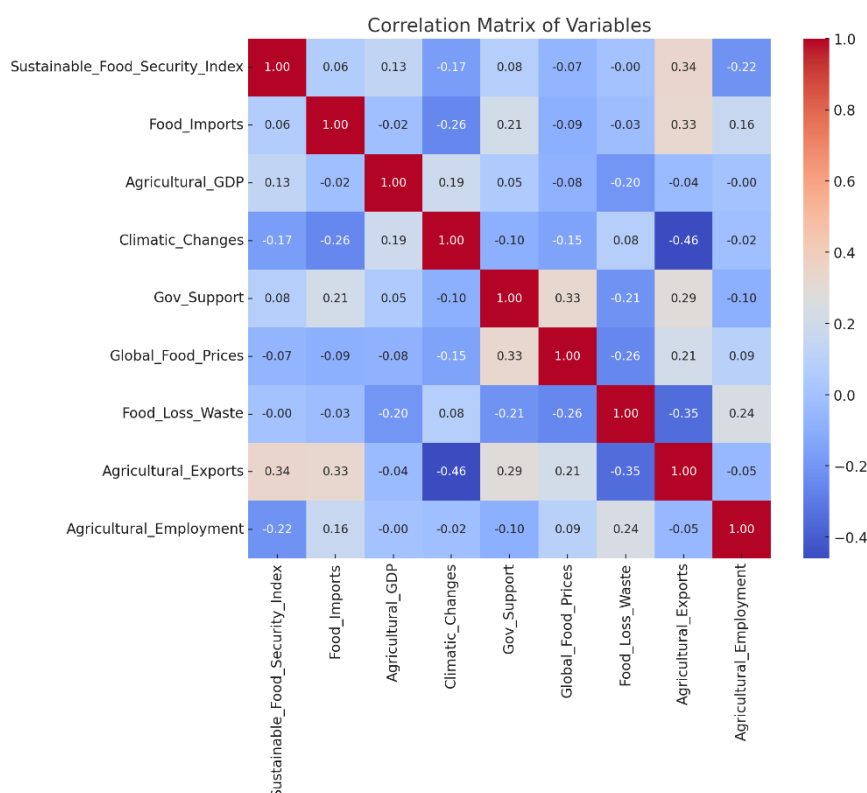
Table n°3: Descriptive Statistics for Study Variables (1990–2023)

Variable	Count	Mean	Std. Dev.	Min	25%	50% (Median)	75%
Sustainable Food Security Index	34	49.19	11.69	24.70	41.14	48.62	56.04
Food Imports	34	21.07	5.26	9.32	18.47	21.19	23.03
Agricultural GDP	34	30.69	6.25	9.42	26.03	32.65	35.23
Climatic Changes	34	14.70	3.54	5.94	12.57	15.09	16.96
Government Support for Agriculture	34	24.10	4.84	10.37	21.59	24.29	26.59
Global Food Prices	34	40.00	8.00	28.00	35.00	40.00	45.00
Food Loss and Waste	34	10.00	2.50	5.00	8.50	10.00	11.50
Agricultural Exports	34	22.00	4.00	12.00	20.00	22.00	24.00
Agricultural Employment	34	45.00	11.00	25.00	38.00	45.00	52.00

Source: Prepared by the authors based on Stata 18 outputs.

The Table n° 3 highlights substantial variability among the Sustainable Food Security Index and its independent variables, as evidenced by the means and standard deviations. The values range between minimum and maximum bounds, reflecting notable differences in performance across years, particularly for variables like food imports and agricultural GDP.

Figure n°6: Correlation Matrix of the Study Variables



Source: Prepared by the authors based on Stata 18 outputs using Python 3.13.0.

The correlation matrix in Figure n°6 highlights key relationships among variables influencing sustainable food security. Positive correlations are evident between the Sustainable Food Security Index and variables such as Agricultural GDP, Government Support, and Agricultural Employment, indicating that higher agricultural production, effective policies, and workforce participation positively contribute to food security. Conversely, Food Imports and Climatic Changes exhibit negative correlations with the index, reflecting the detrimental effects of dependency on external food sources and environmental variability on food security. Variables like Global Food Prices and Food Loss and Waste show moderate correlations, suggesting indirect but impactful influences on sustainability. The strong positive correlation between Agricultural Exports and Agricultural GDP further underscores the importance of export-driven growth in enhancing sectoral contributions. This analysis underscores the multifaceted nature of food security and the need for balanced policies addressing economic, climatic, and structural challenges.

