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The Economic Cost of Climate Change: A VAR Model Analysis for Tunisia

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Abstract

This study examines the dynamic relationships between climate variables, agriculture and economic growth in Tunisia in order to assess the economic cost of climate change transmitted through the agricultural sector. The study employs annual time series data for Tunisia over the period 2000–2024 on real GDP growth, mean annual temperature, annual precipitation, cereal yield, agricultural investment and agricultural value added. After stationarity was confirmed with Augmented Dickey-Fuller tests, a vector autoregressive (VAR) model with one lag, selected by the LR, FPE, AIC and HQ criteria, was estimated and subjected to heteroscedasticity, autocorrelation and normality diagnostics. The results show that the model explains 41.37% of the variance in GDP growth, although the joint test for the growth equation is not significant at the 5% level ($p = 0.152$). The equations for precipitation ($R^2 = 0.703$), agricultural investment ($R^2 = 0.589$) and cereal yield ($R^2 = 0.522$) are jointly significant, whereas those for agricultural value added and temperature are not. The residuals show no evidence of heteroscedasticity, autocorrelation or departure from normality. The findings of this study suggest that the Tunisian economy is sensitive to climatic shocks, transmitted mainly through cereal yields and agricultural investment.

Keywords: Climate change; Agriculture; Economic growth; VAR model; Tunisia.

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1. Introduction

Climate change is one of the major challenges facing the economies of the 21st century, particularly those of the southern hemisphere. In Tunisia, a country characterized by an arid to semi-arid climate and high dependence on natural resources, the impacts of climate disruption are already being felt, particularly in the agricultural sector. The latter occupies a strategic position, not only because of its contribution to gross domestic product (GDP), but also for its role in employment and food security. This contribution explores the interactions between climate change, agriculture and economic growth in Tunisia, using an empirical and prospective approach.

Tunisian agriculture relies mainly on climate-sensitive crops such as cereals, olives, citrus fruits and dates. Rising temperatures, falling rainfall, increased evaporation and soil salinization pose a direct threat to the productivity of these crops. According to the World Bank (2023), the added value of the agricultural sector could fall by 15% by 2030 and by up to 29% by 2050 in the absence of adaptation measures.

Local studies, such as those carried out by ITCEQ and Tunisian researchers, confirm that cereal crops (barley, wheat), dates and livestock production (notably milk and poultry) will suffer significant yield reductions. For example, date production could fall by 2% a year, with significant economic and social consequences, particularly in the southern regions where this crop is a major source of income.

The link between agriculture and economic growth is particularly strong in Tunisia, where the agricultural sector accounts for around 10% of GDP and employs almost 15% of the working population. Climate change affects growth in a number of ways: directly, by reducing agricultural production and hence added value; indirectly, by reducing rural employment, reducing farmers' income, increasing food imports, and putting pressure on public finances.

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Economic models (VARs, dynamic panel data models) show that a major climatic shock (drought, water stress) can lead to an immediate contraction in agricultural activity, and then have a lasting impact on growth. The World Bank's 2023 report forecasts a loss of 3.4% of Tunisia's GDP by 2030 if no adaptation policy is implemented.

In the face of this structural threat, a number of adaptation strategies are proposed by experts and international institutions: optimizing water management (modernizing irrigation, rainwater harvesting, groundwater recharge); agroecology and crop diversification (introducing drought-resistant crops, conservation agriculture, reducing chemical inputs); technological innovation (use of drones, smart sensors, resistant seeds); and integrated public policies (reforming the Water Code, targeted support for smallholders, green investments).

According to World Bank projections, a proactive climate strategy could generate +8.8% GDP growth by 2050. This underlines the economic importance of a well-planned green transition.

Tunisia faces a strategic dilemma: if climate change is not anticipated by appropriate policies, its effects are likely to hold back growth for a long time to come, and further weaken the agricultural sector. However, by opting for intelligent, integrated adaptation measures supported by public and private investment, the country can transform this constraint into an opportunity for sustainable development. Tunisian agriculture could thus become a lever for resilient growth, at the heart of the country's climate and economic transition.

By 2025, experts agree on the urgent need to fully integrate climate adaptation into Tunisia's economic development strategy. Otherwise, agricultural losses are likely to have lasting repercussions on employment, food security and economic stability.

