

Food Security in Algeria: Reality and Challenges A Predictive Prospective Study of Cereal Production

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Abstract

This research aims to study the future trends of cereal production and the self-sufficiency rate in cereals in Algeria, by analyzing the dynamic relationship between four key indicators: the cereal self-sufficiency rate, cereal production, cultivated area, and average rainfall. To achieve this objective, the study relies on annual data covering the period from 1990 to 2021, applying a second-order Vector Autoregression model, VAR(2), to forecast the evolution of these indicators over the future period. The estimation process was preceded by a series of statistical and econometric tests, including the Phillips-Perron stationarity test, selection of the optimal lag length, model stability testing, normality tests for the model residuals, and tests for autocorrelation and homoscedasticity of errors. The results showed that the four variables become stationary after first differencing, and that the second lag is the most suitable for the model; diagnostic tests confirmed the model's stability and its validity for forecasting. The forecasting results point to fluctuations in cultivated area, cereal production, and rainfall levels, alongside a clear downward trend in the cereal self-sufficiency rate, which is projected to reach around 13.92% by 2031. These findings highlight the need to adopt sustainable agricultural policies, strengthen investment in irrigation technologies and water resource management, and raise agricultural productivity, in order to help narrow the gap between domestic production and demand and strengthen food security in Algeria.

Keywords: cereal production; food security; self-sufficiency; Algeria.

1. Introduction

Food security represents one of the most important challenges facing contemporary economies, particularly in countries that rely heavily on imports to meet their food needs. The issue of food security takes on even greater importance for countries experiencing rapid population growth while simultaneously facing limited natural resources and increasing climate variability. In this context, cereals occupy a strategic position within the food security system, being among the most important agricultural products directly linked to food supply and the fulfilment of a significant share of domestic demand.

Algeria is among the countries in which cereals hold considerable economic and food importance; however, domestic production is affected by a set of natural and economic factors, foremost among them the availability of agricultural land and the areas allocated to cereal cultivation, productivity levels, as well as climatic conditions, particularly rainfall rates.

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Consequently, the development of cereal production is not tied to a single factor but is rather the outcome of the interaction of a set of variables that are themselves subject to fluctuation over time. The climatic factor stands out as one of the important determinants of agricultural production, especially given that part of cereal farming is linked to rainfall levels. The applied study confirms that fluctuations in rainfall rates are associated with variations in production and cultivated areas, which calls for the search for more sustainable alternatives and mechanisms for water management and for mitigating the effects of climatic fluctuations.

On the other hand, an increase in domestic production does not necessarily imply an improvement in the self-sufficiency level, since the latter is also determined by the evolution of demand and consumption. Studying the cereal self-sufficiency rate is therefore an important entry point for assessing the capacity of domestic production to keep pace with food needs. In this respect, prospective studies acquire particular importance, as they do not merely explain the historical trajectory of a phenomenon but also seek to identify its future directions, thereby providing information that can support planning and the formulation of agricultural policies. Among the econometric methods used for this purpose is the Vector Autoregression (VAR) model, which allows the study of the dynamic interactions among a set of time-series variables and the forecasting of their future values.

Building on these considerations, the present study relies on four key indicators: the cereal self-sufficiency rate (GS), average rainfall (PR), cereal production (GP), and the area cultivated for cereal production (GA), using annual data for the period 1990–2021.

Research Problem

The research problem is centred on the following main question: To what extent can cereal production, cultivated areas, and rainfall conditions explain the future trends of the cereal self-sufficiency rate in Algeria, and what are the expected trajectories of these indicators over the period 2025–2031?

This problem gives rise to a number of sub-questions:

- Do the time series of the study variables possess the stationarity required for econometric estimation?
- What are the expected future trends of cereal production, cultivated areas, the self-sufficiency rate, and rainfall over the period 2025–2031?
- To what extent can projected domestic production narrow the cereal gap and improve food security in Algeria?

Research Hypotheses

The research proceeds from the following main hypothesis: Changes in cereal production, cultivated areas, and rainfall affect the future trajectory of the cereal self-sufficiency rate in Algeria, and this rate is expected to follow a downward trend in the future. The following sub-hypotheses derive from it:

- First hypothesis: A dynamic relationship exists between the cereal self-sufficiency rate, cereal production, cultivated area, and rainfall rates.
- Second hypothesis: Changes in cultivated area affect cereal production levels.
- Fourth hypothesis: Econometric forecasts point to a continued decline in the cereal self-sufficiency rate in Algeria over the future period.

Significance of the Research

The significance of this research stems from the strategic importance of the cereal sector in achieving food security, and from the need to anticipate its future trends given the changes affecting cultivated areas, production, and climatic conditions. The scientific significance of the study lies in applying a dynamic econometric model – the VAR model – to analyze a set of interrelated variables and forecast their future values. Its practical significance lies in providing future estimates that can help assess the capacity of cereal production to respond to domestic demand, thereby offering

indicators that assist policymakers in designing more effective agricultural policies. The findings gain additional significance given that the forecasts point to a decline in the cereal self-sufficiency rate, reflecting a probable widening of the gap between domestic production and demand in the future.

