Assessment of the Link Between Climate Change and Rice Crop Output in Iraq (1995–2022)

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Abstract:

Climatic-change effects on rice output in Iraq in 1995-2022 is studied in this study, which uses annual time series and appropriate econometric methods based on the EViews 10 software to assess the connection between rice production and a number of major climate indicators including temperature, rainfall, relative humidity and wind speed, and how they have been affected over the years and in what proportion the relationship is over short and long horizons. This remains an important issue because the rice crop is very important in terms of economic and agricultural growth and farmers' economic and agricultural output in Iraq, and as well as because it is sensitive to changes in climate in its production and growth, flowering and grain-formation process for rice plants (and climate change affects production.) So the climatic-change effects on rice output and climate change is crucial for agricultural planning and sustainable development in this context.

The year 1995-2022 data for all climatic variables and rice production and the effects of the climatic factors on rice production were used to determine the magnitude and nature of the climate factors on rice output. The observed positive correlation between the rainfall levels and crop yield indicates that the water of rice is sufficient to support the plant's water needs in its different stages of growth. The correlation between wind speed and rice yield is opposite, as high wind speed leads to crop loss of moisture and vegetative and reproductive effects with it, and impacts on production efficiency and grain growth. The results showed that temperature plays a crucial role in rice crop production, and this influence depends on the level of alignment between temperature and the plant's environmental and physiological needs in its different stages of growth. The relative humidity (in the range of the crop's need) is found to be improved in rice production, and it indicates that various climatic factors should be balanced to create the environment within which rice grows and can complete production stages well. To investigate the long-term equilibrium relationship among the factors in study we have used cointegration method to test the long-term relation between climatic factors and rice crop production. The long-term equilibrium relation between climate variables and crop production has been found in the econometric analysis. The impacts of climate change are not restricted to short-term fluctuations in production but rather impact the crop's long-term production direction. Therefore, to improve agriculture adaptation and rice production sustainability, climate variables must be incorporated into the future agricultural policy and strategy in Iraq.

Keywords: Modern irrigation techniques, climatic factors, rice production, temperatures, rainfall, annual data.

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Introduction

optimal planting and harvesting times, and variety selection in light of environmental conditions. It also helps develop strategies to minimize the effects of climate change. Thus, studying climatic influence on rice production is a critical aspect of agricultural and climate research, providing scientific indicators that help understand the relationship between climatic variables and agricultural output, thereby strengthening the resilience of agricultural systems to climate change in the future and supporting the sustainability of agricultural systems and their resource use in the medium and long term.

Section One: Research Methodology

1: Research Objective

The purpose of this research is to analyze climate-change effects on rice output in Iraq from 1995 to 2022 by studying the relation between crop production and key climatic variables (temperature, rainfall, wind speed and relative humidity.) In addition, the study aims to assess the extent of the impact and its direction and magnitude, as well as to determine the dynamics governing the association among variables in the long and short term. The objective is to identify quantitative indicators that can be used for agricultural planning and management, to improve the efficiency of the agricultural and water resources management and to develop better policies and strategies to respond to climate change and ensure the sustainability of rice production in Iraq.

2: The Research Problem

Rice production in Iraq is subject to temporal variability and fluctuations, mainly due to changes and instabilities in climatic conditions. These changes are temperature changes, rainfall variations, and relative humidity and wind speed.

Rice is a strategic agricultural crop of great economic and nutritional importance to the crops and crop sector. Its productivity and quality depend on the environmental and climatic conditions of the crop during growth. Temperatures, rainfall, relative humidity, and solar radiation are key factors of crop growth, development, and production efficiency. Climate change that affects rice production includes increasing temperature, rainfall volume and time distribution, and changes in humidity and solar radiation, which are the main factors that affect plant physiological activity, growth rate, and yield processes in rice crops. Rice plants are sensitive to temperature at different stages of growth, which affects the quality of their grain production and yield. The crop's productivity depends on the temperature and humidity or the amount of water available to them. When temperatures and solar radiation are within the appropriate range, the rice plant will grow and flower, leading to increased productivity. However, when the temperature is not optimal—whether too high or too low—the growth process is affected, and the plant may have low growth ability, resulting in reduced yield and poor grain quality. Rainfall is important for the crop's water needs; it is not only the total rainfall but also the timing and amount of water required during various stages, including germination, vegetative growth, and grain production. Relative humidity and solar radiation also contribute to the climate for crop growth by influencing transpiration and photosynthesis. Analyzing the impact of climatic factors—whether individually or jointly—is the most useful way to explain the spatial and temporal variation of rice crop productivity and to determine the climatic boundaries best suited for rice production. This analysis provides a scientific basis for crop management plans,

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The value of this analysis is in providing a quantitative and methodological approach to the association linking climate change with rice output in Iraq as it provides a quantitative and methodical understanding of how climate variability and rice output in Iraq is impacted. It does not focus on a general description of climate and agricultural output changes but rather how the reciprocal effects are measured and quantitatively what impact is being made and how and when with more precise statistics and economic analysis.

