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Measuring the Impact of Climate Change on wheat Production in Iraq for the Period (1990- 2021)

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Abstract:

This research aims to study the impact of climate change on wheat production in Iraq during the period from 1990 to 2021. The results showed that climate change, such as high temperatures and low rainfall, contributed to a decrease in productivity. A direct relationship was found between rainfall and temperature with production, while wind speed and carbon emissions showed an inverse relationship with production. The stability of the model was confirmed using the cointegration test, and the results showed that climate factors explain 96% of the changes in wheat production. The research recommends developing policies to adapt to climate change, such as improving water management, developing drought-resistant wheat varieties, and training farmers in sustainable agricultural techniques

Keywords (Climate Change, Wheat Crop, Climate data)

Introduction

Climate change is one of the most significant challenges facing agriculture worldwide, particularly in vulnerable regions like Iraq. Iraq is characterized by a diverse agricultural environment, with wheat being a key pillar of food security and the national economy. However, in recent decades, the country has witnessed notable climate changes, including rising temperatures, increased frequency of extreme weather events, and shifts in rainfall patterns. This research aims to study the impact of these climate changes on wheat production in Iraq during the period from 1990 to 2022. Climatic and production data will be analyzed to determine the relationships between climate factors and agricultural production, and to explore how climate changes affect agriculture, especially under evolving economic and social conditions. Through this research, we seek to provide scientific insights that support policymakers and farmers in adapting to climate change and ensuring the sustainability of wheat production in Iraq.

Research Objective:

This research aims to analyze the impact of climate change on wheat production in Iraq during the period from 1990 to 2021, by studying the relationships between various climate variables and crop productivity. The research also seeks to provide strategic recommendations to help adapt to climate changes and enhance agricultural sustainability in the country.

Research Problem:

The research problem lies in understanding how climate changes, such as rising temperatures and changing rainfall patterns, affect wheat production in Iraq. Farmers face multiple challenges resulting from these changes, threatening food security and negatively impacting the local economy. Therefore, understanding this

relationship is essential for developing effective strategies to adapt to climate change.

Research Hypothesis:

The research hypothesis can be stated as follows: "Climate change negatively impacts wheat production in Iraq, as increased temperatures and changing rainfall patterns contribute to reduced productivity and deteriorating quality."

Importance of the Research:

The importance of this research arises from several aspects, most notably:

1. **Food Security**: Wheat is a crucial component of food security in Iraq. Therefore, understanding the impact of climate changes on its production is vital.
2. **Agricultural Planning**: The research provides insights into how farmers and policymakers can adapt to climate changes, contributing to improved agricultural planning and enhancing its sustainability.
3. **Climate Change Response**: The research helps identify the necessary actions to address climate challenges, thereby strengthening adaptive capacity and reducing potential negative impacts.
4. **Contribution to Academic Studies**: This research contributes to enriching scientific knowledge regarding the impact of climate change on agriculture and serves as a reference for future studies in this field. **Wheat Production in**

Iraq and Salah al-Din Governorate (1990-2022)

Table (1) shows that the average wheat production in Iraq was approximately 2,249,131.636 tons between 1990 and 2022, while the average production in Salah al-Din Governorate was 228,566.4 tons. The production witnessed significant fluctuations, with the highest production level in Iraq recorded in 2014 (5,055,000 tons) and the lowest in 1994 (854,000 tons). In Salah al-Din Governorate, the highest production occurred in 2014 (495,829 tons), and the lowest production was in 1994 (59,972 tons). The data indicates that Salah al-Din's contribution to total production increased due to improvements in production methods, with an average contribution of 6.57% in 2014. However, the lowest contribution percentage (0.80%) was recorded in 1994. The fluctuations in production are attributed to multiple factors, including climatic conditions (such as rainfall), economic conditions (such as prices), and production-related factors concerning farmer efficiency and financing. Additionally, the negative growth rates in Iraq (-0.021) and in Salah al-Din (-0.05) reflect the impact of unsupportive agricultural policies, which led to a lack of expansion in production.

Table (1): Wheat Production in Iraq and Salah al-Din Governorate for the Period (1990-2022)

Relative Importance of Production (%)	Production (tons)		Year	Relative Importance of Production (%)	Production (tons)		Year
	Salah al-Din	Iraq			**Salah al-Din**	Iraq	
3.01	226807	2808800	2011	1.20	90360	1195800	1990
5.68	428459	3062300	2012	1.01	75980	1476400	1991
5.70	429798	4178400	2013	1.55	116694	1310700	1992
6.57	495829	5055000	2014	0.98	73596	911000	1993
4.84	364921	2645000	2015	0.80	59972	854000	1994
5.98	451268	3052900	2016	1.02	76862	1091400	1995
6.25	471640	2974000	2017	1.32	99453	1150000	1996
6.35	479140	2178000	2018	1.07	80974	946700	1997
6.02	454394	4343500	2019	1.66	125051	1474900	1998
6.19	466767	3168262	2020	1.18	89006	1101600	1999
6.19	466767	3229921	2021	0.99	74846	1040300	2000
6.13	462642.7	3580561	2022	1.85	139188	2219400	2001
100.00	7542691	74221344	Total	2.62	197270	2589500	2002
	228566.4	2249131.636	Average	1.87	141098	2329200	2003
6.57	495829	5055000	Max	1.17	88377	1832100	2004
0.80	59972	854000	Min	1.52	114275	2228400	2005
				1.63	122685	2286300	2006

				1.97	148466	2202800	2007
				0.85	63805	1255000	2008
				1.73	130643	1700400	2009
				3.12	235657	2748800	2010