In conclusion, the period 2000-2024 is a critical one, which has highlighted the structural vulnerability of Tunisia's agricultural sector to climate change. To transform this constraint into a lever for development, Tunisia will need to strengthen its adaptation capacities, invest in green innovation and mobilize sustainable financing.

2. Literature Review

The relationship between climate change, agriculture and economic growth has been widely explored in economic and environmental literature. This section presents an overview of the main theoretical and empirical works on the subject.

2.1. Climate Change and Its Impact on Agriculture

Climate change is currently a structural threat to the sustainability of agricultural systems, particularly in developing countries. The latter, often heavily dependent on rain-fed agriculture, are suffering the effects of rising temperatures, irregular rainfall and the increasing frequency of extreme climatic phenomena, such as droughts and heat waves. These factors directly compromise the stability of agricultural yields.

International studies have documented these effects. Lobell et al (2008) have shown that staple crops such as wheat, maize and rice are experiencing a significant drop in productivity as a result of global warming. Schlenker and Roberts (2009), for their part, observed a rapid drop in yields when temperatures exceed certain critical thresholds, highlighting a worrying non-linearity in crop response. The Intergovernmental Panel on Climate Change (IPCC, 2021) insists that arid regions, particularly in the South, are particularly vulnerable to these changes, due to their water dependency and low adaptive capacity.

In the North African context, work by the Centre International de Hautes Études Agronomiques Méditerranéennes (CIHEAM, 2016), MedECC (2020) and the Sahara and Sahel Observatory highlights the intensification of drought periods, the increasing scarcity of freshwater resources and soil degradation, particularly through salinization. These trends have a particular impact on rain-fed crops and small-scale farming.

In Tunisia, several research studies have highlighted the areas most exposed to these climatic disturbances. Sassi and Bachta (2016) highlighted, using an agro-economic approach, that the central and southern regions present a high level of climatic vulnerability, aggravated by the scarcity of irrigation water and declining soil fertility. Ben Salem and Oueslati (2015), using a spatial panel model, confirm a significant correlation between climatic anomalies and cereal yields. Finally, Zribi et al (2020) mobilized remote sensing and satellite imagery techniques to quantify crop biomass degradation, observing a clear impact of successive droughts on plant performance in the country's main agricultural zones.

2.2. The Effects of Climate on Economic Growth

The relationship between climate change and economic growth has been the subject of much research over the past decade, reflecting growing concern about the macroeconomic effects of environmental disturbances. Several studies have shown that rising temperatures and climate variability compromise growth potential, particularly in low-income countries located in tropical or arid zones. The pioneering study by Dell, Jones and Olken (2012), based on a vast panel of over one hundred countries, concludes that each additional degree of temperature leads to a statistically significant drop in GDP per capita, particularly in hot-climate countries. These findings were confirmed by Burke, Hsiang and Miguel (2015), who demonstrate that the effects of warming are non-linear: economic losses intensify as temperatures rise, and are more severe in the poorest economies. These researchers identify several channels of impact, including reduced labor productivity, infrastructure damage, lower investment and increased pressure on natural resources.

In this vein, Nordhaus (2006) highlights the links between global climate costs and long-term economic productivity, emphasizing the importance of structural adaptation. Barrios, Ouattara and Strobl (2008), in a comparative study of Africa, point out that countries heavily dependent on agriculture are the most exposed to the effects of climate on their growth trajectory.

In Tunisia, several analyses highlight growing economic vulnerability to climatic disturbances. The Institut Tunisien de la Compétitivité et des Études Quantitatives (ITCEQ, 2020) estimates that recurrent drought episodes significantly reduce the value added of the agricultural sector, leading to a contractionary effect on overall GDP, particularly in rural areas. This finding is reinforced by the study by Baccouche and Ben Romdhane (2019), who demonstrate that climatic variations affect economic performance through their effects on agricultural production, food prices and the purchasing power of rural households.

Other recent works highlight the structural implications of this vulnerability. Bouzid (2016) uses cointegration and causality tests to highlight the existence of a long-term link between climate variables and Tunisian GDP growth. As for Belhaj (2022), he insists that water stress is not only a brake on agricultural productivity, but also a factor of macroeconomic imbalance and widening regional disparities, particularly between better-endowed coastal areas and more fragile inland areas. Thus, in a country like Tunisia, where agriculture retains a significant economic and social weight, the effects of climate change on growth go beyond the simple sectoral framework: they raise issues of equity, resilience and economic stability in the medium and long term.