The significance of the analysis is to show how the climatic factors are affecting crop production and the relationship between them and the impact of the long- and short-run equilibrium (e.g., in the case of rice production and the level of production volatility during the study interval.) In practice, the results of the analysis are very relevant for decision making of rice production (best-fitting varieties for climate change and optimum planting dates, water-use efficiency, extension and support programs) and to improve the farm sector's capacity to handle climate change-related hazards. In this way, the findings of the study can be a basis for developing agricultural policies that are more climate-adapted so that rice production can be further maintained and sustainable and can be used for food security and agricultural sustainability in Iraq.

5: Spatial and Temporal Scope of the Research

1- The scope of the research is spatial, since we are focusing on rice crop production in Iraq and linking it to the change of key climatic elements relevant to the crop's production. This study covers the period 1995-2022 and the Given that the rice crop is also sensitive to climatic conditions in its stages of growth, and we cannot predict the impact that any change in the growth conditions should have on rice production and stability, it becomes necessary to identify the form of association linking climatic factors and rice production and to know how much and which are the effects of each of them. It is also important to know whether climate change is interrelated but not long-term or short-term and whether the long-term equilibrium relationship is maintained. Therefore, we look at the following key question: What is the nature and magnitude of the effect of shifts in key climatic factors upon rice output across Iraq during the period (1995–2022), and does a persistent equilibrium linkage exist between crop production and the climatic variables under study.

3: Research Hypothesis

The research relies on a single hypothesis: the changes in key climatic elements affect rice crop production in Iraq. And the nature, direction and magnitude of this impact varies according to the specific climatic element and its level, as well as the crop's physiological growth stage and its sensitivity to the current climatic conditions.

The analysis assumes that a long-term equilibrium relationship exists between rice production and the climatic factors that we are investigating and short-term dynamic relationships between rice production and climate (i.e., annual fluctuations or variations in rice production levels in response to climate variations are observed). So, climatic influences on rice output are not limited to immediate reactions but also the long-term production trajectory and long-term stability, too.

4: The Importance of the Analysis

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production and oil extraction. Rice husks are also used for industrial purposes, and rice straw and residues can be used for animal fodder and other products. In this sense, the economic value of the rice crop is not only the edible grains but also the processing of by-products and residues, so that it is an additional economic resource (Al-Ansari, 2024).

Rice is especially important in Iraq as a strategic food crop for food security, as domestic production has been found to be insufficient to satisfy local demand, and thus the country has been forced to import rice to make up for the gap between production and consumption. Population growth, changing consumption patterns, and rising demand have been the major reasons for reliance on imports, meaning that the domestic production process will be crucial for closing the food deficit and reducing reliance on foreign markets (Jbeil and Salem, 2025).

Rice cultivation in Iraq is closely related to land, water, and environmental conditions. Most of the production occurs in central and southern governorates of Iraq: Najaf, Al-Qadisiyah, Al-Muthanna, Dhi Qar, and Maysan. The importance of these governorates varies from season to season, depending on the areas for cultivation, the availability of irrigation water, and the state of agriculture. Najaf Governorate is a rice-growing region, and largely the Al-Mishkhab, Al-Hirah, and Al-Manathirah areas have been associated with the production of rice and the production of different types (Al-Ithawi, 2022).

Iraqi rice has a wide variety of cultivars: Anbar and Jasmine, and other modern or improved ones. Many of them differ in their production and qualitative characteristics, their productivity, and grain characteristics. They are also different in the number of grains per

association linking rice output with climatic change in the country.

2- We used annual data for the variables under study to monitor general trends and changes over time, study the crop's production response to climate change, and test the possibility of short- and long-run associations among the variables during the study period.

Section Two: The Status of Rice Production in Iraq (1995–2022)

The Economic Importance of the Rice Crop in Iraq

Rice (Oryza sativa L.) represents a critical grain crop in Iraq and has significant nutritional, economic, and strategic value for the country. It is the most widely consumed food worldwide and is very important to the local population and food security. The nutritional value of rice is largely due to the high amount of carbohydrates (especially starch) and protein, vitamins, and minerals, making it an integral part of the local diet. Analysis of rice grain indicates that carbohydrates are the fundamental components, while protein and minerals are present in varying amounts. Fats are more concentrated in rice bran than in milled rice, making rice not considered an oil crop. The nutritional value of rice is exemplified by high amounts of energy as it is the main food for humans, and it is processed very much, and the outer layer contains more fiber and nutrients. Rice bran—a byproduct of the polishing process—is key because it contains protein, fiber, fat, and minerals, and it can be used in many food and animal feed applications and for the preparation of rice bran oil (FAO, 2023).

Rice crops have high economic value in addition to edible grains because the grains are mostly used for human consumption, but rice bran can be used for animal feed

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the Anbar ones with high-quality characteristics (Hameed and Musa, 2023).

The rice crop is of nutritional, economic, and marketing value in Iraq, but its production in Iraq has several challenges in terms of the ability to grow it. Among them are the crop's high water requirements, water availability, and the number of water seasons (drought, etc.), as well as high production costs, price fluctuations, and high production inputs. Water availability is a key factor in the area of rice production in Iraq because summer agricultural plans are directly related to water availability and the amount of water released in the agricultural season (Iraqi Ministry of Agriculture, 2022).