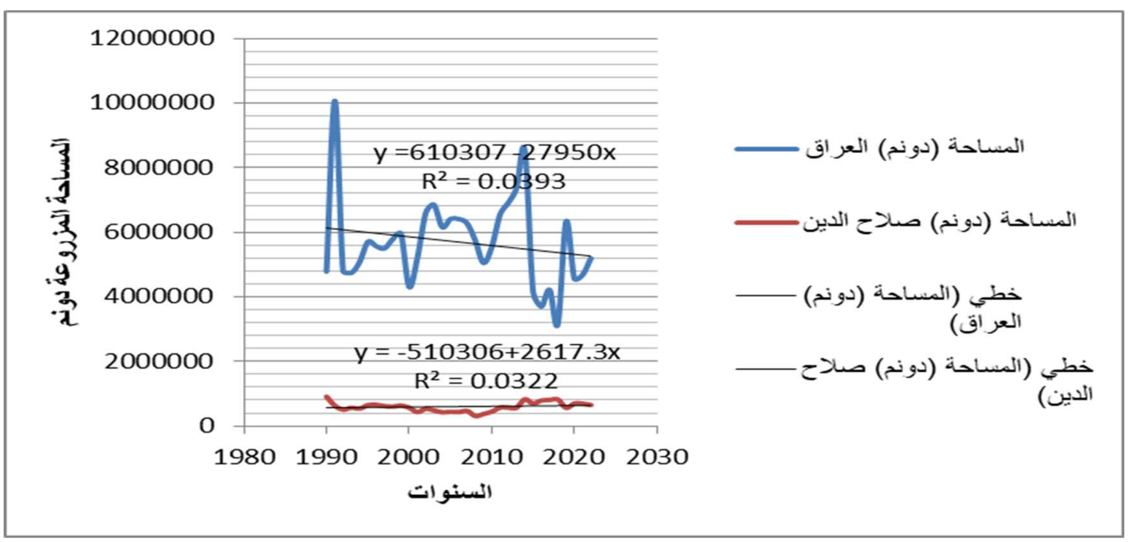
source: Prepared by the researcher based on data from the Republic of Iraq, Ministry of Planning, Central Statistical Organization.

Table (2) Growth Rates of Wheat Production at the National and Salah al-Din Governorate Levels

Salah al-Din	**Iraq**	**Period**
- 0.05	**- 0.021**	**-19902022**

Source: Prepared by the researcher based on data from Table (1).

Figure (1) The General Trend of Wheat Production in Iraq and Salah al-Din for the Period (1990-2022).



Source: Prepared by the researcher based on data from the table.

(1) The Concept of Climate

The climate of Iraq is generally arid and harsh, resembling the extreme desert climate in the southwest of the United States. Summer temperatures reach around 38°C (100°F). The weather is always dry, with no clouds, and rainfall is scarce, especially in the south. The hot summer, with temperatures exceeding 30°C, gives a simple idea of the winter climate, which is cooler than summer, with less rain and sometimes fog. It is rarely colder than summer, with temperatures sometimes dropping to 7°C (20°F). The warm weather is characterized by high temperatures, dry air, sandstorms, and low relative humidity in the afternoon. The humidity also rises in July (between 5-15%). In the southern region, near the Arabian Gulf, the city of Basra has experienced temperatures above 49°C (120°F), with high relative humidity (over 50%) during July and August. (Mansour, 2006: 67). Humidity also increases in July (between 5-15%), with warm weather characterized by high temperatures, dry air, sandstorms, and low relative humidity in the afternoon. In the southern region, the city of Basra, near the Arabian Gulf, has experienced temperatures exceeding 49°C (120°F). "In July and August, the temperature reaches 120°F with high relative humidity (over 50%). As for the mountainous areas in the far north, the summer season is slightly cooler, as these northern mountainous regions lie on the borders of Turkey and Iran, with temperatures ranging from freezing to 18°C (0-18°C) during November and April. Heavy snowfall occurs, especially at higher altitudes (4000-4500 feet, or 1219-1371 meters), which melts in the spring, causing floods in central and southern Iraq. Additionally, cloud cover in the mountainous region is more extensive in winter, and it is classified that half of the days of the year are cloudy in this area. Furthermore, rainfall is much higher than in other parts of Iraq, with an annual rainfall rate ranging from 20 to 40 inches (508 to 1016 mm), which falls between October and April." It must be noted that the scarcity of rainfall and the high temperatures make most areas of Iraq desert-like (Mazal, 1988: 124). The average annual rainfall in Iraq generally ranges between 4 and 7 inches (101 and 178 mm), with most of the rainfall occurring from early November to early April. Between December and March, rain will fall over most parts of Iraq, and thunderstorms will occur in the highest mountainous areas in the north, on the same latitude as Santiago. In the central plains of Iraq, Baghdad receives about 6 inches (150 mm) of rain from early October to April, and the rest of the year is dry, with most of the rainfall coming from thunderstorms. In the south and west of Iraq, rainfall is expected to occur in the desert regions, with less than 2 inches (51 mm) of rain annually. These areas are also exposed to intense rainstorms during the winter, although rarely (Mansour, 2006: 68). The spring season varies significantly from month to month and from year to year, and rainfall can occur during a month or just a few days on average annually. Some desert areas may not experience rain for years, but when it does rain, it may occur suddenly. When it comes to thunderstorms, particularly in the spring and fall, heavy rainfall in the winter may trigger thunderstorms in the alluvial plains. The likelihood of thunderstorms in the northern mountains of Iraq is higher than in other areas (Al-Masoudi, 2013: 47). As a maximum (secondary) limit for rainfall, it occurs in areas close to the Arabian Gulf, where it remains stationary with the semi-cylindrical wind currents that accelerate the occurrence of thunderstorms. Additionally, in the valleys of Mesopotamia, the likelihood of thunderstorms is high, as moisture from the Arabian Gulf moves northwest through its flow from the southeast, contributing to the increased occurrence of these thunderstorms (Hadi, 2013: 65). When thunderstorms occur, they often cause large dust storms that can travel hundreds of miles away from their origin. These dust storms, which are laden with dust and dirt, are locally known as "dust storms" and typically occur in the spring and fall.

Second: Features of Climate Change:

The climate of Iraq is characterized by the following general features (Murad, 2005: 34):

1. Due to the clarity of the atmosphere from clouds for most days of the year, there is a high level of solar radiation, along with the absence of air humidity.
2. Extreme temperatures resulting from the lack of marine influences, changes in the number of sunlight hours, and the angle of solar radiation during the winter and summer seasons.
3. Iraq has a continental climate, which increases the daily and annual temperature range.
4. The scarcity of rainfall and its variability across most of Iraq, as well as low relative humidity, due to its distance from oceanic influences.