Research Objectives

The research seeks to achieve a set of objectives, most notably:

- Analyzing the evolution of cereal production in Algeria over the period 1990–2021.
- Analyzing the evolution of the cereal self-sufficiency rate.
- Highlighting the relationship between climatic variables – particularly rainfall – and cereal production.
- Forecasting the evolution of cereal production, cultivated areas, the self-sufficiency rate, and rainfall up to 2031.

Research Methodology

The study relies on annual data spanning from 1990 to 2021, with the aim of building a forecasting model for four indicators related to cereal production in Algeria. The data were obtained from the database of the Arab Organization for Agricultural Development, published on its official website. EViews 13 software was used for data processing and model estimation.

2. Theoretical Framework

1. The Concept of Food Security

Food security is a concept that aims to ensure a comprehensive and sustainable supply of food for all segments of society at all times. This concept concerns guaranteeing sufficient quantities of balanced and nutritious food for individuals, enabling them to maintain their health and food safety. Food security encompasses multiple dimensions, including the provision of adequate quantities of food, physical and economic access to food, and the availability of a diverse range of food products that meet healthy nutritional needs. The concept also emphasizes food quality and seeks to sustain food production without adverse environmental impact. Food security emerges as a response to the challenges associated with population growth, climate change, and environmental degradation, as ensuring food availability for all is considered essential for preserving human health and the stability of societies.

2. The Main Pillars of Food Security

In order to achieve the objectives of food security comprehensively, all four of the following dimensions must be realized together:

2.1. Physical Availability of Food

The concept of physical food availability relates to the supply side of food security, determined based on food production levels, food stocks, and net trade.

2.2. Physical and Economic Access to Food

The importance of physical and economic access to food becomes apparent when an adequate supply of food exists at the national or state level; this alone does not guarantee food security at the household level. For this reason, food policies have focused on financial, spending, market, and price-related dimensions in order to achieve food security objectives.

2.3. Food Utilization

Regarding the utilization of food, this is understood as the manner in which the body uses the various nutrients present in food; it is affected by factors such as adequate care, dietary practices, food preparation methods, dietary diversity, and food distribution within the household.

2.4. Stability and Sustainability

It is crucial that the stability of the other three dimensions be maintained over time; even if a person consumes a sufficient quantity of food today, they may still be exposed to food insecurity if they lack the ability to access food regularly and sustainably, since climatic, economic, and political factors can all affect the state of food security.

3. The Importance of Food Security

The importance of food security is reflected in a range of aspects affecting individuals and societies comprehensively, including the following points:

- It achieves and supports national independence and social peace by giving strength to political decisions.
- It enables governments to confront both economic and political fluctuations, whether external or internal, through the safest and most optimal means.
- It is exploited by some major world powers, particularly producers of strategic agricultural crops such as cereals, as a tool of political pressure against developing countries, especially those that are non-producing or low-producing, in order to achieve their objectives.
- Achieving food security enables peoples to withstand natural and climatic changes such as drought, rising temperatures, erratic rainfall, and forest fires.
- It contributes to economic integration and interdependence among economic powers and their effectiveness.

4. Economic Forecasting and Its Importance in the Agricultural Sector

Forecasting is an important tool for supporting economic planning, as it allows the estimation of the likely future trends of variables based on available historical information. In the agricultural field, the importance of forecasting increases due to the volatile nature of agricultural production and its sensitivity to climatic and economic factors. Forecasting production, cultivated areas, and the self-sufficiency rate can therefore help in the preparation of more proactive policies.