The Status of Rice Production in Iraq (1995–2022)

Despite the importance of the rice crop in Iraq's production from 1995 to 2022, the reality of rice production from 1995 to 2022 was fluctuating and unstable. The dynamics of rice cultivation in Iraq were influenced by a number of natural, economic and production-related factors (cultivated land, irrigation water availability, productivity, climatic conditions, cost of production inputs and agricultural policies regarding the use of land for the crop, among others). Rice production has increased during some seasons and in some years, while in others, the growth has been unstable, as in some years the number of rice production fell after the cultivated area was reduced due to lower productivity (Jabear and Jasim, 2022). Agricultural research on rice production in Iraq has shown that high production levels are linked to the efficiency with which land, labor, water, fertilizers, and seeds are used, as well as the selection of varieties suited to the environment (Jabear and Jasim, 2022).

panicle, thousand-grain weight, and yield, and some of them, for example, Jasmine, Dijla, and Furat, have been found to be better than others in the yield indicators which are known in the field to be more reliable and favorable. Anbar rice is very much qualitative and is valued by Iraqi consumers; they like the smell, taste, and grain quality characteristics. So, they have a special value. While the yield of some of the Anbar rice is less than the others, high demand and quality characteristics make it important and must be kept and developed to the best of their ability, while it is also important to be able to balance the quality of production with the price of the farmer (Saleh and Al-Sunbul, 2019).

The economic importance of the rice crop is also reflected in the employment opportunities and income of farmers. Rice cultivation involves land preparation, planting, irrigation management, fertilization and pest control, harvesting, drying, storage, transportation, and marketing operations. In addition, rice cultivation is associated with various supporting economic activities that provide production inputs as well as agricultural and marketing services, and the crop's economic impact is wider than just the value of harvested produce itself and its entire production and marketing process (Al-Tamimi and Al-Badri, 2023).

Marketing is an important aspect of rice production in Iraq, with farmers' decisions to grow the crop in this country based on price, production costs, and net returns. Economic studies have shown that there are significant differences in economic efficiency between farmers in the production of rice varieties, and pricing and marketing policies for different types of rice are important to support local rice production from the farmers, particularly

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for the crop, allowing them to grow local varieties that are popular in rural areas and have significant economic and market value (Gokalb and Humaidy, 2023).

Rice productivity is also influenced by the efficiency with which production inputs are utilized. Economic research on rice farmers in Najaf Governorate has shown disparities in technical, economic, and allocative efficiency among growers of different varieties, indicating potential for more efficient use of inputs (Saleh and Al-Sunbul, 2019).

Rice production in Iraq needs to boost yield per unit area, not horizontal expansion. This means developing high-yielding varieties with desirable quality traits while preserving local varieties of high market value—particularly the *Anbar* varieties. Moreover, irrigation water use efficiency must be improved, modern water management techniques must be implemented, and optimal fertilization and pest control practices should be followed, along with appropriate planting and harvesting schedules for each variety. Finally, the economic and marketing aspects of the crop should be supported by providing production inputs at reasonable prices and establishing a pricing policy that encourages farmers to continue cultivating rice. Improving drying, storage, and marketing processes, as well as reducing post-harvest losses—alongside developing the rice value chain and economically utilizing by-products such as rice bran, straw, and husks—would contribute to enhancing crop production efficiency, increasing farmers' incomes, narrowing the gap between production and consumption, and reducing reliance on imports. These measures would thereby strengthen the role of rice in achieving food security and agricultural development in Iraq.

Rice production is also dependent on the cultivated variety; varieties differ in yield-forming potential, grain number per panicle, thousand-grain weight, and grain filling percentage. Field studies conducted at the Al-Mishkhab Rice Research Station have shown that different varieties had different grain numbers, grain weight, and yield. Also, harvest timing is important for yield quality: early harvesting leads to yield loss because the grain is moist, and late harvesting can cause losses due to grain shattering (Musa et al., 2023).

Water availability is a highly relevant factor in rice production throughout the study period, as rice is a crop that requires a significant amount of water to grow. As a result, a decrease in water resources not only reduces productivity but also reduces the total area to be cultivated; rice planning has become very closely related to the available water supply and the decisions made by competent authorities regarding the acreage permitted for planting each season (Jloob, 2025).

Water scarcity, increasing temperatures, and recurring droughts have caused the production of water-intensive summer crops to be restricted, such as rice. This has resulted in significant variations in cultivated areas and production from one season to the next, as some years saw a rise in output due to relatively good water resources, while others saw a dramatic drop due to a decrease in cultivated area (Al-Abboodi and Abdalrzak, 2020).