Third: Factors Affecting the Climate in Iraq:

The most important factors controlling the climatic characteristics of Iraq are: (Al-Amiri, 2005: 84):

1- **Latitude Position:**

Iraq's location relative to the latitude line controls the amount of solar radiation reaching the Earth by influencing the angle of solar radiation and the theoretical number of sunlight hours. The angle of solar radiation is greater in the southern part of Iraq near the Tropic of Cancer than in the north, throughout the year. The angle of solar radiation is lowest in December and reaches its peak in June (values are recorded at the Salahaddin station in northern Iraq and the Basra station in southern Iraq). As for the theoretical number of sunshine hours, it ranges from 9.30 hours at the Salahaddin station to 10 hours in Basra during the 12 months, where it increased to 6 hours in Salahaddin in 2014 and 6.14 hours in Basra. This seasonal and spatial variation has made the summer in Iraq hotter than winter and has made the southern region hotter than the northern region.

2- **Relative Location of the Sea:**

Iraq is bordered by five seas, but only the Mediterranean Sea and the Arabian Gulf influence its climate.

- The Mediterranean Sea, located 450-1200 km from different regions of Iraq, is the main influence on Iraq's climate, as it is the area where atmospheric depressions form in the Mediterranean Sea. These depressions affect the country from the 5th to the 10th month, leading to rainfall (Al-Masoudi, 2013: 23).

- The Arabian Gulf is a small body of water with a minimal impact. Iraq is exposed to its influence during both cold and hot seasons, with warm, humid southern winds that increase humidity and temperatures, especially in southern Iraq (Abd Al-Al, 2013: 45).

3- **Topography:**

The topography of Iraq is one of the factors that clearly affect the spatial changes in its climatic characteristics. The elevation above sea level has a significant impact on the monthly and annual temperature rates, which gradually decrease as one moves from southern Iraq to the north. Additionally, the rising terrain influences rainfall, which increases as one moves from southern Iraq toward the north and northeast

4- **Air Masses:**

The air masses affecting the climate of Iraq vary according to the seasons of the year. During the cold season, Iraq is exposed to low-pressure weather effects as follows (Saleh, 2009: 25-26):

- **Continental Polar Air Masses**: These come from Siberia and enter Iraq from the north and northeast, accompanied by extremely low temperatures, low humidity, clear skies, and no precipitation.
- **Maritime Polar Air Masses**: These come from the North Atlantic and enter Iraq from the northwest, characterized by cold temperatures, high humidity, and more rainfall compared to the previous air masses.
- **Maritime Tropical Air Masses (MT)**: These originate over the Indian Ocean, move towards the Arabian Gulf, and enter Iraq from the southeast. They are characterized by high temperatures, high humidity, and bring warmth and rainfall during the hot season.

5- **Maritime Tropical Air Masses (MT)**

6- **Continental Tropical Air Masses (CT)**: These originate over the Sahara Desert and the deserts of the Arabian Peninsula, entering Iraq from the west and southwest. They lead to high temperatures and dominance of hot, dry conditions.

The topography of Iraq is one of the factors that clearly affect the spatial changes in its climatic characteristics. The elevation above sea level has a significant impact on the monthly and annual temperature rates, which gradually decrease as one moves from southern Iraq to the north. Additionally, the rising terrain influences rainfall, which increases as one moves from southern Iraq toward the north and northeast. 7-

(7) -Drought and Dust Triggering

- **Atmospheric Depressions:**

Front depressions occur in the North Atlantic and move eastward within the scope of opposing winds, some of which pass over the Mediterranean Sea during the cold season. Due to the dominance of low-pressure areas, these regions become favorable for the formation and development of Mediterranean depressions, following three main directions towards the eastern Mediterranean (Al-Zubaidi, 1999: 23):

- The first direction: affects the northeastern and northern areas of Iraq.
- The second direction: affects the eastern, northern, and central parts of Iraq.
- The third direction: heads southeast towards the Arabian Gulf, passing through the central and southern regions of Iraq.

As these depressions enter the country, there are noticeable changes in atmospheric pressure, wind direction and speed, temperature changes, and rainfall. However, due to the shift of the polar front northward over several months (from 6 to 9 months), the path of these depressions moves away from the Mediterranean Sea through Europe, leading to the disruption of the depression patterns in the Mediterranean and the spread of drought during those months. Indian summer cyclones are concentrated in the Arabian Gulf and southern Iraq, which helps increase the frequency of northwestern winds (Khalaf, 2010: 57). The aforementioned factors affect the climatic characteristics of Iraq, varying from place to place and seasonally. Several climatic elements, such as temperature, atmospheric pressure, winds, and rainfall, show varying characteristics.

- **Temperature:** The temperature varies seasonally and spatially in Iraq. During winter, the temperature drops across the country due to the small angle of solar radiation. The theoretical number of daylight hours is reduced, and the actual duration of sunlight decreases due to the presence of fewer clouds. This results in a small amount of solar radiation reaching the Earth's surface, leading to the frequency of polar air masses with a drop in temperature. Temperatures record their lowest levels during the month, which is one of the coldest months of the year. These rates gradually decrease as we move northward (Murad, 2005: 7). This decrease is due to Iraq's location relative to the latitude line and the elevation above sea level. Due to the large number of winter nights, temperatures in the mountainous areas drop below 0°C, causing frost phenomena that damage crops, especially fruit trees.

During the hot season, temperatures rise across Iraq because sunlight strikes the Earth at an angle close to vertical, increasing the theoretical hours of sunlight, while the atmospheric transparency and humidity from the clouds are low. This leads to more solar radiation reaching the Earth's surface, thereby increasing heating. Additionally, the dominance of continental tropical air masses results in a rise in temperature (Al-Fatlawi, 2010: 25).

Due to the elevation above sea level, the temperature gradually decreases as you move from south to north and from east to west in Iraq. The daily temperature range is large, and the temperature in July (month 7) is less humid than in January (month 1). Due to the lack of clouds, daytime heating increases, and the rate of heat loss due to terrestrial radiation at night is higher. The temperature peaks in January (month 1) and July (month 7), with July being the hottest month of the year. The average maximum temperature exceeds 615 meters in most central and southern areas, except for the humid stations, which reached 384 meters due to elevation above sea level, where the average maximum temperature reaches 43 meters.

At this stage, the study variables that make up the standard model are described. Therefore, the function for the first model (climatic model) will be as follows:
Y = F(X1, X2, X3, X4, X5)……………………………(1)

Where:
Y: Represents the dependent variable, represented by agricultural output, expressed as the agricultural sector's share of the GDP.
X1: Represents the annual rainfall rate (mm/year).
X2: Represents the annual temperature rate (°C).
X3: Represents the annual humidity rate (%).
X4: Represents the annual wind speed rate (km/hour).
X5: Represents the actual annual solar radiation (sunshine hours/day).
X6: CO_2 emissions.