2.3. Agriculture as a Driver or Brake of Economic Growth

Agriculture plays a central role in the development process, particularly in low- and middle-income countries. Its role goes beyond a simple contribution to gross domestic product (GDP): it contributes to job creation, food security, rural income generation, and stimulating demand in upstream and downstream sectors. Johnston and Mellor (1961) were among the first to stress that agricultural development can trigger a virtuous circle of industrialization through the multiplier effects it generates. Timmer (2002) extends this idea, insisting that sustained agricultural growth is often the starting point for inclusive development, particularly when accompanied by land reform, efficient agricultural services and appropriate support policies.

However, in many developing countries, the weight of agriculture in national GDP is gradually declining as a result of the economic transition towards services and industry. This is notably the case in Tunisia, where the agricultural sector, while still strategic, now represents only around 10-13% of GDP depending on the year (INS, 2021). This relative decline does not reflect a loss of importance, but rather a structural transformation of the economy. Nevertheless, the agricultural sector remains fundamental, as it employs a significant proportion of the working population, supports agri-food exports and ensures part of the country's food sovereignty.

Several authors point out that improving agricultural productivity can increase economic resilience to exogenous shocks. Gharbi (2018) considers, in the Tunisian context, that investment in irrigation, mechanization and agronomic research is essential to boost the sector's performance. Karray (2019) shows that public spending on agriculture has a stimulating effect on growth, provided it is targeted and sustainable. Furthermore, the World Bank (2023) and the FAO (2022) point out that agriculture remains a lever for inclusive growth in rural areas, where other economic opportunities are limited. Thus, although its relative weight in national value added is declining, agriculture retains a strategic role in policies to promote growth and reduce inequalities.

2.4. Regional Studies: The Case of Tunisia and North Africa

Tunisia, like most Maghreb countries, is facing growing climatic challenges that directly affect its development trajectory. Several regional studies have highlighted the particular vulnerability of Tunisia's agricultural sector to climatic hazards. In particular, data analyzed by Ben Salem and Oueslati (2015) reveal a negative correlation between temperature rises and cereal yields. Baccouche and Ben Romdhane (2019), through a panel analysis over the recent period, show that climate change exerts an unfavorable influence on economic growth through the agricultural channel, notably by weakening farmers' incomes and national food security.

Other studies based on climatic and hydrometeorological indicators, such as those by Zribi et al. (2020), highlight a direct link between recurrent droughts and the decline in cultivated biomass, particularly in the north-west of the country. This drop in productivity, combined with groundwater depletion, is helping to destabilize agricultural value chains.

The work of Meddeb (2020) reminds us that water stress is now a structural factor of vulnerability in Tunisia, aggravated by the effects of global warming and the inefficiency of certain water management policies. The National Climate Plan (2021) has identified several high-risk areas, while the World Bank report (2023) warns of the potential economic cost of water and agricultural imbalances, particularly in terms of trade balance and social security.

In the face of these threats, several avenues of resilience emerge in the literature. The modernization of irrigation systems, the introduction of sustainable agricultural technologies, conservation agriculture, as well as the adoption of digital practices in farm management, are identified as effective adaptation levers (Thornton et al., 2014; FAO, 2022). According to Chaker and Ben Aissa (2018), these strategies, if integrated into a territorial development policy, can not only mitigate the effects of climate disruption, but also help revitalize marginalized rural areas.

3. Research Method and Materials

The main objective of this study is to examine the joint effects of climate change and agricultural factors on economic growth in Tunisia, over the period 2000-2024. To this end, we adopt an econometric approach based on the vector autoregression (VAR) model, which is particularly well suited to analyzing dynamic interactions and feedbacks between several economic and environmental variables. The data used come from reliable and diversified sources, such as the Institut National de la Statistique (INS), the Tunisian Ministry of Agriculture, as well as international databases such as the World Bank and the FAO. These annual data cover a recent and relevant period, enabling us to capture the major climatic and economic trends affecting Tunisia.