The geographical distribution of rice production shows that Najaf Governorate is a key part of the rice production—particularly in the Al-Mishkhab, Al-Hira, and Al-Manathira areas, which are among the most important rice-growing regions of Iraq. The farmers have inherited agricultural skills, and the land is suitable

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Table (1) Rice cultivation area and production in Iraq for the period 1995–2022

Rice production)tonnes(	Area planted with rice in Iraq (donums)	Years
180000	220000	2011
220000	320000	2012
180000	384000	2013
170000	384000	2014
200000	192000	2015
240000	220000	2016
300000	220000	2017
420000	24000	2018
575000	512000	2019
300000	408000	2020
100000	384000	2021
11600	16000	2022
5385600	9888000	**Total**
19234286	35314286	**Average**
575000	700000	**Maximum**
11600	16000	**Minimum**

Rice production)tonnes(	Area planted with rice in Iraq (donums)	years
315000	700000	1995
270000	480000	1996
244000	484000	1997
300000	512000	1998
180000	520000	1999
60000	240000	2000
90000	400000	2001
90000	400000	2002
120000	460000	2003
150000	352000	2004
120000	428000	2005
90000	440000	2006
80000	440000	2007
100000	336000	2008
80000	220000	2009
200000	192000	2010

Ministry of Planning / Central Statistical Organization / Directorate of Agricultural Statistics

which was a huge drop from previous years. In 2001 the area reached 400,000 and remained around the same level in 2002, before slowly decreasing in some years. During 2003-2009 the area was very fluctuating: 460,000 dunams in 2003, 352,000 dunams in 2004 and 428,000 dunams in 2005. In 2006 and 2007 it fell to 440,000 dunams and then in 2008 and 220,000 dunams in 2009 and this is because of a very unstable land area for rice crop.

From 2010 to 2017, the cultivated area fluctuated; it was at 192,000 dunams in 2010 and then increased to 220,000 dunams in 2011, 320,000 dunams in 2012 and 384,000 dunams in 2013 and 2014. It was down to 192,000 dunams in 2015 and then gradually rising to 220,000 dunams in 2016 and then to that level in 2017. This indicates that the area did not go up or down in the same way but had a different direction from year to year.

Table (1) shows the area cultivated with rice and rice production in Iraq from 1995 to 2022. The data show very year-to-year fluctuations in the cultivated area and production and clearly shows a change in the general trend of the time series. The cultivated area grew from 700,000 dunams in 1995 to 16,000 dunams in 2022 and rice production from a high of 575,000 tons in 2019 to a low of 11,600 tons in 2022. These figures show the wide range of fluctuation in rice production and cultivated area throughout the period of study.

At the beginning of the research period, the rice area planted was at high levels with 700,000 dunams in 1995, then fell to 480,000 dunams in 1996 and 484,000 dunams in 1997, before rising to 512,000 dunams in 1998. This fluctuation continued in the following years, and it reached 520,000 dunams in 1999 before decreasing in 2000 to 240,000 dunams,

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dunams and production was 420,000. Production was 220,000 tons in 2017 and 512,000 tons in 2019 (a substantial increase in output with a huge growth in cultivated area) and was 100,000 tons in 2021. Production dropped to 300,000 tons in 2020 and then to 11,600 tons in 2022 .

The arithmetic mean of the cultivated area during the study period was about 353,143 dunams, while the total area recorded was approximately 9,888,000 dunams; average production was ~ 192,343 tons, with a grand total of 5,385,600 tons. While these averages give a general view of area and production during the study period, using the average does not completely capture the nature of the data series because of significant year-to-year variation in the data.

The large difference between the maximum and minimum values suggests that rice production in Iraq during the period studied is unstable. The fluctuations in cultivated area and production levels can be attributed to water availability, restrictions on producing water-intensive crops, climatic conditions, irrigation efficiency as well as agricultural and economic factors affecting the land area the crop is grown on.

Therefore, rice cultivation in Iraq during 1995-2022 shows large fluctuations in area and production with years of high values and years of sharp decline. The trend at the end of the series shows a marked decrease, particularly in 2018 and 2022.

The years 2018-2022 saw more pronounced changes in area and production. In 2018, the cultivated area was 240,000 dunams and 512,000 dunams in 2019, and then dropped to 408,000 dunams in 2020 and 384,000 dunams in 2021 and finally to 16,000 dunams in 2022. The decline in 2022 is the most significant for the whole time series.

For production, in 1995 the volume was 700,000 tons (based on the data in the file), but in 1996 it dropped to 480,000 tons and in 1997 to 484,000 tons. It then rose to 512,000 tons in 1998 and 520,000 tons in 1999, but fell to 240,000 tons in 2000, then to 400,000 tons in 2001 and 2002 (see also for the statistics to show the fluctuation in production in the first years.

Production levels fluctuated from 2003 to 2010, it was 460,000 tons in 2003, 352,000 tons in 2004, and 428,000 tons in 2005. It stabilized at 440,000 tons in 2006 and 2007 and then dropped to 336,000 tons in 2008, 220,000 tons in 2009, and 192,000 tons in 2010. This shows that there were fluctuations in production volume as well as clear instability during this period.

Production occurred between 220,000 and 384,000 tons in 2011-2017. It rose to 320,000 tons in 2012 and reached 384,000 tons in 2013 and 2014, but fell to 192,000 tons in 2015 and reached 220,000 tons in 2016 and 2017. From this data we find that production changed in a non-linear way with the cultivated area over the same period.