Table (3) shows the data related to wheat production in Iraq from 1990 to 2021, along with its correlation to climatic and environmental factors. Below are the key economic points extracted from the data:

1. **Production shows clear fluctuations over the years**, reaching its highest level in 2014 (5,055,000 tons) and its lowest level in 1994 (854,000 tons). This fluctuation reflects the impact of climatic factors such as rainfall and temperatures, in addition to agricultural policies and market conditions.
2. **Annual rainfall rates range between 0.22 mm** (in 2019) and **64.97 mm** (in 2006). This variation in rainfall directly affects wheat production, as reduced rainfall leads to a lack of moisture necessary for crop growth.
3. **Temperatures range between 83.15°C** (in 1992) and **98.57°C** (in 2010). The continuous rise in temperatures can negatively affect crop productivity, requiring farmers to adapt by using better agricultural techniques.
4. **The table shows that the humidity rate fluctuates between 123.19% and 161.65%**. This variation reflects changing weather conditions, as high humidity can lead to fungal problems, while low humidity can negatively affect growth.
5. **Wind speed remained relatively stable**, while **solar brightness ranged between 7.608 hours** (in 1992) and **8.667 hours** (in 2010). Good solar brightness is considered beneficial for plant growth, but it requires balance with other factors to ensure crop success.
6. **The growth rate of production is -0.044**, indicating a decline in production over the years. This suggests that Iraq is facing challenges in sustaining wheat production, which may be due to weak agricultural policies, inefficiency in agricultural practices, or climatic impacts.

Table (3): Climatic Changes for Wheat Production in Iraq from 1990 to 2021.

Actual Solar Brightness (hours/day)	Wind Speed (km/h)	Humidity (%)	Annual Temperature (°C)	Annual Precipitation (mm/year)	Wheat Production (tons)	Year
8.658	**19.37**	**132.86**	**90.57**	**36.03**	**1195800**	**1990**
8.117	**19.32**	**148.93**	**89.17**	**50.37**	**1476400**	**1991**
7.608	**19.8**	**148.79**	**83.15**	**53.89**	**1310700**	**1992**
7.867	**20.07**	**147.15**	**88.54**	**55.52**	**911000**	**1993**
7.975	**19.47**	**150.54**	**92.1**	**64.58**	**854000**	**1994**
8.667	**19.56**	**142.9**	**90.41**	**39.75**	**1091400**	**1995**
8.25	**20.52**	**149.19**	**93.5**	**62.08**	**1150000**	**1996**
8.25	**19.74**	**152.7**	**88.2**	**57.8**	**946700**	**1997**
8.25	**20.45**	**139.16**	**94.1**	**45.07**	**1474900**	**1998**
8.25	**20.21**	**123.19**	**95.38**	**24.96**	**1101600**	**1999**
8.25	**20.29**	**130.64**	**92.03**	**43.46**	**1040300**	**2000**
8.508	**20.18**	**141.35**	**92.85**	**54.25**	**2219400**	**2001**
8.4	**20.29**	**139.82**	**91.4**	**51.22**	**2589500**	**2002**
8.073	**19.9**	**142.67**	**91.61**	**54.64**	**2329200**	**2003**
8.208	**20.27**	**143.19**	**91.36**	**63.65**	**1832100**	**2004**
8.455	**19.74**	**135.86**	**91.28**	**49.97**	**2228400**	**2005**
8.355	**20.48**	**143.19**	**91.91**	**64.97**	**2286300**	**2006**
8.225	**20.16**	**136.9**	**92.26**	**51.89**	**2202800**	**2007**
8.305	**20.09**	**129.4**	**91.97**	**41.84**	**1255000**	**2008**
7.986	**19.74**	**141.85**	**91.6**	**43.43**	**1700400**	**2009**
8.231	**20.48**	**128.54**	**98.57**	**41.51**	**2748800**	**2010**
8.301	**19.77**	**138.62**	**89.74**	**39.35**	**2808800**	**2011**
7.878	**19.85**	**139.34**	**93.55**	**47.26**	**3062300**	**2012**
8.435	**19.49**	**149.93**	**89.65**	**56.61**	**4178400**	**2013**
8.089	**19.91**	**148.56**	**93.29**	**47.67**	**5055000**	**2014**
7.615	**20.09**	**144.88**	**94.18**	**62.93**	**2645000**	**2015**

7.883	**19.47**	**140.46**	**92.77**	**58.51**	**3052900**	**2016**
8.151	**19.89**	**129.54**	**94.48**	**30.33**	**2974000**	**2017**
7.781	**19.48**	**157.73**	**96.13**	**0.26**	**2178000**	**2018**
8.333	**19.87**	**161.65**	**92.28**	**0.22**	**4343500**	**2019**
8.167	**19.75**	**149.64**	**94.3**	**10.27**	**3165166.667**	**2020**
8.383	**19.7**	**156.34**	**94.24**	**11.26**	**3228888.889**	**2021**
8.312	**19.76**	**155.87**	**93.62**	**10.76**	**2,764,692**	**2022**
270.216	**397.89**	**2874.16**	**1858.79**	**43.22151515**	**73401347.56**	Total
8.188363636	**19.8945**	**143.708**	**92.9395**	**39.3665**	**2224283.259**	Max
8.667	**20.52**	**161.65**	**98.57**	**43.22151515**	**5055000**	Min
7.615	**19.32**	**128.54**	**89.65**	**0.22**	**0.044**	Growth