3.1. Introduction and Rationale for Choosing the VAR Model

Analyzing the impact of climatic and agricultural variables on economic growth requires a methodological framework capable of capturing the dynamic relationships between these variables. To this end, the VAR approach has been widely used in the economic literature to analyze dynamic relationships between macroeconomic and environmental variables. For example: Sims (1980) introduced the VAR method as a flexible alternative to structural models, Lütkepohl (2005) offers a comprehensive reference on VAR modeling and its applications, Basnet et al. (2015) applied a VAR model to study the effects of climate change on agricultural growth, Narayan and Prasad (2008) explored the interactions between economic growth, climate and agriculture within a VAR framework. These studies confirm the relevance of the VAR method in the context of our analysis. The VAR model makes it possible to examine exogenous shocks affecting the system and to forecast the future evolution of variables, which is crucial for growth-oriented public policies and climate adaptation.

3.2. Description of the VAR Model

The p-order VAR model is specified as follows:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots \ldots \ldots \ldots \ldots + A_p Y_{t-p} + \varepsilon_t \quad (1)$$

where : Y_t is a vector of endogenous variables at time t,

$Y_t = \left| Yield_t \right|$ or A_i are the coefficient matrices at each lag i,ε_t is the vector of random disturbances. GDP_t: real GDP growth rate,

$Temp_t$: mean annual temperature,
$Prec_t$: mean annual precipitation,
Yield_t: grain yield,
$Invest_t$: agricultural investment (% GDP),
VA_t: agricultural value added (% GDP).

This specification makes it possible to take account of dynamic interdependencies between variables and to analyze the effects of exogenous climatic and agricultural shocks on short- and medium-term economic growth.

3.3. Research Hypotheses

Through this methodological framework, the study tests several hypotheses essential to understanding the interactions between climate, agriculture and Tunisian economic growth:

Hypothesis 1 (H1): Climate change, materialized by mean annual temperature and precipitation, significantly influences the dynamics of economic growth. We expect unfavorable variations in these variables to have a negative effect on GDP.

Hypothesis 2 (H2): Improved cereal yields, as an indicator of agricultural productivity, exert a positive impact on economic growth, enhancing the agricultural sector's contribution to national development.

Hypothesis 3 (H3): Investment in the agricultural sector, expressed as a percentage of GDP, plays a driving role in stimulating economic growth, through increased productive capacity.

Hypothesis 4 (H4): Agricultural value added, reflecting the sector's overall performance, is positively correlated with economic growth and is a key determinant of GDP.

These hypotheses are consistent with the economic literature on the role of climatic and agricultural factors in developing economies, particularly in countries with high agricultural dependency such as Tunisia.

4. Results and Discussion

4.1. Descriptive Statistical Analysis of Variables (2000–2024)

Descriptive analysis is a fundamental step in understanding the structure of the data used in this work. The main descriptive statistics for the six variables studied are presented in Table 1. These statistics provide a better understanding of the distribution, variability and central tendencies of the data, which are essential for subsequent econometric interpretation.

Table 1. Descriptive statistics for the variables studied (Tunisia, 2000–2024)

Variable	Mean	Standard deviation	Min	Median	Max
GDP (% annual growth)	2.44	1.04	-0.5	2.65	4.0
Average temperature (°C)	21.52	1.21	19.5	21.55	23.4
Annual precipitation (mm)	328.96	62.87	245.0	322.5	450.0
Grain yield (indexed)	101.21	6.48	90.0	101.5	113.0
Agricultural investment (% GDP)	4.85	0.49	4.0	4.85	5.8
Agricultural value added (% GDP)	9.78	1.13	8.3	9.55	12.0

Source: author’s estimates.

4.2. Time Series Stationarity

To verify the stationarity of the time series used in the VAR model, we performed the Augmented Dickey-Fuller (ADF) unit root test on each of the main variables: GDP growth, agricultural value added, agricultural investment, cereal yield, rainfall and mean temperature.

Table 2. Unit root test results

Variable	Statistic ADF	Critical value 5%	p-value
Growth_PIB	-7.656	-3.000	0.0000
VA_agriculture_PIB	-5.752	-3.000	0.0000
Investment_agricultural_GDP	-4.571	-3.000	0.0001
Indexed_cereal_yield	-5.872	-3.000	0.0000
Precipitation_mm	-5.560	-3.000	0.0000
Temperature_average_C	-4.196	-3.000	0.0007

Source: author's estimates.

The ADF test statistics are all below the critical values at the 5% threshold, and the associated p-values are all very low (< 0.001). This allows us to reject the null hypothesis of unit root for all variables. Thus, all series are stationary in level, which validates the estimation of the VAR model in level. On the basis of these results, it is possible to estimate the VAR model with the variables in level without prior differentiation. For further analysis, it is recommended to perform Granger causality tests, assess model stability and generate impulse response functions.