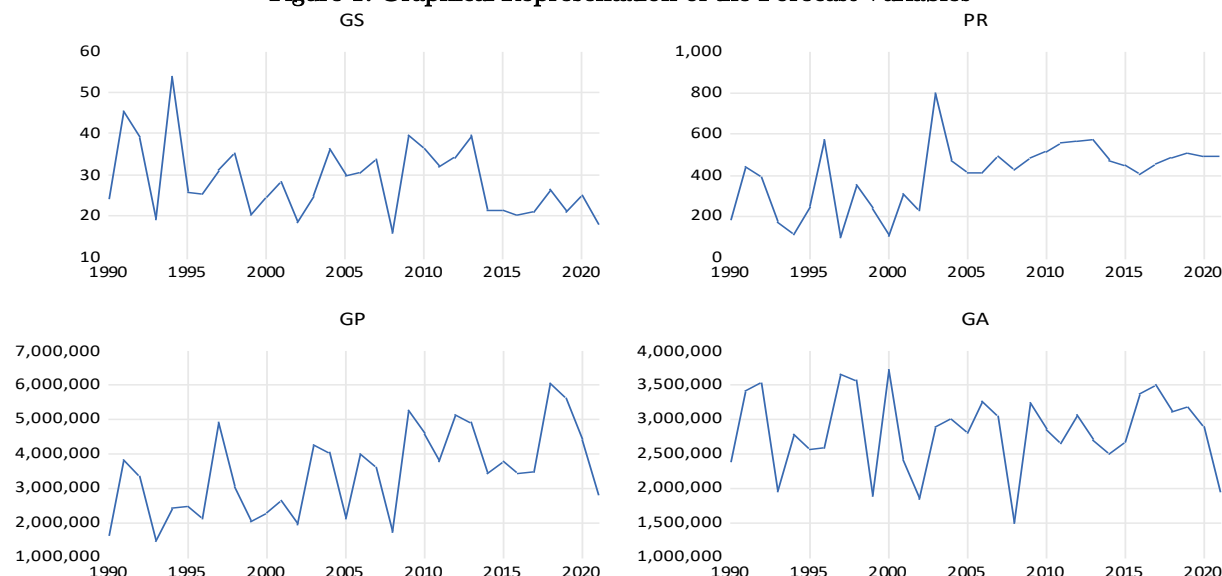
3. Applied Framework

Section One: Presentation of the Study Variables

1. Presentation of the Model and Study Variables

A VAR (Vector Autoregression) model is adopted to forecast four indicators contributing to cereal production in Algeria for ten years beyond the sample, up to 2031, based on the period extending from 1990 to 2021. The data were obtained from the database of the Arab Organization for Agricultural Development, published on its official website. The variables reflect four indicators contributing to cereal production, detailed as follows:

- Cereal self-sufficiency rate (GS), measured in percentage.
- Average annual rainfall (PR), measured in millimetres.
- Cereal production (GP), measured in tonnes.
- Area cultivated for cereal production (GA), measured in hectares.

Figure 1: Graphical Representation of the Forecast Variables

Source: Prepared by the researcher using EViews 13.

2. Stationarity Tests

The analysis of the stationarity of the time series under study constitutes a preliminary and fundamental stage for understanding the nature of the changes occurring in their values across different time periods, and for determining how to treat the components of the variables with a view to identifying the appropriate forecasting model. Three well-known tests exist for this purpose: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. This study relies on the Phillips-Perron (PP) test, considered one of the most robust tests, applied to the four forecast variables across three statistical specifications: intercept and trend, intercept only, and none. The results were as follows:

Table 1: Unit Root Tests for the Forecast Variables

Variable	Model	At Level	After First Difference	Decision
GS	Intercept & trend	0.0001	0.0001	I(1)
//	Intercept only	0.0001	0.0001	//
//	None	0.3230	0.0001	//
PR	Intercept & trend	0.0012	0.0001	I(1)
//	Intercept only	0.0033	0.0001	//
//	None	0.4695	0.0001	//
GP	Intercept & trend	0.0003	0.0001	I(1)
//	Intercept only	0.0019	0.0001	//
//	None	0.4188	0.0001	//
GA	Intercept & trend	0.0001	0.0001	I(1)
//	Intercept only	0.0000	0.0001	//

//	None	0.4418	0.0001	//
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Source: Prepared by the researcher using EViews 13 and Appendices 1–6.

It is observed that none of the four variables is stationary at its original level, but all become stationary after first differencing across the three statistical specifications; they are therefore integrated of order one, I(1).

Section Two: Estimation of the VAR Model

1. Determining the Lag Length and Testing Model Stability

Before estimating the VAR model equations, the appropriate lag order must be determined. The lag order p is selected based on information criteria such as AIC, BIC, and HQ, among others, choosing the value of p that minimizes these criteria. The table below shows the test results.

Table 2: Selection of the Appropriate Lag Order for the VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1139.925	NA	3.60e+30	81.70895	81.89927	81.76714
1	-1112.409	45.20510	1.60e+30	80.88637	81.83795*	81.17728
2	-1088.336	32.67053*	9.75e+29*	80.30973	82.02256	80.83336*
3	-1071.091	18.47679	1.10e+30	80.22080*	82.69489	80.97715

Source: Prepared by the researcher using EViews 13.

According to the information criteria, most indicators reach their minimum value at the second lag; the estimated model therefore takes the VAR(2) specification.

2. Estimation of the VAR(2) Model

After determining the optimal lag order for the forecasting model, which led to adopting lag order 2 as the appropriate lag with which to provide the optimal model enabling estimation and forecasting of the system composed of four variables, each variable in this system is explained by its own lagged values over two periods, in addition to the constant term and the first and second lags of the other variables. In this case, the ordinary least squares method can be used to estimate the VAR(2) model; the estimation results were as follows:

Table 3: VAR(2) Model Estimation Results

D(GA)	D(GP)	D(PR)	D(GS)	
-20094.84	-33877.55	-0.023064	-1.066621	D(GS(-1))
(16017.7)	(31869.3)	(3.59291)	(0.22940)	
[-1.25454]	[-1.06301]	[-0.00642]	[-4.64965]	
-6990.220	-16607.87	9.464015	-0.631812	D(GS(-2))
(16730.3)	(33287.0)	(3.75274)	(0.23960)	
[-0.41782]	[-0.49893]	[2.52189]	[-2.63692]	