The year 2018 is an the data, where while the cultivated area was 24000

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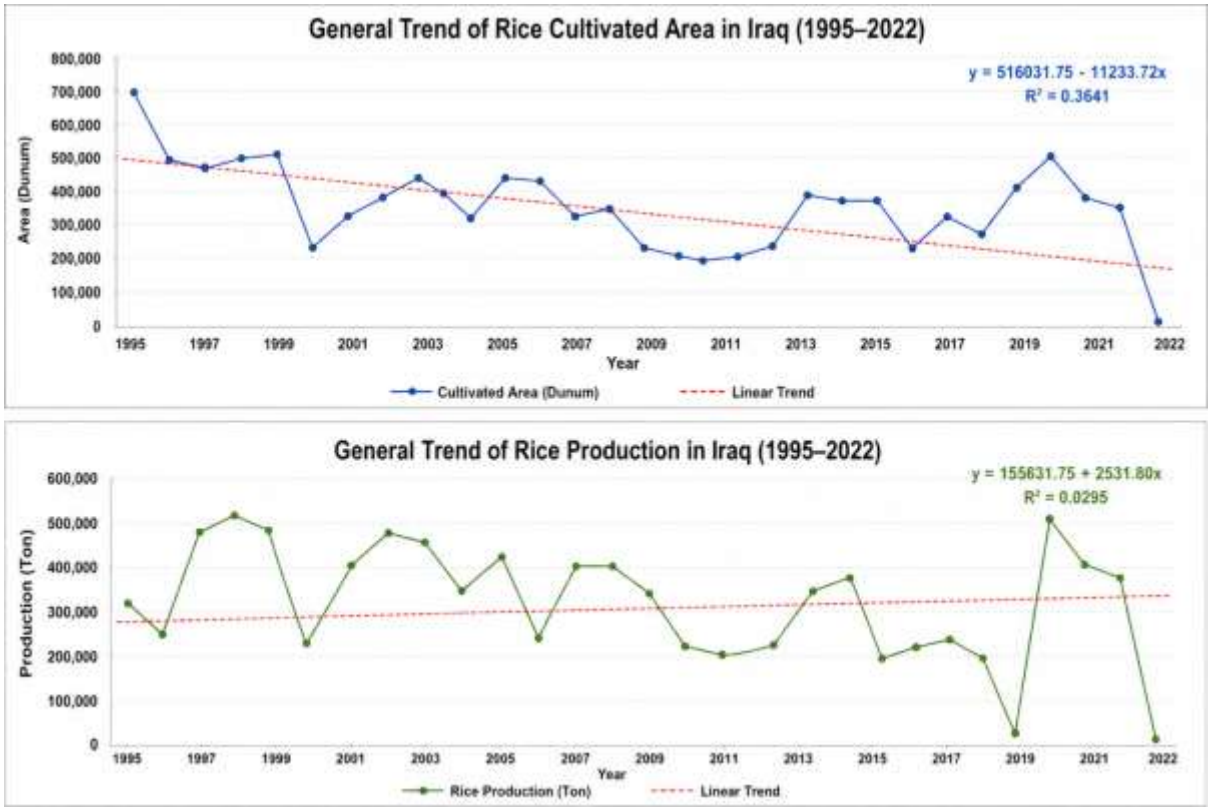


Figure (1) General trend of rice cultivation area and production in Iraq for the period 1995–2022.

Climate Model:

rice cultivation depends on the integration of climatic and water-related elements and their alignment with the crop's physiological requirements; any imbalance in these elements can negatively affect plant growth and productivity (Abdelaal, 2013).

A standard model is applied to quantify the effect of climatic factors on the agricultural sector. Climatic factors are represented as independent variables influencing agricultural production, expressed as follows: Y = F(X1, X2, X3, X4, X5, ...) (1). In general, the success of

Y = Rice production (tons)

X1 = Percentage of humidity.(%)

X2 = Average annual temperature (°C)

X3 = Actual annual sunshine duration (hours/day)

X4 = Average annual rainfall (mm/year)

X5 = Average annual wind speed (km/h)

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Table (2) Climatic factors affecting rice crop production for the period 1995–2022

Average wind speed (km/h)	Annual rainfall (mm/year)	Actual annual sunshine duration (sunshine in hours/day)	Average annual temperature (°C)	Humidity level(%)	Rice production (tonnes)	years
19.56	142.90	8.667	22.49	39.75	315000	1995
20.52	149.19	8.250	22.87	62.08	270000	1996
19.74	152.70	8.250	22.16	57.80	244000	1997
20.45	139.16	8.250	23.37	45.07	300000	1998
20.21	123.19	8.250	23.37	24.96	180000	1999
20.29	130.64	8.250	22.86	43.46	60000	2000
20.18	141.35	8.508	23.48	54.25	90000	2001
20.29	139.82	8.400	22.84	51.22	90000	2002
19.90	142.67	8.073	23.01	54.64	120000	2003
20.27	143.19	8.208	22.88	63.65	150000	2004
19.74	135.86	8.455	22.96	49.97	120000	2005
20.48	143.19	8.355	23.00	64.97	90000	2006
20.16	136.90	8.225	22.92	51.89	80000	2007
20.09	129.40	8.305	23.09	41.84	100000	2008
19.74	141.85	7.986	23.07	43.43	80000	2009
20.48	128.54	8.231	24.47	41.51	200000	2010
19.77	138.62	8.301	22.61	39.35	180000	2011
19.85	139.34	7.878	23.21	47.26	220000	2012
19.49	149.93	8.435	22.87	56.61	180000	2013
19.99	148.56	8.089	23.32	47.67	170000	2014
20.09	144.88	7.615	23.54	62.93	200000	2015
19.74	140.46	7.883	23.36	58.51	240000	2016
19.89	129.54	8.151	23.38	30.33	300000	2017
19.48	157.73	7.781	24.18	0.26	420000	2018
19.87	161.65	8.383	23.55	0.22	575000	2019
19.75	149.64	8.167	23.43	10.27	300000	2020
19.70	156.34	8.383	23.67	11.26	100000	2021
19.76	155.87	8.312	23.71	10.76	11600	2022
559.48	3993.11	230.041	649.67	1165.92	5385600	**Total**
19.98	142.61	8.216	23.20	41.64	192342.86	**Average**
20.52	161.65	8.667	24.47	64.97	575000	**Maximum**
19.48	123.19	7.615	22.16	0.22	11600	**Minimum**