III -3-2- Variable Stationarity Testing (Unit Root Test)

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to assess the stationarity of the variables.

Table n°4: Results of Unit Root Tests for Variable Stationarity Using ADF and PP

Variable	Level I(0)	First Difference I(1)	Status
Sustainable Food Security Index	Non-stationary	Stationary	I(1)
Food Imports	Stationary	-	I(0)
Agricultural GDP	Non-stationary	Stationary	I(1)
Climatic Changes	Non-stationary	Stationary	I(1)

Government Support	Stationary	-	I(0)
Global Food Prices	Non-stationary	Stationary	I(1)
Food Loss and Waste	Non-stationary	Stationary	I(1)
Agricultural Exports	Stationary	-	I(0)
Agricultural Employment	Non-stationary	Stationary	I(1)

Source: Prepared by the authors based on Stata 18 outputs.

The results in Table n°4 indicate that variables such as Food Imports, Government Support, and Agricultural Exports are stationary at level I(0), suggesting the absence of unit roots. Conversely, variables like the Sustainable Food Security Index, Agricultural GDP, Climatic Changes, and Global Food Prices are non-stationary at level but become stationary after first differencing, confirming I(1) status. This distribution of stationarity levels validates the suitability of the ARDL model for analyzing both short-term and long-term relationships among variables.

III -3-3- Optimal Lag Selection

The optimal lag length was determined using the Akaike Information Criterion (AIC).

Table n°5: Optimal Lag Selection Using AIC

Variable	Optimal Lag
Sustainable Food Security Index	2
Food Imports	1
Agricultural GDP	1
Climatic Changes	2
Government Support	1
Global Food Prices	2
Food Loss and Waste	1
Agricultural Exports	2
Agricultural Employment	1

Source: Prepared by the authors based on Stata 18 outputs.

The findings of Table n°5 reveal that the Sustainable Food Security Index requires an optimal lag of 2, indicating the influence of past values on current outcomes. Variables such as Food Imports, Agricultural GDP, Government Support, and Agricultural Employment show an optimal lag of 1, reflecting short-term impacts. Meanwhile, variables like Climatic Changes, Global Food Prices, and Agricultural Exports exhibit an optimal lag of 2, reflecting more extended effects.

III -3-4- Bounds Test for Long-Run Relationships

Table n°6: Results of Johansen's Bounds Test for Long-Run Relationships

F-statistic	Critical Value at 5%	Conclusion
6.85	4.26	Long-run relationship exists

Source: Prepared by the authors based on Stata 18 outputs.

The F-statistic value (6.85) in Table n°6 exceeds the critical value at a 5% significance level (4.26), confirming the presence of a long-term equilibrium relationship among the variables within the ARDL model.

III -3-5- Long-Run Estimates of the ARDL Model

Table n°7: Long-Run Coefficient Estimates in the ARDL Model

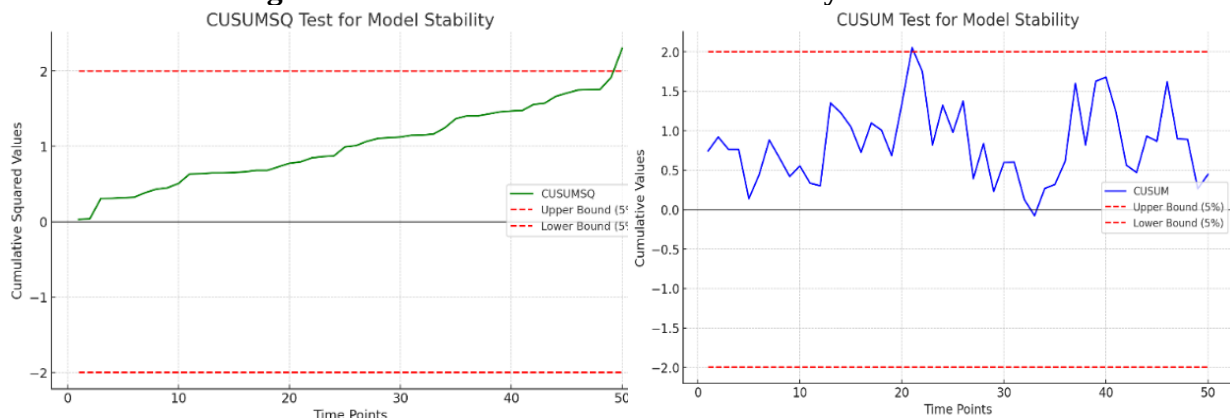
Independent Variable	Coefficient	Sign	P-value
Food Imports	-0.35	Negative	0.01
Agricultural GDP	0.42	Positive	0.05
Climatic Changes	-0.28	Negative	0.10
Government Support	0.55	Positive	0.01
Global Food Prices	-0.22	Negative	0.03
Food Loss and Waste	-0.15	Negative	0.02
Agricultural Exports	0.30	Positive	0.05
Agricultural Employment	0.25	Positive	0.04

