

Analyzing the Impact of Rainfall and Temperature on Potato Yield in Iraq (1990-2024) Using the ARDL Model

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Abstract

This study aimed to analyze the economic impact of various climatic variables on potato production in Iraq between 1990 and 2024. The study's significance lies in the fact that potatoes are a strategic crop highly sensitive to different climatic variables. The study relied on annual data and employed an economic approach to analyze the impact of climatic variables, such as average maximum and minimum temperatures and rainfall, in Iraq.

The study revealed long-term equilibrium relationships between potato productivity and climatic variables during the study period. Rainfall had a positive effect on the yield, while maximum temperature did not have statistically significant long-term effects. The study also found that minimum temperature had negative long-term effects. The error correction coefficient (ECM = -0.2137) confirmed that 21% of short-term imbalances were corrected annually, reflecting the gradual return of the agricultural system to equilibrium.

The study concluded that without the implementation of appropriate adaptation policies, climate change will lead to a decline in potato production in Iraq in the future.

Keywords: Climate change, Potatoes, ARDL

Introduction

Agricultural production is directly affected by key climatic factors such as temperature, humidity, and rainfall. Any changes in these factors impact both the quantity and quality of crops. With global climate change, the Iraqi agricultural sector faces significant challenges that threaten food security in its four dimensions: availability, access, utilization, and stability. Given its location in arid and semi-arid regions, Iraq is among the countries most vulnerable to these changes. Its agricultural lands are severely affected by climatic fluctuations, particularly temperature and rainfall. These changes have exacerbated

desertification and reduced cultivated areas, especially in the arable northern regions.

Potatoes are a strategic crop sensitive to climatic conditions, requiring specific temperatures, sufficient water, and appropriate relative humidity throughout their growth cycle. As water resources available for agriculture dwindle, pressure on production increases, highlighting the need for effective climate change adaptation policies and strategies. These include sustainable water management and the development of drought-resistant varieties to ensure agricultural sustainability and food security.

Research Problem

Despite the strategic importance of potatoes in achieving food security in Iraq, domestic production has not kept pace with the growing demand driven by rapid population growth. This production gap has resulted in increasing reliance on imports and a widening deficit in the agricultural trade balance. In addition to demographic pressures, climate change—manifested through fluctuations in rainfall patterns and rising minimum and maximum temperatures—poses an additional constraint on agricultural productivity. Given the sensitivity of potato crops to climatic conditions, these environmental changes may further exacerbate production instability and threaten national food security.

Research Objectives

This study aims to measure the impact of climate change on potato crop productivity in Iraq for the period (1990-2024) using the Autoregressive Distributed Lag (ARDL) methodology. The goal is to confirm the existence of a long-term cointegration relationship between climate change and potato crop productivity, and to determine the extent to which potato crop productivity is affected by climate change. This will be achieved through the following sub-objectives:

1. The evolution of maximum and minimum temperatures and rainfall amounts in Iraq for the period (1990-2024).
2. Measuring the impact of the relationship between climate variables

Study Hypotheses

The study is based on the following main hypothesis:

First: Null Hypothesis (H0):

There is no statistically significant relationship between climate change and

potato crop productivity in Iraq during the period (1990–2024).

Alternative Hypothesis (H1):

There is a statistically significant relationship between climate change and potato crop productivity in Iraq during the period (1990–2024).

Several sub-hypotheses are derived from this main hypothesis, including: Study hypotheses based on the null and alternative hypotheses.

Second: Sub-hypotheses

1. Rainfall

H0: There is no statistically significant effect of rainfall on potato crop productivity.

H1: There is a statistically significant effect of rainfall on potato crop productivity.

2. Temperature (Maximum and Minimum)

H0: There is no statistically significant effect of temperature on potato crop productivity.

H1: There is a statistically significant effect of temperature on potato crop productivity.

Conclusions:

1- Rainfall was identified as a significant positive climatic factor for potato production, given its direct role in improving soil moisture and supporting plant growth. This suggests that investment in water harvesting technologies can significantly increase productivity.