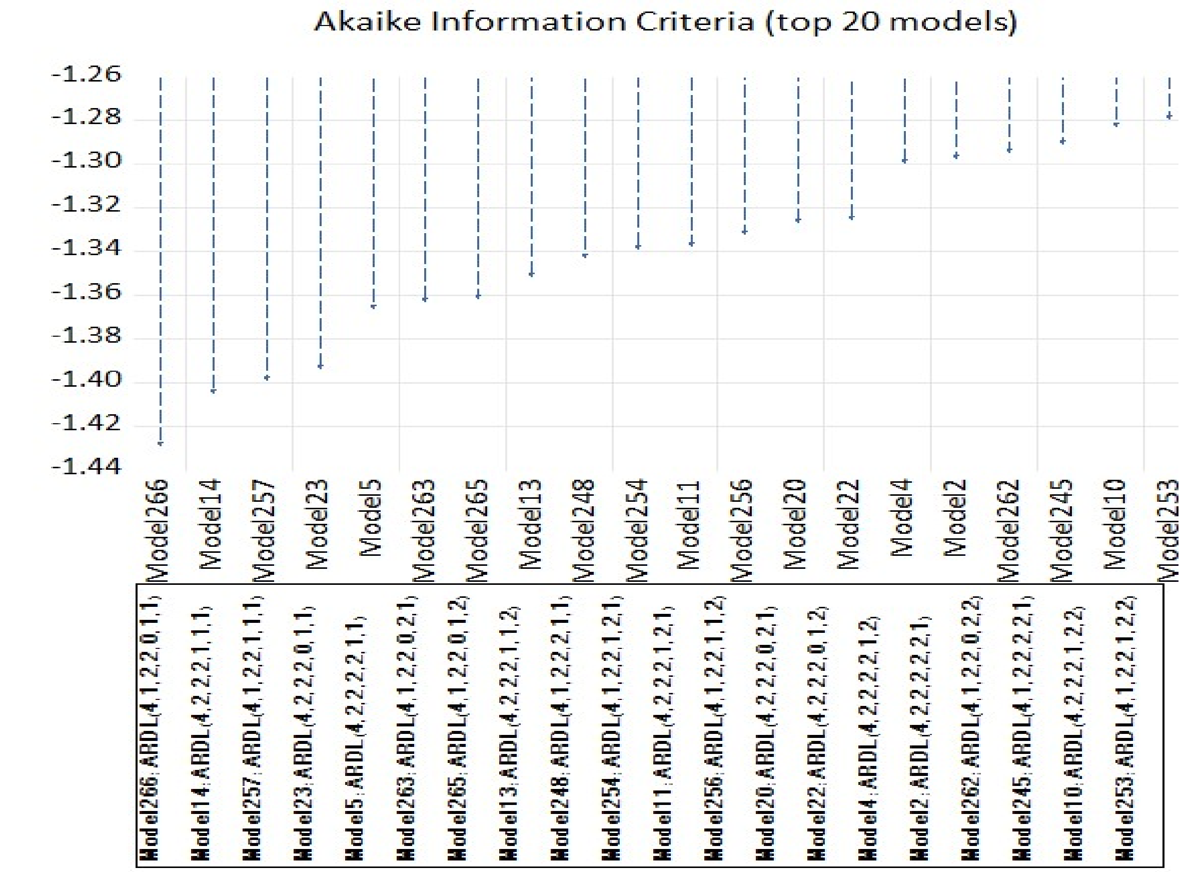
Source: Iraqi Meteorological and Seismological Organization.

Results of the Economic and Econometric Analysis of the Climatic Factors Affecting Wheat Production in Iraq for the Period (1990-2022)

To estimate the climatic factors affecting wheat production in Iraq during the period (1990-2022), the following steps of quantitative analysis must be followed:

Determining the Optimal Lags Periods:

There are several criteria used to determine the optimal lag periods for the model, and using the (AIC) criterion, the model that will be chosen when applying the (ARDL) methodology is (4.1.2.2.0.1,1). The optimal lag period is selected based on the lowest value of this criterion, and figure (3) illustrates this (Pesaran & Smith, 2001: 291-293).



"Figure (3) Results of the Lag Periods According to the AIC Criterion"

Source: Prepared by the researcher based on the outputs of the Eviews12 software"

"Preliminary estimation of the Autoregressive Distributed Lag (ARDL) model:

After verifying the stationarity of the time series for the variables using unit root tests, we proceed with the preliminary estimation of the Autoregressive Distributed Lag (ARDL) model using the statistical software (Eviews12). As shown in Table (4), the value of the adjusted R-squared (Adjusted R2) is 0.96, which means that the independent variables included in the estimated model explain about 96% of the variation in the dependent variable. This indicates that the explanatory factors have the largest impact on the function, while the remaining 4% is unexplained and attributed to variables not included in the model, with their effects absorbed by the stochastic variable. (Christian & Zeileis, 2020: 115-120)"

"Table (4) Preliminary estimation results of the (ARDL) model

Dependent Variable: LNY
Method: ARDL
Date: 05/05/24 Time: 19:06
Sample (adjusted): 1994 2022
Included observations: 29 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LNX1 LNX2 LNX3 LNX4 LNX5 LNX6
Fixed regressors:
Number of models evalulated: 2916
Selected Model: ARDL(4, 1, 2, 2, 0, 1, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNY(-1)	0.598922	0.100102	5.983087	0.0001
LNY(-2)	-0.036815	0.134900	-0.272908	0.7896
LNY(-3)	-0.088922	0.127691	-0.696388	0.4995
LNY(-4)	0.316054	0.096983	3.258853	0.0068
LNX1	0.203272	0.029754	6.831813	0.0000
LNX1(-1)	-0.139241	0.024294	-5.731383	0.0001
LNX2	3.582460	1.302546	2.750352	0.0176
LNX2(-1)	-1.503357	0.989580	-1.519188	0.1546
LNX2(-2)	2.988096	1.169826	2.554308	0.0253
LNX3	2.346978	0.543322	4.319682	0.0010
LNX3(-1)	-1.551522	0.562698	-2.757291	0.0174
LNX3(-2)	-3.619839	0.502744	-7.200169	0.0000
LNX4	-2.513597	2.185113	-1.150328	0.2724
LNX5	3.934374	1.001719	3.927624	0.0020
LNX5(-1)	-5.295099	1.275299	-4.152047	0.0013
LNX6	-1.551480	0.252660	-6.140582	0.0001
LNX6(-1)	1.931340	0.294687	6.553872	0.0000

R-squared	0.983733	Mean dependent var	14.60327
Adjusted R-squared	0.962043	S.D. dependent var	0.526058
S.E. of regression	0.102490	Akaike info criterion	-1.428077
Sum squared resid	0.126051	Schwarz criterion	-0.626558
Log likelihood	37.70711	Hannan-Quinn criter.	-1.177051
Durbin-Watson stat	1.905043		

*Note: p-values and any subsequent tests do not account for model

Source: Prepared by the researcher based on the outputs of the (Eviews12) program."