440.1838 (818.058) [0.53808]	1926.789 (1627.63) [1.18380]	-0.522002 (0.18350) [-2.84474]	-0.010194 (0.01172) [-0.87009]	D(PR(-1))
1306.182 (822.257) [1.58853]	411.5870 (1635.99) [0.25158]	-0.308379 (0.18444) [-1.67198]	-0.002730 (0.01178) [-0.23185]	D(PR(-2))
0.038323 (0.14308) [0.26784]	-0.372674 (0.28468) [-1.30910]	4.29E-05 (3.2E-05) [1.33622]	2.90E-06 (2.0E-06) [1.41566]	D(GP(-1))
-0.181243 (0.14510) [-1.24910]	-0.337266 (0.28869) [-1.16825]	1.15E-05 (3.3E-05) [0.35364]	7.29E-07 (2.1E-06) [0.35096]	D(GP(-2))
-0.561569 (0.22911) [-2.45104]	-0.198717 (0.45585) [-0.43592]	-3.62E-05 (5.1E-05) [-0.70532]	-1.04E-06 (3.3E-06) [-0.31797]	D(GA(-1))
-0.318079 (0.22116) [-1.43821]	-0.442327 (0.44003) [-1.00522]	-0.000142 (5.0E-05) [-2.86127]	-5.20E-07 (3.2E-06) [-0.16406]	D(GA(-2))
-61950.51 (119208.) [-0.51968]	10594.23 (237180.) [0.04467]	9.855541 (26.7394) [0.36858]	-1.678534 (1.70724) [-0.98319]	C
0.640510	0.507178	0.605768	0.636170	R-squared
0.496714	0.310049	0.448075	0.490638	Adj. R-squared
7.84E+12	3.10E+13	394422.4	1607.855	Sum sq. resids
626065.4	1245638.	140.4319	8.966201	S.E. equation
4.454300	2.572825	3.841436	4.371344	F-statistic

-422.8306	-442.7812	-179.1585	-99.37195	Log likelihood
29.78142	31.15732	12.97645	7.473927	Akaike AIC
30.20576	31.58165	13.40078	7.898260	Schwarz SC
-54773.10	-18779.31	3.708621	-0.739310	Mean dependent
882495.2	1499626.	189.0277	12.56306	S.D. dependent
	4.77E+29	Determinant resid covariance (dof adj.)		
	1.08E+29	Determinant resid covariance		
	-1133.927	Log likelihood		
	80.68463	Akaike information criterion		
	82.38197	Schwarz criterion		
	36	Number of coefficients		

Source: Prepared by the researcher using EViews 13.

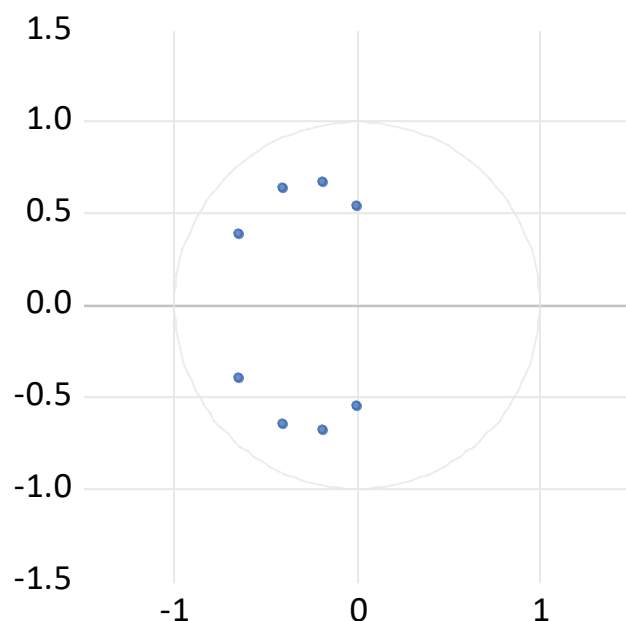
The diagnostic tests below verify the statistical and econometric validity of the model before it is used for forecasting.

3. VAR(2) Model Stability Test

The model stability test, illustrated in the figure below, shows that no roots of the characteristic polynomial lie outside the unit circle, since all root moduli are below one, as detailed in Appendix 7. The model is therefore stable.

Figure 2: VAR(2) Model Stability Test Results

Inverse Roots of AR Characteristic Polynomial



Source: Prepared by the researcher using EViews 13.

4. Normality Tests

The Jarque-Bera test determines whether the estimation residuals are normally distributed. Acceptance of the null hypothesis implies that the random errors are normally distributed, a necessary condition especially in small samples. Based on the test results shown in the table below and in Appendix 8, all four equations of the structural model show error distributions consistent with normality, since the probability values of the test statistic all exceed 5%. The estimates are therefore suitable for forecasting.

Table 4: Normality Tests for the VAR(2) Model Residuals

Equation	Jarque-Bera Statistic	Probability
GS	1.056178	0.5897
PR	3.884895	0.1434
GP	0.687563	0.7091
GA	0.388990	0.8233

Source: Prepared by the researcher using EViews 13.

5. Autocorrelation and Heteroskedasticity Tests

The absence of autocorrelation among the errors is one of the fundamental conditions that must be satisfied in models estimated by ordinary least squares within VAR models, since the efficiency of the estimators depends heavily on the fulfilment of this condition. To confirm that the model was estimated with statistical soundness, the hypothesis of no third-order autocorrelation in the errors of the whole structural model is tested using the LRE and RAO statistics.

The test results, shown in the table below, confirm the absence of third-order autocorrelation among the errors, given the probability values of the LRE and RAO test statistics of 0.338 and 0.348 respectively, which exceed the 5% significance level.

Table 5: Autocorrelation and Heteroskedasticity Test Results

Lag	LRE Statistic Probability	RAO Statistic Probability	White Chi-sq Probability
1	0.3734	0.3835	
2	0.1084	0.1149	0.6956
3	0.3382	0.3483	

Source: Prepared by the researcher using EViews 13 and Appendices 7–8.