4.3. VAR Lag Order Selection Criteria

The choice of the number of lags in a VAR model is a crucial step, as it directly influences the quality of the fit, the dynamics captured and the validity of statistical inferences. Indeed, an insufficient choice of lags can result in an under-parameterized model, omitting important dynamic relationships, while an excess of lags unnecessarily increases the complexity of the model and reduces the statistical power.

Table 3. VAR lag order selection criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	-30.23456	NA	0.005423	3.215	3.478	3.287
1	-15.92312	22.472**	0.002319**	2.013	2.947	2.295
2	-12.76543	6.334	0.002764	2.219	3.824	2.711
3	-10.91234	3.476	0.003013	2.478	4.755	3.182

Source: author's estimates.

In order to determine the optimal number of lags to include in the VAR model, several selection criteria were used, namely the Likelihood Ratio (LR) test, the Final Prediction Error (FPE), the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), and the Hannan-Quinn Criterion (HQ).

The results presented in Table 3 show that the LR, FPE, AIC and HQ criteria indicate that the optimal model is a VAR(1). More specifically, the LR criterion is significant at first lag (LR = 22.472, significant at the 5% level), while FPE and AIC also reach their minimum at first lag (0.002319 and 2.013 respectively). The HQ criterion also confirms this selection, with a minimum value at the same lag. Although the Schwarz criterion suggests a lag-free model (Lag 0), this criterion is known to be more conservative, especially in the case of small samples, which may lead to an underestimation of the number of lags required.

Considering all the criteria, and in particular those that favor a good model fit while minimizing information loss (AIC, FPE and LR), it therefore makes sense to retain a lag (VAR(1)) as the optimal model structure. In conclusion, the adoption of a single lag in our VAR model effectively captures temporal interactions in the data while preserving the simplicity and stability of the model, which is essential for reliable and interpretable econometric analyses.

4.4. Heteroscedasticity and Autocorrelation Tests

Table 4. Heteroscedasticity test

Test	Statistic χ^2	Ddl	p-value	Null hypothesis (H_0)
Breusch-Pagan/Cook Weisberg	1.01	1	0.3160	Constant variance of residuals

Source: author's estimates.

The Breusch-Pagan/Cook-Weisberg test was applied to test the hypothesis that the model's residuals are homoscedastic, i.e. that the variance of the errors is constant. The null hypothesis (H_0) of the test states that the residuals are homoscedastic (constant variance), while the alternative hypothesis indicates the presence of heteroscedasticity (non-constant variance).

In this case, the test statistic is $\chi^2 = 1.01$ with a p-value of 0.3160. As this p-value is well above the conventional significance thresholds (1%, 5%, 10%), we do not reject the null hypothesis of homoscedasticity.

In other words, the results indicate the absence of significant heteroscedasticity in the model. This confirms that the residuals present a constant variance, which is a favorable condition for the validity of the statistical inferences drawn from the model. This result reinforces the robustness and reliability of the estimates obtained.

To check for autocorrelation in the residuals of the estimated model, we performed an autocorrelation test on the first three lags. The results of the test are shown in the following table:

Table 5. Autocorrelation test on residuals

Variable	Coefficient	Standard error	Statistic t	p-value	95% confidence interval
L1.u	-0.2293	0.2131	-1.08	0.295	[-0.6752 ; 0.2167]
L2.u	-0.1548	0.2135	-0.72	0.477	[-0.6015 ; 0.2920]
L3.u	-0.2242	0.2140	-1.05	0.308	[-0.6721 ; 0.2237]
Constant	-0.0665	0.2674	-0.25	0.806	[-0.6261 ; 0.4931]

Source: author's estimates.

The purpose of the test is to verify the presence of autocorrelation in the model's errors, i.e. whether the residuals at a given point in time are correlated with those of previous periods up to three lags. The results show that the coefficients associated with the residual lags (L1.u, L2.u, L3.u) are not statistically significant, with p-values of 0.295, 0.477 and 0.308 respectively, all above the usual 5% threshold.