"Cointegration Test Using the Bounds Testing Approach

To verify the existence of cointegration, which indicates a long-term equilibrium relationship between the study variables, the cointegration test will be conducted using the bounds testing approach (Pesaran et al., 2001: 289-326). This test relies on the F-statistic. We reject the null hypothesis (H0: b = 0), which asserts that there is no cointegration between the variables in the model, in favor of the alternative hypothesis (H1: b ≠ 0), which suggests that there is cointegration between the variables. From Table (5), we observe that the calculated F-statistic is (10.57), which is greater than the critical F-values at both the lower and upper bounds. This means that we reject the null hypothesis (H0: b = 0) and accept the alternative hypothesis (H1: b ≠ 0), indicating the existence of a long-term equilibrium relationship (cointegration) between the variables under study."**

"Table (5) Results of the Cointegration Test Using the Bounds Testing Approach"(bounds testing)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	10.57841	10%	1.75	2.87
k	6	5%	2.04	3.24
		2.5%	2.32	3.59
		1%	2.66	4.05

"Source: Prepared by the researcher based on the outputs of the Eviews12 software."

"Estimation and Interpretation of the Short- and Long-Term Relationship Model According to the ARDL Model:

As shown in Table (6), the coefficient of the independent variable, annual rainfall rate (mm/year) (LnX1), is (0.203). This indicates a direct relationship between the annual rainfall rate and wheat production. That is, a 1% increase in the annual rainfall rate will lead to a 0.203% increase in wheat production. This variable was statistically significant at the 1% significance level. In the long run, the direct relationship between rainfall rate and wheat production remained unchanged (Hamilton, 1994: 570–575). "As for the coefficient of the independent variable, the annual temperature rate (°C) (LnX2), it is (3.582). This indicates a positive relationship between the annual temperature and wheat production. That is, a 1% increase in the annual temperature rate will lead to a 3.582% increase in wheat production. This is consistent with economic logic, and this variable is statistically significant at the 5% significance level. In the long term, we observe that the positive relationship between temperature rate and wheat production in Iraq remains unchanged. Furthermore, the coefficient of the independent variable, the annual humidity rate (%) (LnX3), is (2.346)." "This indicates a positive relationship between humidity rate and wheat production. That is, a 1% increase in the humidity rate will lead to a 2.346% increase in wheat production. This is consistent with economic logic, and the variable is statistically significant at the 1% significance level. However, in the long term, we observe that the relationship between humidity rate and wheat production becomes inverse. (Greene, 2018: 510-515). It was found that the coefficient of the independent variable, the wind speed rate (km/hour) (LnX4), is (-2.513), indicating an inverse relationship between wind speed rate (km/hour) and wheat production. That is, a 1% increase in wind speed rate (km/hour) will lead to a 2.513% decrease in wheat production. This is consistent with economic logic, but the significance of this variable was not observed at the 5% significance level. Furthermore, the coefficient of the independent variable, actual solar brightness (annually, hours of sunlight per day) (LnX5), is (3.934), indicating a positive relationship between actual solar brightness and wheat production. "There is a positive relationship between actual solar brightness (annually, hours of sunlight per day) and wheat production. That is, a 1% increase in actual solar brightness will lead to a 3.934% increase in wheat production in Iraq. The significance of this variable was observed at the 1% significance level in the short term, but its significance was not observed in the long term.

It was found that the coefficient of the independent variable, carbon dioxide emissions (kiloton) (LnX6), is (-1.551), indicating an inverse relationship between carbon dioxide emissions (kiloton) and wheat production. That is, a 1% increase in carbon dioxide emissions will lead to a 1.551% decrease in wheat production. This is consistent with economic logic and is statistically significant at the 1% significance level, but its significance was not observed in the long term.

Table (6): Estimation of the Error Correction Model and Short- and Long-Term Relationships According to the (ARDL) Model."

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNY(-1)*	-0.210762	0.066877	-3.151498	0.0084
LNX1(-1)	0.064031	0.022328	2.867735	0.0141
LNX2(-1)	5.067198	1.635544	3.098173	0.0092
LNX3(-1)	-2.824382	0.796831	-3.544517	0.0040
LNX4**	-2.513597	2.185113	-1.150328	0.2724
LNX5(-1)	-1.360725	1.570336	-0.866519	0.4032
LNX6(-1)	0.379860	0.230100	1.650844	0.1247
D(LNY(-1))	-0.190316	0.114698	-1.659287	0.1229
D(LNY(-2))	-0.227132	0.088859	-2.556084	0.0252
D(LNY(-3))	-0.316054	0.096983	-3.258853	0.0068
D(LNX1)	0.203272	0.029754	6.831813	0.0000
D(LNX2)	3.582460	1.302546	2.750352	0.0176
D(LNX2(-1))	-2.988096	1.169826	-2.554308	0.0253
D(LNX3)	2.346978	0.543322	4.319682	0.0010
D(LNX3(-1))	3.619839	0.502744	7.200169	0.0000
D(LNX5)	3.934374	1.001719	3.927624	0.0020
D(LNX6)	-1.551480	0.252660	-6.140582	0.0001

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 1: No Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNX1	0.303806	0.141119	2.152833	0.0524
LNX2	24.04228	9.522646	2.524747	0.0267
LNX3	-13.40081	5.548212	-2.415339	0.0326
LNX4	-11.92624	10.53492	-1.132067	0.2797
LNX5	-6.456217	7.484645	-0.862595	0.4053
LNX6	1.802316	1.085458	1.660420	0.1227

EC = LNY - (0.3038*LNX1 + 24.0423*LNX2 -13.4008*LNX3 -11.9262*LNX4 -6.4562*LNX5 + 1.8023*LNX6)

Source: Prepared by the researcher based on the outputs of the (Eviews12) program."

It is evident from Table (7) that the error correction term has a value of (-0.210) and is significant at the 1% level. This satisfies the necessary and sufficient condition, meaning that the short-term disequilibrium (imbalance) in wheat production can be corrected towards the long-term equilibrium relationship. 4.76 = 1 / 0.210 = ECM, which indicates that it would take four years and seven months to return to the equilibrium state.