From the same table, the White test results – which assess the presence of homoscedasticity or heteroskedasticity in the residuals of the VAR(2) model estimation – show that the error variance is homogeneous, given a Chi-square statistic probability value of 0.695, which exceeds the 5% significance level; there is therefore no heteroskedasticity problem among the estimation residuals.

Section Three: Evaluation of the Study Forecasts

1. Forecast Evaluation Indicators

The forecast quality is evaluated using four indicators: the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE), the Mean Absolute Percentage Error (MAPE), and the Theil inequality coefficient. The best forecasts are those achieving the lowest values on these indicators; the results obtained are presented in the following table:

Table 6: Forecast Evaluation Indicators

Variable	Inc. Obs.	RMSE	MAE	MAPE	Theil
GA	31	519,919.0	405,423.7	16.53391	0.091381
GP	31	1,034,446	794,199.1	24.05973	0.140254
GS	31	7.446025	6.041571	22.98193	0.128544
PR	31	116.6223	87.94717	28.58431	0.133043

Source: Prepared by the researcher using EViews 13.

Overall, the indicators achieved small values, denoting high forecasting quality. In terms of RMSE, the best forecasting performance was recorded for GS, followed by PR and then GA. In terms of the Theil coefficient, which is always bounded within [0,1], the best-performing models were for GA, followed by GS and PR, then GP, as shown in Table 6.

2. Forecast Values

The figures in Appendices 12–15 show the forecast graphs of the study variables, while the table below presents the numerical content of the forecasts for the future period from 2025 to 2031, comprising seven forecast values.

Table 7: Forecast Values for the Cereal Production Indicators

Year	GA (ha)	GP (t)	GS (%)	PR (mm)
2025	2,525,616.70	3,876,165.73	16.94	542.96
2026	2,650,441.53	4,631,053.46	18.55	584.42
2027	2,489,488.51	4,178,629.02	16.26	547.15
2028	2,396,465.81	4,075,892.76	15.61	556.39
2029	2,500,466.49	4,429,539.85	15.63	567.91
2030	2,463,151.51	4,399,583.32	15.09	586.15
2031	2,357,627.36	4,321,345.33	13.92	572.52

Source: Prepared by the researcher using EViews 13.

Section Four: Study Results

1. Analysis of the Forecast Results

Using VAR(2) forecasting models, this study forecasts the future values of four indicators representing cereal production in Algeria; the forecast evaluation indicators showed high quality. The forecast direction for each variable indicates the following:

1.1. Cultivated Area for Cereal Production (GA)

The area will experience fluctuations with a slight downward tendency, reaching its highest value in 2026 at 2,650,441 hectares, and falling to its lowest value in 2028 at 2,396,465 hectares, before stabilizing at 2,357,627 hectares in 2031. This fluctuation reflects instability in land allocation for cereal cultivation, which may result from changes in agricultural policies or environmental effects. The slight decline points to challenges in expanding agricultural areas or a shift towards other crops.

1.2. Cereal Production (GP)

Production follows a fluctuating trend with relative stability in the later years of the forecast, recording its highest value in 2026 at 4,631,053 tonnes and its lowest value in 2025 at 3,876,165 tonnes, before stabilizing at 4,321,345 tonnes in 2031. The fluctuation in production aligns with changes in cultivated area, although the relative stability may reflect an improvement in agricultural techniques or better resource management.

1.3. Cereal Self-Sufficiency Rate (GS)

The rate is expected to decline gradually from 23.20% in 2025 to 13.92% in 2031. This sustained decline indicates a widening gap between domestic production and demand, which may reflect population growth or changes in consumption patterns that outpace the increase in domestic production.

1.4 Average Annual Rainfall (PR)

Rainfall will fluctuate with a slight increase, reaching its lowest value in 2025 at 542.96 mm and its highest value in 2030 at 586.30 mm, before stabilizing at 572.52 mm in 2031 (these remain mere projections based on past data, intended to offset reliance on varied and alternative rainfall sources, as rainfall ultimately rests with providence). This fluctuation reflects climatic variability, though the slight increase may point to gradual climatic changes. This fluctuation has a direct impact on cereal production and cultivated areas, warranting the adoption of groundwater exploitation, irrigated land use, and modern irrigation technologies.

In conclusion, the analyses indicate a clear relationship between cultivated area and cereal production, with a significant influence of rainfall levels. Despite the relative improvement in production, the self-sufficiency rate is declining, pointing to challenges in meeting rising demand. The fluctuations across all indicators underscore the need for flexible and sustainable agricultural strategies, and there may be a need to improve irrigation techniques and water management to reduce dependence on variable rainfall. These analyses highlight the future challenges facing Algeria's cereal production sector and underscore the importance of strategic planning to ensure food security.

2. Discussion of the Results

The forecasting results reveal an important paradox in the future of Algeria's cereal sector: on one hand, the model projects that cereal production will continue at levels approaching four million tonnes for much of the forecast period; on the other hand, the self-sufficiency rate shows a clear downward trend. This paradox suggests that assessing the performance of the cereal sector should not rely on the volume of production alone, but must also take into account the relationship between production and the level of domestic demand. If production maintains a certain level while demand grows at a faster pace, the self-sufficiency rate will decline even without a significant fall in production.