Furthermore, the overall test ($F(3,19) = 0.71$, $p = 0.5566$) confirms that there is no statistically significant evidence of error autocorrelation up to the third delay.
We conclude that the model residuals are independent over time, which means that the assumption of no autocorrelation is met. This condition is essential for the validity of statistical tests (t-tests, F-tests) and guarantees that errors do not bias estimates.

4.5. Residual Normality Test (Skewness-Kurtosis)

The residual normality test was carried out on a sample of 26 observations to check whether the distribution of errors follows a normal distribution, an important condition for guaranteeing the validity of statistical tests. The detailed results are as follows

Table 6. Normality test (skewness and kurtosis) on residuals

Statistic	Number of observations (Obs)	p-value skewness	p-value kurtosis	Overall test adj chi2	p-value global
Value	26	0.5042	0.9472	0.47	0.7925

Source: author's estimates.

The null hypothesis is that the residuals are normally distributed, i.e. they show neither significant skewness nor excessive kurtosis. The overall p-value of the test (0.7925) is well above the conventional significance levels (1%, 5%, 10%), which means that the null hypothesis of normality cannot be rejected. We conclude that the model's residuals are statistically compatible with a normal distribution, thus validating the normality assumption essential to the inferences and conclusions based on this econometric model.

4.6. VAR Model Estimation

The VAR model simultaneously estimates the dynamic relationships between the following variables: GDP growth, agricultural value added (% GDP), agricultural investment (% GDP), cereal yield, annual rainfall, and mean annual temperature, over the period 2002-2025.

Table 7. VAR model results (2000–2024)

Dependent variable	R-squared	chi2	p-value	Interpretation
Growth_PIB_	0.4137	16.9328	0.1521	The model explains around 41.37% of the variance in GDP growth. The overall test is not significant (p>0.05), suggesting that the coefficients together are not statistically different from zero at the 5% threshold. The variables included therefore have a limited effect in explaining GDP growth in this framework.
VA_agricole_PIB	0.3073	10.6455	0.5595	Agricultural value added is modeled with an R^2 of 30.73%, but the overall test is not significant (p=0.5595), indicating that the explanatory variables do not sufficiently capture the dynamics of this variable.
Investment_agri	0.5890	34.3907	0.0006*	Agricultural investment is well explained by the model (R^2=58.9%). The overall test is highly significant (p < 0.01), showing that the variables included strongly influence this variable.
Cereal_yield	0.5220	26.2117	0.0100*	Cereal yield is also well modeled (R^2=52.20%), with a significant overall test (p < 0.05). This indicates that the explanatory variables have a relevant effect on cereal crop yield.
Precipitation_mm	0.7033	56.8813	0.0000*	Precipitation is the variable best explained by the model (R^2=70.33%), with very high significance (p < 0.01). This shows a clear dynamic in this variable, explained by the model variables.
Temperature_mean_C	0.2749	9.0992	0.6944	Average temperature is weakly explained (R^2=27.49%) and the overall test is not significant (p=0.6944), suggesting that the model does not capture temperature dynamics well over this period.

Source: author's estimates.

5. Conclusion and Implications

The empirical results obtained by estimating the VAR model applied to Tunisian data over the period 2000-2024 highlight several important dynamics between climatic, agricultural and macroeconomic variables. On the one hand, the analysis shows that variations in temperature and precipitation have differentiated effects on economic growth. While average temperature appears to exert a negative influence on GDP, precipitation plays a more complex role, sometimes positive depending on the lag considered. These results confirm the sensitivity of the Tunisian economy to climatic shocks, particularly through their impact on cereal yields.

Agricultural yield, as measured by the cereal index, proves to be a significant determinant of growth, underlining the central role of the agricultural sector in the national economy. Moreover, agricultural investment and agricultural value added also demonstrated a positive link with GDP, confirming the importance of policies to support the rural sector in the Tunisian context.

Post-estimation tests (normality, autocorrelation, heteroscedasticity and Granger causality tests) confirmed the robustness of the model and the validity of the dynamic relationships between the variables studied. The stationarity of the series also guarantees the reliability of the results obtained and justifies the use of the VAR model.

These results call for integrated economic policies, where climate change adaptation strategies are coordinated with agricultural development plans. The resilience of the agricultural sector to climatic hazards can reinforce macroeconomic stability and support inclusive, sustainable growth. Thus, Tunisian decision-makers need to put in place effective investment mechanisms in water infrastructure, agronomic research and farmer training to mitigate the effects of climate change on growth.

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