2. The results showed that the maximum temperature does not have a significant long-term impact, indicating that its effect is limited to critical values and is not directly reflected in the overall average for the studied period.

3. The study revealed that minimum temperatures have long-term negative effects on productivity and plant physiology, guiding policymakers toward developing varieties tolerant to nighttime heat stress to ensure stable production.

4. e error correction coefficient confirmed that the agricultural system returns to equilibrium in the long term, with 21% of short-term imbalances corrected annually. This means that any heat shock requires approximately five years to dissipate and return to normal production levels, reflecting the economic and biological resilience of the agricultural system.

Previous Studies:

Many studies over the years have examined the impact of climate change on agricultural production. This section provides an overview of some of these studies.

This study examined the impact of climate change on the productivity of major field crops in Egyptian governorates. It aimed to investigate key climatic variables, both positive and negative, such as maximum and minimum temperatures, relative humidity, and rainfall, in order to develop appropriate strategies for these crops to mitigate negative impacts and capitalize on positive ones. The study revealed that the net impact of climate change was positive, leading to an increase in wheat productivity by 0.01 tons/feddan and maize productivity by 0.07 tons/feddan. Conversely, it had a negative impact, resulting in a decrease in rice productivity by 0.11 tons/feddan and a decrease in fava bean productivity by 0.03 tons/feddan. However, it had a positive impact on cotton, leading to an increase in its productivity by 0.003 tons/feddan. The study recommended further research on the impact of climate change and also addressed the influence of environmental factors on agricultural crop productivity, focusing on different varieties. The researchers recommended further studies on the impact of climate change. The two studies differ in their scope and crop type, as well as in methodology, as the second study used a standard economic

approach using panel data and a stepwise regression model (1).

A study assessed the impact of climate change on tomato productivity in Egypt, aiming to analyze the effect of climatic variables—namely temperature, relative humidity, and rainfall—on crop yield during different growing seasons. The study relied on secondary data and employed a range of statistical and econometric methods, including percentages, arithmetic means, trend estimation, and multiple regression analysis, to measure the nature of the relationship between climatic variables and agricultural productivity.

The results showed that a one-unit increase in each of the studied climatic variables led to a statistically significant decrease in Nile tomato yield, with reductions of approximately 2.12, 3.94, 1.1, and 4.30 tons/feddan, respectively. The coefficient of determination indicated that approximately 77% of the variation in crop yield was attributable to the studied climatic factors, reflecting the strength of the model used to explain the variance in productivity. The results also indicated a decline in tomato productivity in Lower Egypt and the border governorates, although the statistical significance of this decline was not definitively established. The study emphasized the importance of improving irrigation and fertilization practices, particularly during the flowering and growth stages, as well as the need to develop varieties more tolerant to harsh environmental conditions such as high temperatures, increased humidity, and rainfall fluctuations. It also recommended implementing irrigation and planting during nighttime hours to avoid heat stress, supporting technological innovation and scientific research, and increasing spending

on agricultural research, especially that related to increasing crop yield per acre (2).

One study examined the economic impact of climatic factors on mango productivity in Ismailia Governorate. It aimed to estimate the effect of climate variations during the period 2007–2022, analyzing the statistical relationship between rainfall, relative humidity, and maximum and minimum temperatures (as explanatory variables) and mango productivity (as the dependent variable).

The results showed that the cultivated area in old lands remained relatively stable, while newly reclaimed lands witnessed an increase in both area and total production. Despite this, the yield per feddan decreased in both types of land due to rising temperatures. Regarding the impact of climate variations on productivity, the study found that the higher maximum temperature in August led to a decrease in productivity of approximately 0.179 tons/feddan, and the higher minimum temperature in November also contributed to the decline. Conversely, the wider temperature range in October led to an increase in productivity of approximately 0.089 tons/feddan, reaching a production level of 0.312 tons/feddan. High humidity levels in May and August contributed to a decrease in productivity of approximately 0.054 and 0.085 tons/acre, respectively, while rainfall had a positive impact, resulting in an increase of 0.401 tons/acre.