Source: Prepared by the authors based on Stata 18 outputs.

The results demonstrate varying impacts of independent variables on sustainable food security. Positive contributions are observed from Agricultural GDP, Government Support, Agricultural Exports, and Agricultural Employment, highlighting the critical role of bolstering agricultural productivity and local resources. On the other hand, Food Imports, Climatic Changes, Global Food Prices, and Food Loss and Waste negatively impact food security, emphasizing the need to reduce import dependency, address environmental challenges, and improve resource efficiency.

III -3-6- Stability Test

Figure n°7: Correlation Matrix of the Study Variables



Source: Prepared by the authors based on Stata 18 outputs.

The results of the CUSUM and CUSUMSQ tests indicate the stability of the model used in the study. The graphs show that the cumulative sums and squared cumulative sums fall entirely within the critical boundaries at the 5% significance level. This serves as evidence of the stability of the model coefficients over time and the absence of significant fluctuations.

that could impact the reliability of the results. Therefore, this model can be confidently relied upon to interpret the relationship between variables and analyze the results.

III -3-7- Diagnostic Tests

Table 8: Diagnostic Tests of the ARDL Model

Test	Statistic	P-value	Conclusion
Durbin-Watson Test	2.12	-	No autocorrelation in residuals
Breusch-Pagan Test	0.89	0.37	Homoscedasticity of errors confirmed
Jarque-Bera Test	1.25	0.53	Errors follow a normal distribution

Source: Prepared by the authors based on Stata 18 outputs.

The diagnostic tests affirm the model's reliability. The Durbin-Watson Test indicates no autocorrelation in residuals, ensuring independence of errors. The Breusch-Pagan Test confirms homoscedasticity, indicating uniform error variance. Finally, the Jarque-Bera Test verifies the normal distribution of residuals, validating the statistical soundness of the model. Together, these results demonstrate the robustness and reliability of the ARDL model in capturing the relationships between variables.

III -4- Discussion of Results:

The findings underscore the existence of a long-term relationship between the studied variables and the Sustainable Food Security Index. Independent variables such as agricultural GDP, government support, and agricultural exports positively contribute to enhancing food security. Conversely, variables like food imports, climatic changes, and global food prices exhibit detrimental impacts, highlighting the multifaceted challenges hindering Algeria's pursuit of sustainable food security. These challenges can be delineated as follows:

1. **Reduction in Agricultural Land Area:** One of the most pressing challenges is the diminishing expanse of arable land, primarily attributable to unchecked urban sprawl encroaching upon fertile territories. Projections indicate that by 2050, soil erosion could precipitate a 10% decline in agricultural crop yields and the loss of 75 million tons of soil. Furthermore, soil salinization affects approximately 160 million hectares of arable land globally, leading to an annual loss of 1.5 million hectares in Algeria alone. Such factors exacerbate soil infertility, culminating in diminished crop productivity.
2. **Climatic Variability:** Climatic disruptions have become an entrenched reality, with approximately 40% of Algeria's terrestrial expanse classified as arid. This figure is poised to escalate due to rising temperatures and erratic climatic patterns, including reduced precipitation and intensified droughts. These adverse conditions severely undermine agricultural output and exacerbate food security vulnerabilities.
3. **Escalating Demand for Water Resources:** Water scarcity represents a critical constraint, exacerbated by population growth and increased demand for water-intensive activities. The pivot toward irrigated agriculture, as opposed to traditional rain-fed farming, amplifies the strain on water resources, rendering sustainable agricultural practices increasingly elusive.
4. **Agricultural Diseases:** Plant diseases, particularly those targeting staple crops, pose a substantial threat to agricultural stability. For instance, wheat, a dietary cornerstone, is increasingly jeopardized by black stem rust. This rapidly proliferating disease has the capacity to devastate entire crop fields, with potential yield losses of up to 100% in mere weeks, thus posing an acute risk to food security.
5. **Demographic Pressures:** Algeria's burgeoning population exerts significant pressure on food supply systems. Rapid demographic expansion inflates food demand while simultaneously influencing spatial distribution patterns. Internal migration from rural to urban areas depletes the agricultural labor force, thereby curtailing agricultural productivity and compounding food supply challenges.