The results also reveal the importance of cultivated areas, as the forecasts show fluctuation and a relative tendency towards a decline in the area allocated to cereals, which may limit the possibility of achieving a sustained increase in production through horizontal expansion. Furthermore, the climatic factor emerges as an element that must be taken into account when formulating agricultural policies, since the forecasts point to continued fluctuation in rainfall rates. Accordingly, improving productivity and developing irrigation techniques and water resource management may prove more sustainable than relying on the expansion of cultivated areas or on rainfall alone.

4. Conclusion

This study arrived at findings of considerable interest. The research on the prospective study of cereal production in Algeria, which relied on a VAR model to forecast four key indicators of cereal production in Algeria, concludes that the self-sufficiency rate is expected to decline gradually from 23.20% in 2023 to 13.92% in 2031 according to this predictive prospective study, indicating a widening gap between domestic production and demand. This decline reflects the effect of population growth or changes in consumption patterns that outpace the increase in domestic production, confirming the validity of the hypothesis.

Sustainable agricultural policies focused on investment in research and development, improved management, and adaptation to climatic change will be essential to achieving food security in light of the climatic challenges facing Algeria. Despite these positive findings, challenges remain, such as the decline in the cereal self-sufficiency rate, fluctuations in

rainfall rates, and disparities in mechanization levels among farmers. The study emphasizes the importance of government initiatives in agricultural investment and the development of innovative financing mechanisms for the sector, to ensure continued improvement of food security in Algeria.

Accordingly, strengthening food security in Algeria requires a shift from policies that respond to shocks after they occur towards proactive policies based on long-term planning and quantitative foresight, with a focus on raising agricultural productivity, developing research and development, improving mechanization, expanding irrigated areas, and enhancing the efficiency of water resource use. In light of this, the study affirms that achieving a more sustainable level of food security in the cereal sector requires an integrated approach combining increased production, improved productivity, adaptation to climatic change, development of resource management, and the use of economic forecasting tools in agricultural decision-making.

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Appendices :**Appendix (01): Unit Root Test for the Variables at Their Original Level, Intercept and Trend Model**

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:30

Sample: 1990 2021

Exogenous variables: Individual effects, individual linear trends

Newey-West automatic bandwidth selection and Bartlett kernel

Total (balanced) observations: 124

Cross-sections included: 4

Method	Statistic	Prob. **
PP - Fisher Chi-square	67.6482	0.0000
PP - Choi Z-stat	-7.02203	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results GROUP01

Series	Prob.	Bandwidth	Obs
GS	0.0001	3.0	31
PR	0.0012	3.0	31
GP	0.0003	6.0	31
GA	0.0001	3.0	31

Appendix (02): Unit Root Test for the Variables at Their Original Level, Intercept Model

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:30

Sample: 1990 2021

Exogenous variables: Individual effects

Newey-West automatic bandwidth selection and Bartlett
kernel

Total (balanced) observations: 124

Cross-sections included: 4

Method	Statistic	Prob. **
PP - Fisher Chi-square	66.9305	0.0000
PP - Choi Z-stat	-6.88743	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results GROUP01

Series	Prob.	Bandwidth	Obs
GS	0.0001	4.0	31
PR	0.0033	2.0	31
GP	0.0019	3.0	31
GA	0.0000	3.0	31

Appendix (03): Unit Root Test for the Variables at Their Original Level, Model Without Intercept and Trend

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:30

Sample: 1990 2021

Exogenous variables: None

Newey-West automatic bandwidth selection and Bartlett
kernel

Total (balanced) observations: 124

Cross-sections included: 4

Method	Statistic	Prob. **
PP - Fisher Chi-square	7.14702	0.5209
PP - Choi Z-stat	-0.44364	0.3286

** Probabilities for Fisher tests are computed using an
asymptotic Chi-square distribution. All other tests
assume asymptotic normality.

Intermediate Phillips-Perron test results GROUP01

Series	Prob.	Bandwidth	Obs
GS	0.3230	4.0	31
PR	0.4695	9.0	31
GP	0.4188	4.0	31
GA	0.4418	4.0	31

Appendix (04): Unit Root Test for the Variables After First Differencing, Intercept and Trend Model

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:31

Sample: 1990 2021

Exogenous variables: Individual effects, individual linear
trends

Newey-West automatic bandwidth selection and Bartlett
kernel

Total (balanced) observations: 120

Cross-sections included: 4

Method	Statistic	Prob. **
PP - Fisher Chi-square	613.131	0.0000
PP - Choi Z-stat	-21.9668	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results D(GROUP01)

Series	Prob.	Bandwidth	Obs
D(GS)	0.0000	2.0	30
D(PR)	0.0000	29.0	30
D(GP)	0.0000	0.0	30
D(GA)	0.0000	3.0	30

Appendix (05): Unit Root Test for the Variables After First Differencing, Intercept Model

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:31

Sample: 1990 2021

Exogenous variables: Individual effects

Newey-West automatic bandwidth selection and Bartlett kernel

Total (balanced) observations: 120

Cross-sections included: 4

Method	Statistic	Prob. **
PP - Fisher Chi-square	112.958	0.0000
PP - Choi Z-stat	-9.54070	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results D(GROUP01)

Series	Prob.	Bandwidth	Obs
D(GS)	0.0000	2.0	30
D(PR)	0.0001	29.0	30
D(GP)	0.0000	1.0	30
D(GA)	0.0000	2.0	30