Table (7) Error Correction Term

ARDL Error Correction Regression
Dependent Variable: D(LNY)
Selected Model: ARDL(4, 1, 2, 2, 0, 1, 1)
Case 1: No Constant and No Trend
Date: 05/05/24 Time: 19:17
Sample: 1990 2022
Included observations: 29

ECM Regression
Case 1: No Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNY(-1))	-0.190316	0.059145	-3.217796	0.0074
D(LNY(-2))	-0.227132	0.059973	-3.787242	0.0026
D(LNY(-3))	-0.316054	0.066997	-4.717441	0.0005
D(LNX1)	0.203272	0.019492	10.42857	0.0000
D(LNX2)	3.582460	0.730971	4.900960	0.0004
D(LNX2(-1))	-2.988096	0.616427	-4.847444	0.0004
D(LNX3)	2.346978	0.341508	6.872396	0.0000
D(LNX3(-1))	3.619839	0.320278	11.30217	0.0000
D(LNX5)	3.934374	0.637954	6.167176	0.0000
D(LNX6)	-1.551480	0.184132	-8.425922	0.0000
CointEq(-1)*	-0.210762	0.019998	-10.53913	0.0000

R-squared	0.961942	Mean dependent var	0.038281
Adjusted R-squared	0.940799	S.D. dependent var	0.343931
S.E. of regression	0.083683	Akaike info criterion	-1.841870
Sum squared resid	0.126051	Schwarz criterion	-1.323240
Log likelihood	37.70711	Hannan-Quinn criter.	-1.679441
Durbin-Watson stat	1.905043		

* p-value incompatible with t-Bounds distribution.

Source: Prepared by the researcher based on the outputs of the Eviews12 software."

Diagnostic Tests:

After obtaining the short-term and long-term relationship for wheat production using the (ARDL) model, we will evaluate the model to assess the efficiency of the model used, through the following diagnostic tests:

Autocorrelation Test:

This test is used to verify that the model is free from autocorrelation issues (serial correlation between values) using the Wooldridge test (2016). According to Table (8), the model does not suffer from an autocorrelation problem, as the F-statistic value is (0.486) with a p-value of (0.628), which is greater than (5%). Therefore, we can accept the null hypothesis stating that there is no serial autocorrelation issue between the residuals.

Table (8) Breusch-Godfrey Serial Correlation LM Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.486989	Prob. F(2,10)	0.6283
Obs*R-squared	2.573850	Prob. Chi-Square(2)	0.2761

Source: Prepared by the researcher based on the outputs of the program (Eviews12).

Heteroskedasticity Test

This test is used to check whether the estimated models suffer from the problem of heteroskedasticity. According to Gujarati (2003), the results in Table (9) show that the model does not suffer from heteroskedasticity, as the F-statistic value is (0.567) with a probability level of (0.743), which is greater than (5%). Therefore, we can accept the null hypothesis, which states that there is no heteroskedasticity problem.

Table (9) Heteroskedasticity Test: For the Null Hypothesis of Homoscedasticity

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	0.567065	Prob. F(17,11)	0.8580
Obs*R-squared	13.54465	Prob. Chi-Square(17)	0.6990
Scaled explained SS	2.322117	Prob. Chi-Square(17)	1.0000

Source: Prepared by the researcher based on the outputs of the (Eviews12) program.

Model Adequacy Test in Terms of Functional Form: Ramsey Reset Test

Through the **Ramsey Reset Test**, we can assess the adequacy of the model in terms of its functional form. As shown in Table (10), the value of its **F-statistic** is (0.14) with a significance level of (0.709), which is greater than (5%). Therefore, this model is acceptable, and we can accept the null hypothesis that the model does not suffer from an issue of functional form mis-specification. (Breusch & Pagan, 2021: 257-254)

Table (10) Ramsey Reset Test for Model Adequacy in Terms of Functional Form.

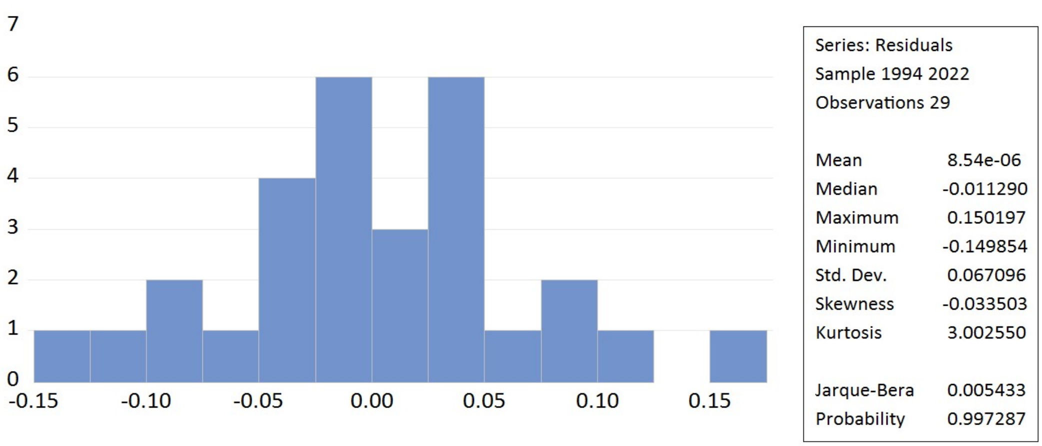
Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: LNY LNY(-1) LNY(-2) LNY(-3) LNY(-4) LNX1 LNX1(-1) LNX2 LNX2(-1) LNX2(-2) LNX3 LNX3(-1) LNX3(-2) LNX4 LNX5 LNX5(-1) LNX6 LNX6(-1)

	Value	df	Probability
t-statistic	0.381796	11	0.7099
F-statistic	0.145768	(1, 11)	0.7099
Likelihood ratio	0.381774	1	0.5367

Source: Prepared by the researcher based on the outputs of the (Eviews12) program.

Jarque-Bera (JB) Normality Test for Residuals:
To verify the normal distribution of the residuals of the regression equation, the Jarque-Bera (JB) test is used. As shown in Figure (4), the regression equation's residuals are normally distributed, with the JB value being (0.0054) at a significance level of (0.997), which is greater than (5%). Therefore, we accept the null hypothesis that the residuals of the model follow a normal distribution (Stock & Watson, 2019: 383-385)

Figure (4) Jarque-Bera (JB) Test for Normal Distribution of Residuals.