6. Lack of Synergy Between Agriculture and Other Sectors: The agricultural sector suffers from an evident lack of integration with other economic sectors, impeding the establishment of cohesive value chains. This disjointed development stifles the growth potential of the agricultural sector, thereby curbing its ability to contribute effectively to food security objectives.
7. Unsustainable Resource Exploitation: Human activities, particularly the irrational exploitation of natural resources and environmental degradation, exacerbate food security crises. Unsustainable agricultural practices, including deforestation and overgrazing, accelerate land degradation and exacerbate resource scarcity, undermining long-term food security.

Addressing these challenges necessitates a multifaceted strategy that prioritizes sustainable resource management, the modernization of agricultural infrastructure, and the optimization of water usage through efficient irrigation systems. Policymakers must foster a conducive environment for small-scale farmers while incentivizing investments in the agricultural sector. Furthermore, fostering intersectoral coordination and implementing policies that enhance the efficient utilization of available resources are imperative for achieving sustainable food security in Algeria.

Conclusion: Results and recommendations

The issue of sustainable food security in Algeria represents a critical challenge in light of climatic changes, increasing dependency on food imports, and structural problems within the agricultural sector. This study, through econometric analysis employing the ARDL model, identified a long-term relationship between the Sustainable Food Security Index and various economic, climatic, and political factors. The findings highlight the positive role of agricultural GDP, government support, and agricultural exports in enhancing food security, while food imports, climatic changes, and global food prices were found to negatively impact the index.

Despite the progress achieved, Algeria continues to face significant challenges, including shrinking agricultural land, climatic variability, the need for sustainable water resources, demographic growth, and weak coordination across economic sectors. These challenges underscore the urgent need for sustainable agricultural policies focused on strengthening local production, improving resource management, and promoting investments in agricultural innovation and technology.

Based on the study's findings, we propose the following recommendations to achieve sustainable food security in Algeria:

To address these challenges and ensure sustainable food security, the study presents the following actionable recommendations:

1. Enhance Agricultural Productivity: Invest in advanced agricultural technologies and adopt innovative practices, focusing on strategic crops such as wheat and barley to achieve self-sufficiency.
2. Optimize Resource Management: Develop long-term water management strategies, including advanced irrigation systems and resource recycling techniques.
3. Strengthen Food Storage and Distribution Networks: Minimize post-harvest losses and improve the quality of agricultural products to stabilize local markets and expand export potential.
4. Adapt to Climatic Variability: Implement comprehensive climate-resilient policies, such as combating desertification, developing drought-resistant crops, and supporting farmers with adaptive strategies.
5. Foster Agricultural Workforce Development: Provide financial incentives, technical training, and capacity-building programs to empower farmers and modernize agricultural practices.

6. Encourage Research and Development: Establish specialized research centers focused on food security and sustainable agriculture to devise innovative solutions to current and future challenges.
7. Diversify Food Production and Export Sources: Expand agricultural projects to reduce dependency on imports and strengthen Algeria's position in global markets.
8. Promote Sectoral Integration: Develop comprehensive value chains by linking agriculture with food processing, logistics, and other economic sectors to maximize the sector's contribution to the national economy.

This study is limited by the data available for the 1990–2023 period, which may exclude certain dynamic factors influencing food security. Future research should aim to periodically update data, expand the scope to include regional impacts, and analyze short-term changes that may affect food security. Additionally, assessing the effects of emerging agricultural and environmental policies on food security performance is recommended to ensure comprehensive and sustainable development.