Appendix (06): Unit Root Test for the Variables After First Differencing, Model Without Intercept and Trend

Null Hypothesis: Unit root (individual unit root process)

Series: GS, PR, GP, GA

Date: 08/21/24 Time: 14:32

Sample: 1990 2021

Exogenous variables: None

Newey-West automatic bandwidth selection and Bartlett kernel

Total (balanced) observations: 120

Cross-sections included: 4

Method	Statistic	Prob.**
PP - Fisher Chi-square	676.317	0.0000
PP - Choi Z-stat	-24.1095	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate Phillips-Perron test results D(GROUP01)

Series	Prob.	Bandwidth	Obs
D(GS)	0.0000	2.0	30
D(PR)	0.0000	29.0	30
D(GP)	0.0000	1.0	30
D(GA)	0.0000	2.0	30

Appendix (07): Stability Test for the VAR(2) Model

Roots of Characteristic Polynomial

Endogenous variables: D(GS) D(PR) D(GP)

D(GA)

Exogenous variables: C

Lag specification: 1 2

Date: 08/21/24 Time: 14:34

Root	Modulus
-0.413178 - 0.644501i	0.765570
-0.413178 + 0.644501i	0.765570
-0.653691 - 0.391584i	0.762004
-0.653691 + 0.391584i	0.762004
-0.189711 - 0.671125i	0.697423
-0.189711 + 0.671125i	0.697423
-0.004852 - 0.544299i	0.544320
-0.004852 + 0.544299i	0.544320

No root lies outside the unit circle.

VAR satisfies the stability condition.

Appendix (08): Normality Tests for the VAR(2) Model

VAR Residual Normality Tests

Orthogonalization: Cholesky (Lutkepohl)

Null Hypothesis: Residuals are multivariate normal

Date: 08/21/24 Time: 14:35

Sample: 1990 2021

Included observations: 29

Component	Skewness	Chi-sq	df	Prob.*
1	0.166323	0.133707	1	0.7146
2	0.642494	1.995191	1	0.1578
3	0.031826	0.004896	1	0.9442
4	-0.102411	0.050692	1	0.8219
Joint		2.184485	4	0.7019

Component	Kurtosis	Chi-sq	df	Prob.
1	2.126259	0.922471	1	0.3368
2	4.250557	1.889705	1	0.1692
3	3.751642	0.682667	1	0.4087
4	2.470877	0.338298	1	0.5608
Joint		3.833141	4	0.4291

Component	Jarque-Bera	df	Prob.
1	1.056178	2	0.5897
2	3.884895	2	0.1434
3	0.687563	2	0.7091
4	0.388990	2	0.8233

Joint	6.017626	8	0.6453
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* Approximate p-values do not account for coefficient estimation

Appendix (09): Serial Correlation Test for the VAR(2) Model

VAR Residual Serial Correlation LM Tests

Date: 08/21/24 Time: 14:35

Sample: 1990 2021

Included observations: 29

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	17.18952	16	0.3734	1.103774	(16, 40.4)	0.3835
2	23.20506	16	0.1084	1.594922	(16, 40.4)	0.1149
3	17.75876	16	0.3382	1.147624	(16, 40.4)	0.3483

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	17.18952	16	0.3734	1.103774	(16, 40.4)	0.3835
2	44.64323	32	0.0680	1.577879	(32, 34.8)	0.0951
3	71.26090	48	0.0163	1.773136	(48, 21.3)	0.0758

Appendix (10): Heteroskedasticity Test for the VAR(2) Model

VAR Residual Heteroskedasticity Tests (Levels and Squares)

Date: 08/21/24 Time: 14:36

Sample: 1990 2021

Included observations: 29

Joint test:

Chi-sq	df	Prob.
150.3741	160	0.6956

Individual components:

Dependent	R-squared	F(16,12)	Prob.	Chi-sq(16)	Prob.
res1*res1	0.422677	0.549099	0.8694	12.25763	0.7261
res2*res2	0.661826	1.467794	0.2534	19.19296	0.2588
res3*res3	0.366355	0.433628	0.9399	10.62429	0.8321
res4*res4	0.617758	1.212107	0.3737	17.91498	0.3289
res2*res1	0.469878	0.664768	0.7803	13.62645	0.6265
res3*res1	0.437796	0.584034	0.8439	12.69607	0.6948
res3*res2	0.468005	0.659787	0.7844	13.57213	0.6306
res4*res1	0.587809	1.069543	0.4617	17.04645	0.3826
res4*res2	0.431232	0.568641	0.8554	12.50574	0.7085
res4*res3	0.634422	1.301546	0.3265	18.39824	0.3011

Appendix (11): Forecast Quality Evaluation

Forecast Evaluation

Date: 08/21/24 Time: 14:38

Sample: 1990 2021

Included observations: 32

Variable	Inc. obs.	RMSE	MAE	MAPE	Theil
GA	31	519919.0	405423.7	16.53391	0.091381
GP	31	1034446.	794199.1	24.05973	0.140254
GS	31	7.446025	6.041571	22.98193	0.128544