Iraqi Meteorological Organization and Seismology

Section Three: Economic and Econometric Analysis of Climatic Factors Affecting Rice Production in Iraq (1995–2022)

1: Testing the Stationarity of Time Series for Economic Variables

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of the null hypothesis regarding the existence of a unit root. However, after taking the first difference of the variables and re-conducting the test, the results indicate that stationarity is achieved at the first difference for all variables; this leads to the rejection of the null hypothesis and the acceptance of the alternative hypothesis, confirming that the time series are stationary at their first difference.

Table (3) reports outcomes from the Augmented Dickey-Fuller (ADF) unit-root procedure, conducted under three specifications: with an intercept only; with an intercept and a time trend; and with neither an intercept nor a time trend. The results indicate the presence of a unit root in the time series of most variables at their original levels, confirming a lack of stationarity and leading to the acceptance

Table (3) Results of the variable stationarity test using the Augmented Dickey-Fuller (ADF) test.

UNIT ROOT TEST RESULTS TABLE (ADF)

Null Hypothesis: the variable has a unit root

		Y	X1	X2	X3	X4	X5
	At Level						
With Constant	t-Statistic	-2.7924	-1.4554	-4.5863	-4.7202	-2.8520	-1.7462
	Prob.	***0.0731***	***0.5403***	***0.0012***	***0.0008***	***0.0645***	***0.3974***
		*	n0	***	***	*	n0
With Constant & Trend	t-Statistic	-2.8518	-2.3720	-6.5410	-4.8599	-3.3757	-9.5877
	Prob.	***0.1930***	***0.3846***	***0.0001***	***0.0030***	***0.0759***	***0.0000***
		n0	n0	***	***	*	***
Without Constant & Trend	t-Statistic	-1.5200	-0.9604	0.5668	-0.0910	0.0675	-0.8239
	Prob.	***0.1182***	***0.2924***	***0.8322***	***0.6425***	***0.6954***	***0.3485***
		n0	n0	n0	n0	n0	n0
	At First Difference						
		d(Y)	d(X1)	d(X2)	d(X3)	d(X4)	d(X5)
With Constant	t-Statistic	-3.7398	-4.8851	-10.2316	-6.8374	-6.2060	-5.3531
	Prob.	***0.0094***	***0.0006***	***0.0000***	***0.0000***	***0.0000***	***0.0002***
		***	***	***	***	***	***
With Constant & Trend	t-Statistic	-3.6667	-4.7493	-10.0138	-6.8260	-6.2150	-5.2564
	Prob.	***0.0433***	***0.0041***	***0.0000***	***0.0000***	***0.0001***	***0.0015***
		**	***	***	***	***	***
Without Constant & Trend	t-Statistic	-3.7785	-4.8834	-10.3483	-6.9953	-6.3277	-14.9592
	Prob.	***0.0005***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***
		***	***	***	***	***	***

Notes:

a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

This Result is The Out-Put of Program Has Developed By:

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Source: Prepared by the researcher based on outputs from the **EViews 10** software.

2: Cointegration Test for Economic Variables Using the Johansen Method

avoidance of spurious regression. Given the nature of the time-series data—specifically with the variables stationary at the first order, I(1)—and the fact that the choice of testing tool depends on data characteristics, Table (4) presents the results of the residual stationarity test for the cointegration model of the economic variables.

After the ADF unit-root findings confirmed that all variables are stationary at the first difference, the next step checks for cointegration across the variables. The objective of this test is to determine whether a long-run equilibrium relationship exists between the dependent variable and the independent economic variables, thereby ensuring the

Table (4) Results of the Johansen test for residual stationarity of the cointegration model for economic variables.

Date: 08/20/26 Time: 14:30
Sample (adjusted): 1997 2022
Included observations: 26 after adjustments
Trend assumption: Linear deterministic trend
Series: Y X1 X2 X3 X4 X5
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.907485	168.5202	95.75366	0.0000
At most 1 *	0.769429	106.6303	69.81889	0.0000
At most 2 *	0.676586	68.48322	47.85613	0.0002
At most 3 *	0.541259	39.13388	29.79707	0.0032
At most 4 *	0.516099	18.87288	15.49471	0.0149
At most 5	5.66E-06	0.000147	3.841466	0.9918

Trace test indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.907485	61.88991	40.07757	0.0001
At most 1 *	0.769429	38.14710	33.87687	0.0145
At most 2 *	0.676586	29.34933	27.58434	0.0294
At most 3	0.541259	20.26100	21.13162	0.0658
At most 4 *	0.516099	18.87273	14.26460	0.0087

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At most 5	5.66E-06	0.000147	3.841466	0.9918

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Prepared by the researcher based on outputs from the **EViews** software.

ensures the derivation of accurate and reliable statistical parameters .