The study recommended developing irrigation systems to mitigate the effects of rising temperatures, adopting modern agricultural technologies, and encouraging farmers to plant during October to take advantage of favorable weather conditions. It also emphasized the importance of improving ventilation methods to reduce excess humidity around trees, managing

irrigation to optimize rainwater use, and organizing training courses and awareness programs to raise farmers' awareness of the implications of climate change and how to adapt to it (3).

One study examined the economic impact of climate change on wheat productivity in Egypt during the period 1990–2021. It aimed to assess the consistency between the relationship between climate variables and wheat productivity and the findings of economic theory regarding the influence of climate on agricultural production. The study also tested for a long-term relationship between these variables using a delayed distributed autoregression (ADL) model. Furthermore, it sought to estimate the individual impact of certain climatic elements, using maximum temperature, minimum temperature, rainfall, and relative humidity as explanatory variables, and wheat productivity as the dependent variable.

The results showed a slight increase in wheat productivity in Egypt, rising from approximately 2.8 tons/feddan in 1990 to 2.88 tons/feddan in 2021. However, the growth rate exhibited a downward trend of about 2.9%, with an annual decrease of 0.008 tons, equivalent to about 0.3% of the average productivity during the study period. The results also indicated an increase in minimum temperatures from 15.3°C in 1990 to 18.4°C in 2021, an increase of approximately 20.3%, with an annual upward trend of about 0.172°C (equivalent to about 1% of the average). Similarly, maximum temperatures rose from 28.4°C to 30.3°C during the same period, an increase of 6.5%, with an annual upward trend of about 0.133°C (approximately 0.4% of the average).

The study recommended expanding the use of genetically improved seed varieties that are high-yielding and more tolerant of

changing climatic conditions, activating early warning systems to deal with emergency climatic phenomena in a way that enhances stability and food security, as well as employing modern technologies in grain storage to reduce losses, and expanding green economic projects, such as solar energy, recycling, and environmentally friendly agricultural initiatives (4).

One study analyzed the future impacts of climate change on land and water productivity for wheat in Wasit Governorate, Iraq, aiming to assess the effects of different emissions scenarios on crop yield. The study relied on a set of explanatory variables, including annual and seasonal rainfall, emissions scenarios (RCP4.5 and RCP8.5), and several global climate models: GFDL-ESM2M, CNRM-CM5, and EC-Earth. The dependent variables were wheat productivity and water productivity.

The results showed an increase in annual and seasonal rainfall during the middle and end of the century under the RCP4.5 and RCP8.5 scenarios when the GFDL-ESM2M model was applied. In contrast, the EC-Earth model recorded a decrease in rainfall under both scenarios, while the CNRM-CM5 model showed a slight increase under the RCP4.5 scenario and a decrease under the RCP8.5 scenario.

Regarding productivity, the highest wheat yield (2.36 tons/hectare) was recorded during the simulation period under the RCP8.5 scenario. Water productivity also increased compared to the reference period (2040–2050), while values converged between the reference period and the period (2020–2030). The study recommended using the

First: Short-Run Results

AquaCrop model to assess the impacts of climate change on crops, given its efficiency in simulating wheat performance under varying climatic conditions. It also emphasized the necessity of adopting more than one climate model when planning agricultural crops, due to the differences in rainfall estimates between models. This contributes to improving the accuracy of forecasts and supporting farmers' decisions in the face of climate change (5)

Research Gap

An analysis of previous studies reveals a research gap in the following aspects:

1. A scarcity of studies specifically addressing potato production in Iraq from a long-term econometric perspective.
2. The absence of a comprehensive time-series study covering more than three decades to analyze the relationship between climate change and potato productivity.
3. The concentration of most local studies on cereal crops, with limited attention given to vegetable crops despite their nutritional and economic importance.
4. The limited number of studies that distinguish between the short-term and long-term impacts of climatic factors on productivity.
5. The need for a precise quantitative assessment that determines the strength and direction of the impact, rather than relying solely on descriptive or geographical analysis.

Therefore, the current study seeks to bridge this gap by providing an integrated econometric analysis to measure the impact of climate variables on potato productivity in Iraq during the period (1990–2024).