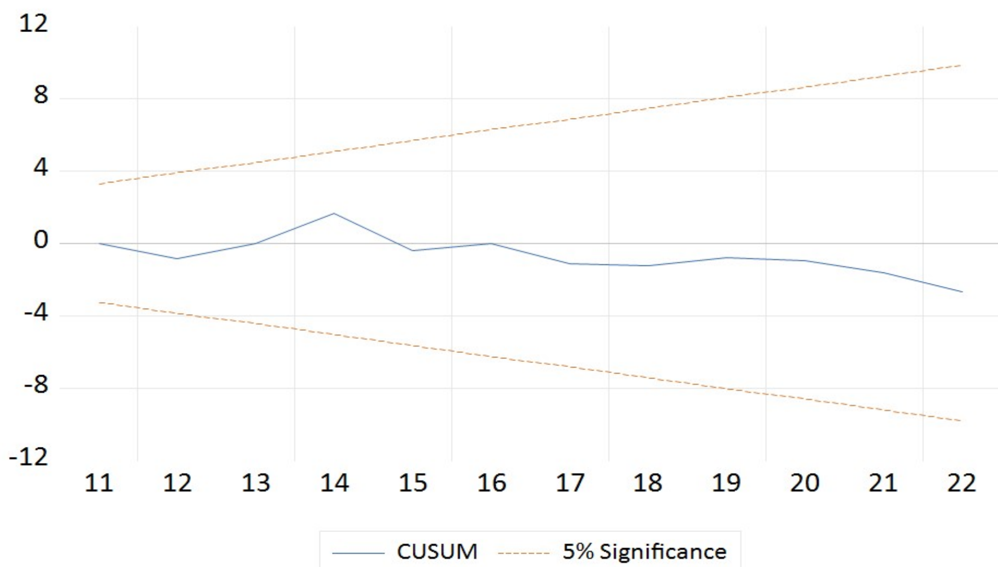
Source: Prepared by the researcher based on the outputs of the (Eviews12) program.

Stability Test of the Estimated Model Using the CUSUM Squares Test

CUSUM: The structural stability test of the estimated ARDL model for short- and long-term relationships is conducted using the cumulative sum of residuals (CUSUM) and the cumulative sum of squared residuals (CUSUM sum of squares). These are essential tests in this field because they confirm two important things: ensuring that the data used in the study is free from structural changes and assessing the consistency and stability of short-term parameters with long-term parameters. Such tests are always associated with the Autoregressive Distributed Lag (ARDL) model. If the graphs of both tests lie within the critical boundaries at the 5% significance level, it indicates that all estimated parameters are stable and there are no structural changes. Figure (5) shows the cumulative sum of residuals, where the graph falls within the critical boundaries at the 5% significance level, indicating no structural changes and the alignment of long-term parameters with short-term ones. Figure (6) shows the cumulative sum of squared residuals (CUSUM Sq.), demonstrating that the parameters were stable throughout the study period, indicating no structural changes in wheat production.

(Wooldridge, 2020: 621-623)

Figure (5) CUSUM Test for Model Stability



Source: Prepared by the researcher based on the outputs of the (Eviews12) program.

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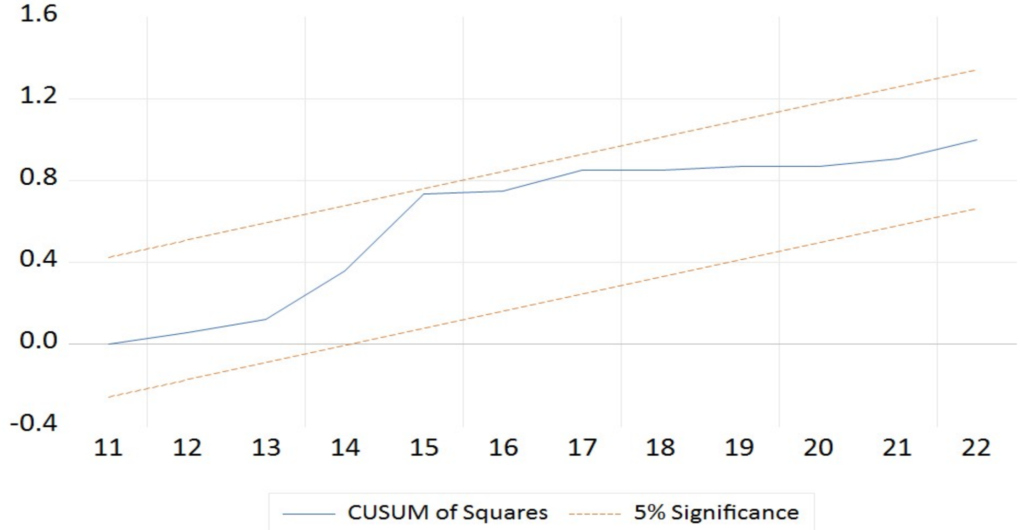
Figure (6) CUSUM Sq. Test for Model Stability



Source: Prepared by the researcher based on the outputs of the (Eviews12) program.

Conclusions:

1. **Impact of Climate on Agricultural Production:** Climate changes in Iraq, such as increasing temperatures and fluctuating rainfall, negatively affect wheat production, reducing productivity and crop quality.
2. **Fluctuation in Production:** Iraq has witnessed fluctuations in wheat production, with increases and decreases due to climatic and economic factors, including a significant drop in some years, such as 1994.
3. **Role of Agricultural Policies:** Current agricultural policies are insufficient to tackle the climate challenges, and traditional farming practices may be inadequate.
4. **Declining Productivity:** The decline in wheat productivity, with a negative growth rate of (-0.044), poses a threat to food security in Iraq.
5. **Climatic Factors:** There is a direct relationship between rainfall, temperature, and production in the short term, while high humidity and wind speed lead to decreased production.
6. **Stability and Model:** The stable economic model explains about 96% of the changes in production, with an adjustment period of about four and a half years for equilibrium after short-term disturbances.

Recommendations:

1. **Strengthening Climate Adaptation Policies:** Develop agricultural policies that support drought and heat resistance technologies, such as modern irrigation systems and the cultivation of wheat varieties resistant to harsh climatic conditions.

2. **Improving Water Resource Management:** Implement water-saving irrigation techniques and enhance water storage to address water scarcity.
3. **Investing in Agricultural Research and Development:** Increase research efforts to develop wheat varieties that can withstand high temperatures and are more resistant to diseases.
4. **Farmer Training:** Provide training programs for farmers on sustainable farming techniques and weather data analysis to adapt to climate changes.
5. **Enhancing Public-Private Sector Collaboration:** Strengthen collaboration to ensure agricultural sustainability in Iraq and address climate and economic challenges.
6. **Using Geographic Information System (GIS) Technologies:** Use GIS technologies to monitor climate changes and better plan agricultural activities.
7. **Raising Awareness on Food Security:** Increase awareness about the importance of food security and the impact of climate change on agricultural production.

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