Estimating the Parameters of the Long-Run Relationship Between Economic Variables and Rice Production Using the DOLS Model

Given the nature of the data, which lack stationarity at level I (0) and integrated of the first order I (1), and the existence of a cointegration relationship among the study variables, the estimation of the long-run relationship parameters was proceeded with. Dynamic Ordinary Least Squares (DOLS) methodology was employed. The importance of this methodology lies in its ability to provide efficient estimates that overcome the biases of Ordinary Least Squares (OLS) resulting from serial correlation and endogeneity of the variables. The results of the DOLS model estimation indicate an excellent goodness of fit, as the model accounts for roughly 96.8% of the variations in rice production in Iraq ($R^2 = 0.9678$).

The results indicate the existence of five cointegration vectors according to the trace test and three vectors according to the maximum eigenvalue test. Consequently, H0 is rejected whereas H1—positing the presence of cointegration—is accepted; this confirms a stable, balanced long-term economic relationship between the dependent variable and the independent (economic) variables, thereby justifying the use of DOLS estimators. The findings of the current study align with the methodology established by Engle and Granger (1987.(Stationarity of the residuals at level I(0) serves as conclusive evidence of cointegration and the stability of the long-run equilibrium linkage. These results align with the findings of Gujarati and Porter (2009), confirming that this test is a fundamental safeguard against the risks of spurious regression and

Table (5) Estimated regression function for the variables using the DOLS method.

Dependent Variable: Y
Method: Dynamic Least Squares (DOLS)
Date: 08/20/26 Time: 14:36
Sample (adjusted): 1997 2021
Included observations: 25 after adjustments
Cointegrating equation deterministics: C
Fixed leads and lags specification (lead=1, lag=1)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 3.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	-8385.818	3661.154	-2.290485	0.0838
X2	-425692.8	183688.4	-2.317473	0.0814
X3	-862498.2	313468.8	-2.751464	0.0513

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X4	5138.105	1449.131	3.545645	0.0239
X5	165264.1	223925.7	0.738031	0.5015
C	13936105	7166551.	1.944604	0.1237

R-squared	0.967878	Mean dependent var	191560.0
Adjusted R-squared	0.807268	S.D. dependent var	119596.6
S.E. of regression	52504.39	Sum squared resid	1.10E+10
Long-run variance	3.36E+09		

Prepared by the researcher based on outputs from the EViews 10 software.

into improved water-use efficiency and increased total productivity per cultivated area (Alwan and Abbas, 2021Next is the average temperature (X2), which shows a negative coefficient (Prob = 0.0814), followed—at the 10% significance level—by actual sunshine duration (X3), also with a negative coefficient (Prob = 0.0513). The negative signs associated with these climatic variables are attributed to exacerbated heat stress, excessive evaporation, and the warming of irrigation water, all of which harm productivity (Deng, 2015). Rainfall (X4) is the variable with a significant positive effect at the 5% level (Prob = 0.0239), owing to its role in supporting water availability and irrigation (Al-Dulaimi, 2022); meanwhile, wind speed (X5) did not show a statistically significant effect (Prob = 0.5015), and the constant term (C) was statistically non-significant (Prob = 0.1237).

Testing the Validity of the Estimated Model

Several diagnostic tests are performed together with the DOLS method to validate the validity and accuracy of the model results and ensure that the underlying assumptions are met to ensure reliability and precision of the results.

Residual Autocorrelation (Q-statistics)

Table (5) presents the estimation results of the DOLS model, summarizing the relationship between the dependent variable (y) and the independent economic variables (X). The R-squared value of 0.967878 indicates that approximately 96% of the variation in the response variable (rice production) is accounted for by the explanatory variables (economic variables) entered in the model, while 4% is linked to factors omitted from the model. The coefficient for the moisture level variable (X1) was approximately 8385.818, with a p value of 0.0838—which is less than the significance level (0.10)—indicating that this variable has a statistically significant impact on rice production in Iraq .The positive impact of relative humidity on rice production in Iraq stems from its physiological and environmental role in mitigating summer climatic stress. Reducing the atmospheric vapor pressure deficit helps to prevent excessive transpiration and water evaporation and to promote fertilization and fruit set efficiency by preventing pollen dehydration and reducing the incidence of empty grains (florets). Furthermore, it minimizes direct evaporation from floodwater and mitigates the severity of harsh heatwaves in the cultivation regions of the Middle Euphrates and the South; this ultimately translates

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This test is used to assess model validity and ensure the absence of residual autocorrelation.

Table (6) Q-statistics test for autocorrelation

Date: 08/20/26 Time: 15:35
Sample: 1995 2022
Included observations: 25

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.210	0.210	1.2399	0.265
		2	-0.090	-0.140	1.4759	0.478
		3	-0.379	-0.350	5.8824	0.117
		4	-0.223	-0.101	7.4875	0.112
		5	-0.153	-0.185	8.2811	0.141
		6	0.123	0.025	8.8206	0.184
		7	0.172	0.017	9.9362	0.192
		8	0.037	-0.140	9.9910	0.266
		9	-0.187	-0.204	11.472	0.245
		10	-0.174	-0.118	12.834	0.233
		11	-0.168	-0.224	14.191	0.223
		12	0.103	-0.017	14.738	0.256

*Probabilities may not be valid for this equation specification.