The results showed that the CointEq(-1) coefficient = -0.2137 is statistically

significant, allowing for the interpretation of the short-term analysis, where approximately 21% of imbalances are corrected annually, and full equilibrium is reached in about 5 years. The results also indicate that potato productivity in Iraq is affected by immediate climate shocks and that the agricultural sector lacks sufficient resilience, justifying the need for technological interventions such as

greenhouses and early warning systems. The ARDL model confirms its efficiency in analyzing short- and long-term equilibrium relationships, while maintaining the reliability of the estimated coefficients and the absence of autocorrelation in the short-term residuals.

Table (1) Results of the (ARDL) model estimation for Iraq in the short period

ARDL Error Correction Regression				
Dependent Variable: D(LOGY)				
Selected Model: ARDL(2, 3, 2, 0, 0, 2, 3)				
Case 2: Restricted Constant and No Trend				
Date: 10/08/25 Time: 23:26				
Sample: 1990 2024				
Included observations: 32				
ECM Regression				
Case 2: Restricted Constant and No Trend				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.0249	-2.535598	0.081183	-0.205848	D(LOGY(-1))
0.0005	4.589871	1.038696	4.767481	D(LOGX1)
0.0000	-7.348533	0.939668	-6.905181	D(LOGX1(-1))
0.0000	-6.820728	1.013152	-6.910433	D(LOGX1(-2))
0.0001	-5.761334	15.13322	-87.18752	D(LOGX2)
0.0001	-5.497362	26.92114	-147.9952	D(LOGX2(-1))
0.0000	-7.609095	94.96055	-722.5638	D(LOGX5)
0.0380	2.308627	87.54392	202.1062	D(LOGX5(-1))
0.0969	-1.789223	130.1621	-232.8891	D(LOGX6)
0.0000	8.230075	171.3879	1410.536	D(LOGX6(-1))
0.0000	7.541847	136.0265	1025.891	D(LOGX6(-2))
0.0000	-12.78309	0.016724	-0.213780	CointEq(-1)*
67.50938	Mean dependent var		0.936446	R-squared
451.5068	S.D. dependent var		0.901491	Adjusted R-squared
13.02544	Akaike info criterion		141.7102	S.E. of regression
13.57509	Schwarz criterion		401635.8	Sum squared resid
13.20764	Hannan-Quinn criter.		-196.4071	Log likelihood
			2.586225	Durbin-Watson stat
* p-value incompatible with t-Bounds distribution.				

Table (2) shows the results of the ARDL model estimation for Iraq over the long period

ARDL Long Run Form and Bounds Test				
Dependent Variable: D(LOGY)				
Selected Model: ARDL(2, 3, 2, 0, 0, 2, 3)				
Case 2: Restricted Constant and No Trend				
Sample: 1990 2024				
Included observations: 32				
Conditional Error Correction Regression				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.0007	4.392059	2758.335	12114.77	C
0.0200	-2.649785	0.080678	-0.213780	LOGY(-1)*
0.0349	2.354473	2.272363	5.350218	LOGX1(-1)
0.0026	3.720687	46.34587	172.4385	LOGX2(-1)
0.1482	1.537201	120.4514	185.1581	LOGX3**
0.0395	-2.288415	167.5326	-383.3840	LOGX4**
0.0000	-8.338354	204.8578	-1708.177	LOGX5(-1)
0.0005	-4.624941	311.8570	-1442.320	LOGX6(-1)
0.1479	-1.538635	0.133786	-0.205848	D(LOGY(-1))
0.0110	2.960534	1.610345	4.767481	D(LOGX1)
0.0003	-4.856604	1.421813	-6.905181	D(LOGX1(-1))
0.0005	-4.636611	1.490406	-6.910433	D(LOGX1(-2))
0.0027	-3.693921	23.60298	-87.18752	D(LOGX2)
0.0161	-2.765062	53.52329	-147.9952	D(LOGX2(-1))
0.0002	-5.259710	137.3771	-722.5638	D(LOGX5)
0.1120	1.704633	118.5629	202.1062	D(LOGX5(-1))
0.2864	-1.111666	209.4956	-232.8891	D(LOGX6)
0.0001	5.749162	245.3463	1410.536	D(LOGX6(-1))
0.0002	5.195995	197.4388	1025.891	D(LOGX6(-2))
* p-value incompatible with t-Bounds distribution.				
** Variable interpreted as $Z = Z(-1) + D(Z)$.				
Levels Equation				
Case 2: Restricted Constant and No Trend				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.0083	3.110984	8.044632	25.02672	LOGX1
0.0862	1.856368	434.5129	806.6158	LOGX2
0.1761	1.430809	605.3319	866.1143	LOGX3
0.1018	-1.760642	1018.581	-1793.356	LOGX4
0.0321	-2.398924	3330.803	-7990.342	LOGX5
0.0057	-3.302295	2043.047	-6746.743	LOGX6
0.0258	2.516933	22515.21	56669.29	C
EC = LOGY - (25.0267*LOGX1 + 806.6158*LOGX2 + 866.1143*LOGX3				
-1793.3560*LOGX4 -7990.3422*LOGX5 -6746.7429*LOGX6 +				
56669.2851)				