PR	31	116.6223	87.94717	28.58431	0.133043
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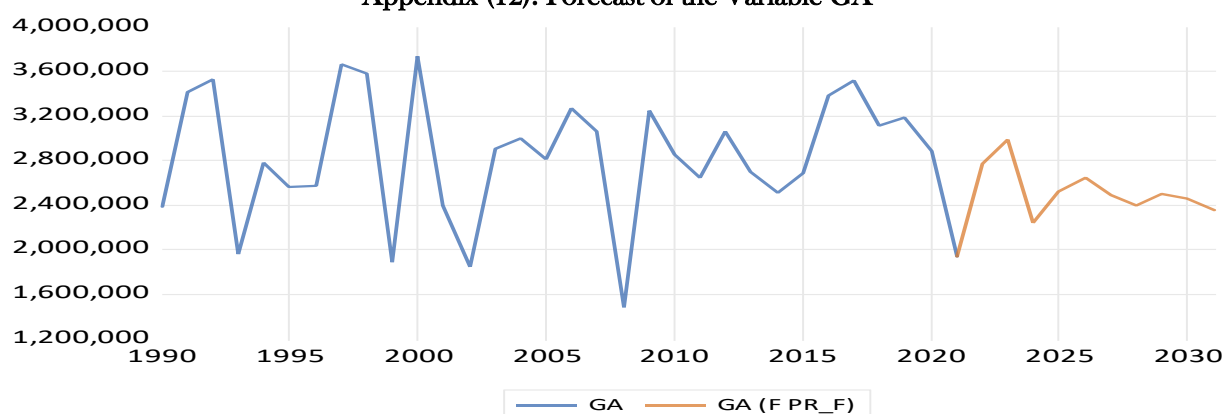
RMSE: Root Mean Square Error

MAE: Mean Absolute Error

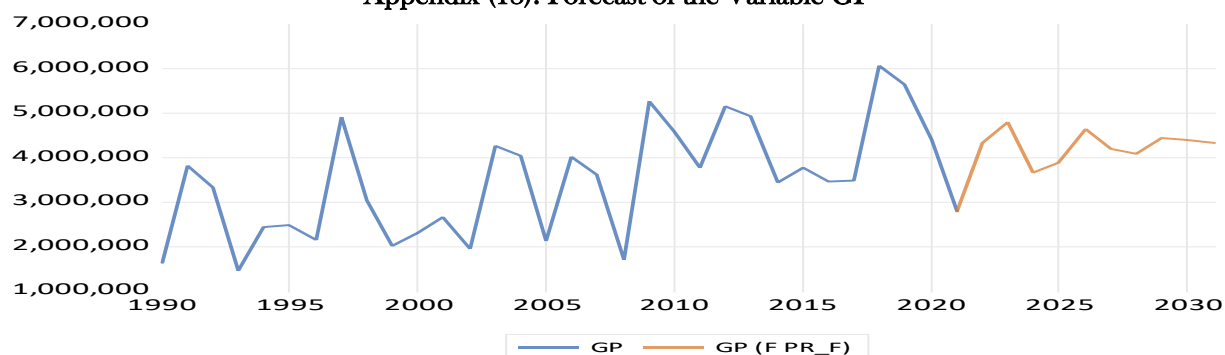
MAPE: Mean Absolute Percentage Error

Theil: Theil inequality coefficient

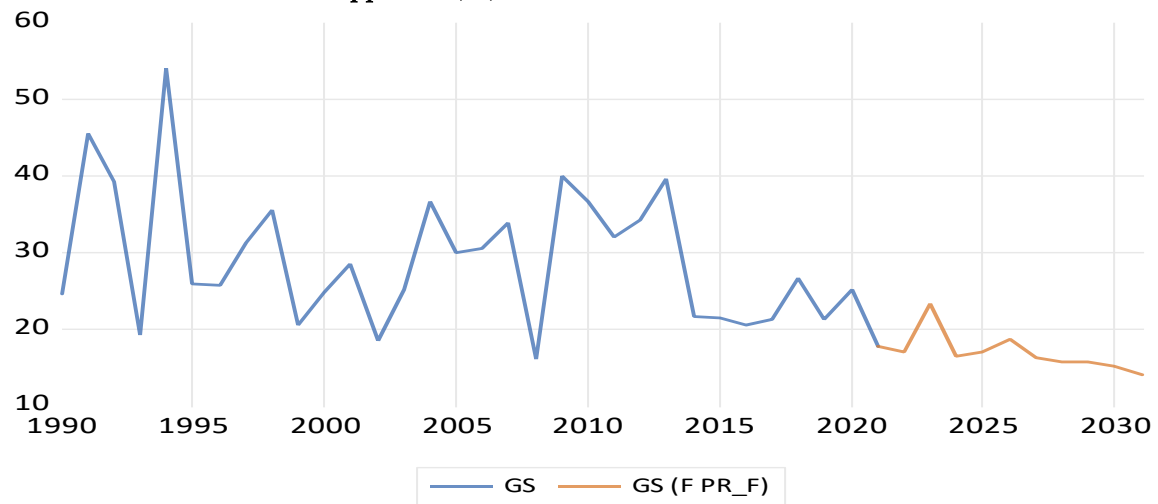
Appendix (12): Forecast of the Variable GA



Appendix (13): Forecast of the Variable GP



Appendix (14): Forecast of the Variable GS



Appendix (15): Forecast of the Variable PR