Source: Prepared by the researcher based on outputs from the EViews 10 software.

significance threshold. Accordingly, we reject H1 and retain H0, which proves that the model is not affected by residual autocorrelation.

Findings reported in Table (6) show that the residual autocorrelation coefficients lie within the 95% confidence interval and all the p-values are higher than the 0.05

Test for Homogeneity of Variance (Squared Residuals)

This test is used to detect the problem of heteroscedasticity (that is, whether the fluctuation of the residuals is stable) by examining the squared residuals.

Table (7) Test for Homogeneity of Variance for Economic Variables

Date: 08/20/26 Time: 15:40
Sample: 1995 2022
Included observations: 25

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.078	0.078	0.1717	0.679
		2	-0.164	-0.171	0.9609	0.619
		3	0.110	0.143	1.3305	0.722
		4	0.051	-0.003	1.4146	0.842
		5	-0.089	-0.054	1.6838	0.891
		6	-0.179	-0.179	2.8169	0.831
		7	-0.216	-0.229	4.5606	0.713
		8	-0.145	-0.174	5.3983	0.714
		9	0.082	0.080	5.6846	0.771
		10	-0.097	-0.120	6.1055	0.806
		11	-0.185	-0.145	7.7488	0.736
		12	-0.041	-0.178	7.8349	0.798

*Probabilities may not be valid for this equation specification.

Source: Prepared by the researcher based on outputs from the EViews 10 software.

null hypothesis, where the model is free from heteroskedasticity (i.e., the variance or dispersion of the random variable is constant or homogeneous). We therefore establish the condition

Based on the standard test results in Table (7), we see that the p-values for all lag periods are significantly higher above the 0.05 significance threshold. Thus, we reject the alternative hypothesis and retain the

variables. of homoskedasticity for the economic

Jarque-Bera Normality Assessment of Residuals

This test is employed to verify that the residuals follow a normal distribution, a fundamental requirement for ensuring the validity of the statistical tests used in the model**.**

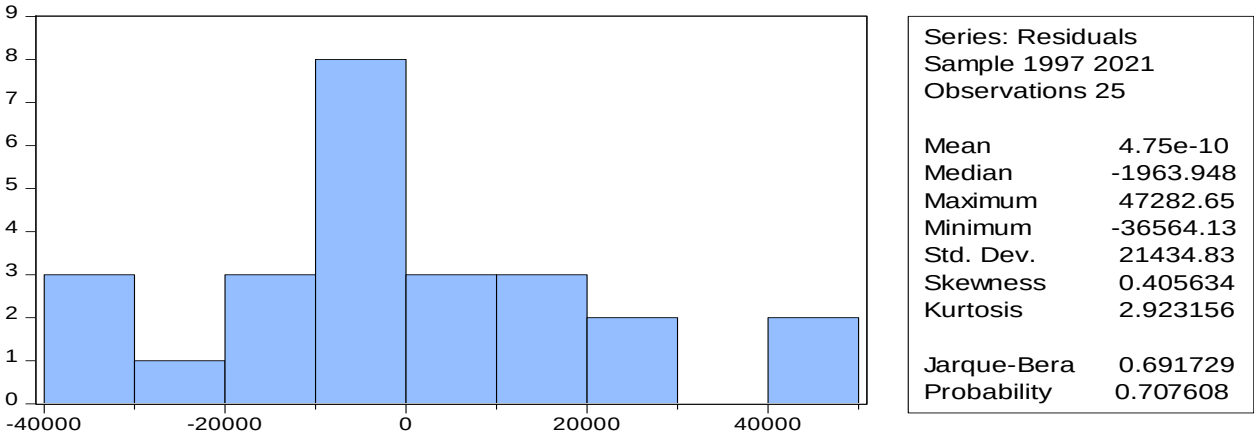


Figure (2) Normal distribution of residuals

Source: Prepared by the researcher based **on EViews 10** software output.

nature and that the harvest levels are in large part due to changes in the production environment. Water use efficiency and irrigation methods and the application of modern irrigation techniques and development of drought and heat-resistant rice varieties and climate monitoring and agricultural forecasting programs are recommended to improve it, the research also points out. It also suggests that flexible agricultural policies with more flexible agricultural policies for less water resources and climate change and supporting sustainable rice production (i.e., in Iraq) should be adopted to meet their agricultural needs.

Findings from Figure (2) indicate that the Jarque-Bera procedure statistic is close to 0.691729 and p value is 0.707608, which is much higher than the standard value of 0.05. Therefore, we reject the other hypothesis and accept the null hypothesis where the residuals follow a normal distribution. In other words, these residuals of the estimated model for the economic variables are normal and it is an indication of the quality and performance of the model.

The analysis showed that the cultivated area of rice farming in Iraq and production of this crop fluctuates significantly from year to year and the production of rice is seasonal in

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