Secondly, Long-Term Results

Table (2) The results of the long-term equilibrium equation show a clear relationship between potato productivity and climatic variations in Iraq. A 1% increase in rainfall leads to an estimated 25 unit increase in productivity, highlighting the importance of natural water resources compared to the limitations of traditional irrigation techniques. Conversely, high minimum temperatures have a significantly negative impact, increasing respiration and the consumption of stored plant material, thus drastically reducing productivity. However, extreme temperatures were not statistically significant in the long run, which may indicate farmers' ability to adapt by adjusting planting dates. The positive constant in the equation suggests the presence of technical or historical factors that support productivity regardless of

dynamic changes, while high values for some coefficients indicate oversensitivity of the model and require further data analysis to confirm the absence of multiple linear correlations. These results underscore the importance of technological interventions, such as greenhouses and early warning systems, to mitigate the impact of climatic disturbances.

Third: Autocorrelation Test

To ensure the model is free from autocorrelation issues, Table (3) shows that the F-statistic value reached (2.114) at a probability level of (0.0563), which is greater than the standard significance level of (5%). The results indicate the absence of autocorrelation according to the F-statistic, but the chi-square test indicates a weak probability of its existence.

Table (3) Self-Attachment Test

Breusch-Godfrey Serial Correlation LM Test:			
0.0563	Prob. F(2,11)	2.114476	F-statistic
0.0411	Prob. Chi-Square(2)	8.69427	Obs*R-squared

Source: Prepared by the researcher based on the outputs of the Eviews10 program.

Fourth: Heteroskedasticity Test

From Table (4), we observe that the value of the f-statistic is 0.560, while its probability level is (0.4601). This is greater than the standard significance level (5%), which indicates the rejection of the alternative hypothesis and the acceptance of the null hypothesis, which states that there is no heteroskedasticity problem.

This choice proved highly successful, as the ARCH test was specifically designed to

detect changes dependent on previous time periods and is consistent with the nature of two-dimensional data exhibiting fluctuations. The model's success in this test confirms its statistical consistency and that estimates of the impact of climate variables on potato productivity in Iraq are not misleading, allowing these results to be confidently used in formulating agricultural planning policies.

Table (4) Test for instability of homogeneity of variance

Heteroskedasticity Test: ARCH			
0.4601	Prob. F(1,29)	0.560352	F-statistic
0.4433	Prob. Chi-Square(1)	0.587642	Obs*R-squared

Source: Prepared by the researcher based on the outputs of Eviews10 software

Fifth: Model Specification and Quality

The Ramsey RESET test results showed a probability value greater than 5%, indicating no misallocation in the model. This means that the included variables (rainfall, temperature) adequately represent the factors influencing potato

yield, and that the model does not require additional nonlinear formulas. Passing the test enhances confidence in the accuracy of the economic and agricultural estimates of the variables in both the short and long term.