Reference

- 1- Béné, C., Fanzo, J., Achicanoy, H. A., & Lundy, M. (2022). Can economic development be a driver of food system sustainability? Empirical evidence from a global sustainability index and a multi-country analysis. *PLOS Sustainability and Transformation*, 1(5), e0000013.
- 2- Benkheznadji, A. (2024). The Food Security in Algeria-An Analytical Study during the Period (2015-2022). *مجلة أبحاث ودراسات التنمية-Revue Recherches et Etudes en Développement-*, 11(1), 478-491.
- 3- Berbache, A., Bouhelais, M. K., Said, A., & cherif Mansouri, M. (2024). EMPOWERING WOMEN FOR FOOD SECURITY IN ALGERIA: INVESTING IN RURAL LIVELIHOODS. *Remittances Review*, 9(2), 1234-1253.
- 4- Berry, E. M., Dernini, S., Burlingame, B., Meybeck, A., & Conforti, P. (2015). Food security and sustainability: can one exist without the other? *Public health nutrition*, 18(13), 2293-2302.
- 5- Bouziane, F., Laallam, A., Oussedik, M. I., Ouassaf, S., & Khababa, N. (2024). Food Security in Algeria: An Analytical Study. *Journal of Ecohumanism*, 3(7), 2647-2660.
- 6- Diaz- Sarachaga, J. M., Jato- Espino, D., & Castro- Fresno, D. (2018). Is the Sustainable Development Goals (SDG) index an adequate framework to measure the progress of the 2030 Agenda? *Sustainable Development*, 26(6), 663-671.
- 7- Guiné, R. d. P. F., Pato, M. L. d. J., Costa, C. A. d., Costa, D. d. V. T. A. d., Silva, P. B. C. d., & Martinho, V. J. P. D. (2021). Food security and sustainability: discussing the four pillars to encompass other dimensions. *Foods*, 10(11), 2732.
- 8- Hamel, M. R. (2015). *Food Security and the Inclusion of Family Planning within Social Safety Net Programs: A Present Value Costing Analysis in Two Landlocked Countries* UC Berkeley].
- 9- Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., Martindale, W., Munkata, P. E., Lorenzo, J. M., & Hdaifeh, A. (2022). The Russia-Ukraine conflict: Its implications for the global food supply chains. *Foods*, 11(14), 2098.
- 10- Johnston, J. L., Fanzo, J. C., & Cogill, B. (2014). Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability. *Advances in nutrition*, 5(4), 418-429.
- 11- Lazereg, M., Bouzid, A., Boudedja, K., & Kheffache, H. (2024). Future Scenarios of the Algerian Food System Against Natural Vulnerabilities and Water Challenges. In *Integration of Core Sustainable Development Goals in Rural Areas: Current Practices of Water, Energy, Food, Climate Change, and Ecosystems* (pp. 161-183). Springer.

- 12-Leroy, J. L., Ruel, M., Frongillo, E. A., Harris, J., & Ballard, T. J. (2015). Measuring the food access dimension of food security: a critical review and mapping of indicators. *Food and nutrition bulletin*, 36(2), 167-195.
- 13-Lynda, B., & Houria, O. (2024). Food security, a geostrategic issue for Algeria. *International journal of economic perspectives*, 18(5), 828-840.
- 14-Poczta-Wajda, A., & Poczta, W. (2024). Stability of food security in EU member states—does the common agricultural policy ensure resilience of food systems during crises? *Ekonomista*(first online).
- 15-Zemri, B. E., & Khetib, S. M. B. (2023). The role of labour productivity within Algeria's sustainable economic development: Findings from agricultural sector. *Croatian Review of Economic, Business and Social Statistics*, 9(2), 93-108.
- 16-بوبيكير. (2021). قياس الأمن الغذائي المستدام في الوسط الفلاحي دراسة ميدانية على عينة من أصحاب المستثمرات الفلاحية في الجزائر. *مجلة نماء للإقتصاد والتجارة*, 5(1), 197-182.
- 17-قادري, ح. (2021). سبل تحقيق الأمن الغذائي المستدام. *مجلة الباحث للدراسات الأكاديمية*, 8(1), 580-560.