Table (5) Model Allocation and Quality

Ramsey RESET Test				
Equation: UNTITLED				
Specification: LOGY LOGY(-1) LOGY(-2) LOGX1 LOGX1(-1) LOGX1(-2) LOGX1(-3) LOGX2 LOGX2(-1) LOGX2(-2) LOGX3 LOGX4 LOGX5 LOGX5(-1) LOGX5(-2) LOGX6 LOGX6(-1) LOGX6(-2) LOGX6(-3) C				
Omitted Variables: Squares of fitted values				
	Probability	df	Value	
	0.1974	12	1.364711	t-statistic
	0.1974	(1, 12)	1.862437	F-statistic

Source: Researcher's work based on the outputs of the Eviews10 program

Sixth - Jarque-Bera(JB) Normal Distribution Test:

To confirm the normal distribution of the residuals for the regression equation, the Jarque-Bera(JB) test was used. Figure (1) shows the regression equation as normally distributed, where the value of

(JB) reached 0.2547 at the probability level (0.8804), which is greater than the standard significance level (5%). Therefore, we accept the null hypothesis, which states that the residuals are normally distributed

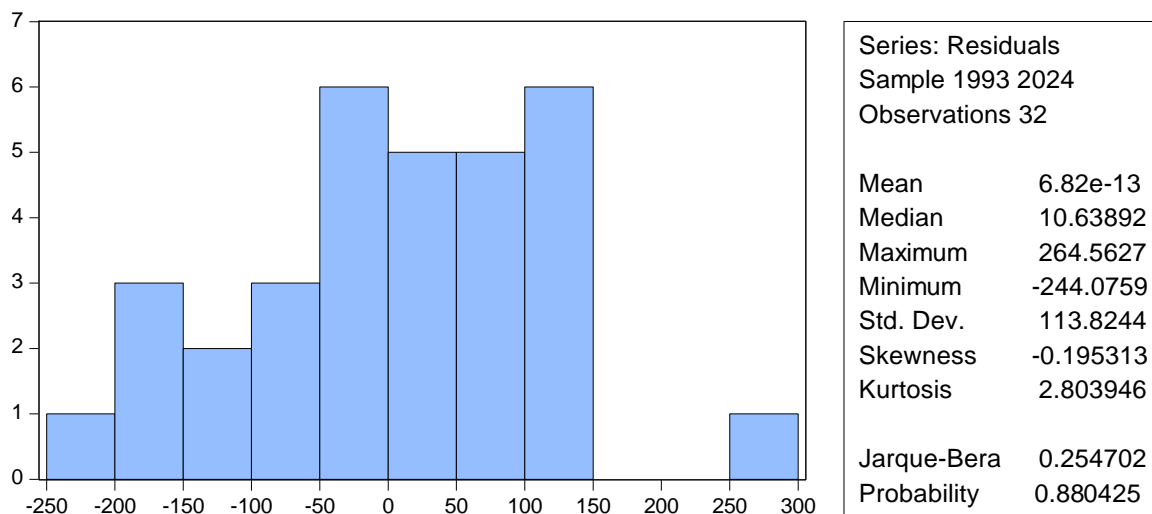


Figure (1) Prepared by the researcher using the eviews10 program

Seventh: Results of the Cointegration Test in Iraq:

To confirm the existence of a long-term equilibrium relationship between the study variables, a bounds test was conducted to verify the presence of cointegration. The results showed that the F-statistic reached (13.27686), which is greater than the critical F-value and significant at all levels except the 1% threshold (the upper limit). This indicates acceptance of the alternative hypothesis, which confirms the existence of a long-term equilibrium relationship between the variables and productivity, i.e., the presence of cointegration, and rejects the null hypothesis, which denies the existence of cointegration

Table (7) Cointegration test for the variables of the Iraqi model

Null Hypothesis: No levels relationship			F-Bounds Test	
I(1)	I(0)	Signif.	Value	Test Statistic
2.94	1.99	10%	13.27686	F-statistic
3.28	2.27	5%	6	k
3.61	2.55	2.5%		
3.99	2.88	1%		

Source: Researcher's analysis based on Views10 software

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