The economic effects of climatic environmental changes on the agricultural crop production index in Iraq for the period (1990-2024)

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Abstract

This manuscript aims to examine the impact of climate change and environmental variables on the agricultural crop production index in Iraq during the period 1990–2024. The research seeks to identify the long-run and short-run relationships between agricultural production and a set of economic, environmental, and climatic variables using the Vector Error Correction Model (VECM). The dependent variable is the agricultural crop production index, while the independent variables include the revenues of the Tigris and Euphrates rivers, carbon dioxide (CO_2) emissions, methane (CH_4) emissions, nitrous oxide (N_2O) emissions, average temperature, and rainfall rate. Annual time-series data were collected from national and international statistical sources. The empirical results indicate the existence of a long-run equilibrium relationship between the study variables. The findings reveal a negative and statistically significant impact of the Tigris and Euphrates river revenues on the agricultural crop production index, reflecting structural and institutional inefficiencies in water resource management and agricultural infrastructure. Carbon dioxide emissions were found to have a significant positive effect on the crop production index, indicating that increased agricultural output in Iraq is associated with emission-intensive production practices rather than improvements in environmental efficiency. Methane emissions did not show a statistically significant effect, while nitrous oxide emissions exerted a negative impact on agricultural production, highlighting deficiencies in the management of agricultural inputs. Moreover, average temperature and rainfall rate had significant negative effects on the crop production index due to heat stress, increased evaporation, irregular rainfall patterns, soil saturation, and erosion. Based on these findings, the study recommends enhancing institutional and administrative efficiency in the agricultural sector, improving water resource management, investing in modern agricultural infrastructure, and promoting the adoption of low-emission and climate-smart agricultural technologies. In addition, strengthening climate change adaptation strategies such as developing heat- and drought-resistant crop varieties, improving irrigation systems, and expanding climate monitoring and early warning systems is essential to achieving sustainable agricultural development and food security in Iraq.

Keywords: Climate Change, Agricultural Crop Production Index, Environmental Emissions, Water Resources, VECM Model, Iraq.

Introduction

Climate change represents one of the most significant environmental challenges facing the agricultural sector in Iraq at the present time, due to its direct and indirect impacts on the crop production index. Over recent decades, Iraq has experienced noticeable

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increases in temperature, fluctuations in rainfall levels, and recurrent drought events. These climatic changes have negatively affected agricultural production, particularly strategic crops such as wheat, barley, rice, and maize [10].

Numerous studies indicate that rising temperatures beyond normal levels lead to a shortening of the vegetative growth period of crops, increased evaporation rates, and reduced water-use efficiency. Consequently, overall crop productivity in Iraq has declined [7]. Furthermore, changes in rainfall patterns and their irregular temporal and spatial distribution have contributed to a reduction in rain-fed cultivated areas and an increased risk of production failure during several agricultural seasons [6].

From an economic and econometric perspective, previous studies have demonstrated a statistically significant relationship between climatic variables particularly temperature and rainfall and the crop production index. Deviations of these variables from their normal levels result in sharp fluctuations in annual agricultural output [9]. The findings also indicate that field crops are more vulnerable to climate change compared to horticultural crops, due to their heavy dependence on prevailing climatic conditions [8].

The impacts of climate change are not limited to production aspects alone; they extend to food security and economic stability. A decline in crop production increases reliance on food imports and contributes to rising food prices, thereby placing additional pressure on the national economy and reducing real household incomes [15]. Accordingly, studying the impact of climate change on the crop production index in Iraq is of great importance, as it provides a scientific foundation to support agricultural policies and enhance adaptation strategies to future climatic changes.

The problem addressed by this study is that Iraq is expected to experience numerous climate changes in the coming periods, which will impact its economic structure. The Iraqi agricultural sector is among the most affected by environmental and climatic changes. Climate change leads to far-reaching and unpredictable environmental, social, and economic consequences. Although the impact of climate change on human activity, including agriculture and industry, has recently been established, there is insufficient research to measure the effect of climate and environmental changes on agricultural crop production. This is because monitoring and observing climate changes is a long-term process, and translating these phenomena into numerical values is challenging. Therefore, the study problem can be formulated through the following questions:

• How have environmental and climatic changes affected the agricultural crop production index in Iraq for the period 1990-2024?

• What methods and measures can the agricultural economy adopt to mitigate the effects of climate and environmental changes on the agricultural sector in Iraq?

Study Objectives:

1.To determine the impact of environmental and climatic changes on the agricultural crop production index in Iraq for the period 1990-2024, using the VECM model.

2. To identify the most important methods and procedures that the agricultural economy can adopt to mitigate the effects of climatic and environmental changes on the agricultural sector in Iraq, by studying current agricultural policies for reducing climate change and how to address it

The study assumes that environmental and climatic changes have varying effects of

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intensity on the agricultural crop production index in Iraq during the period 1990 to 2024.

Material and Methods

Prepare samples:

Vector error correction model (VECM). The concept of this model is based on the assumption that there is a long-term equilibrium relationship, and despite its existence, it is rarely achieved, as the difference between the two values at each time period is represented by the equilibrium error, and this error or at least part of it is modified or corrected in the long term, so this model was named the error correction model [1]: The vector error correction model (VECM) is used when the variables included in the model have the joint integration property, and this is a necessary condition for applying this model. Which is an auto-regressive vector model (VAR) with an error correction term added to it in order to overcome errors in describing the models [5]. The presence of joint integration between the studied variables indicates the existence of a long-term equilibrium relationship. In this case, there must be a causal relationship in at least one direction, which is revealed by the Granger causality test. However, the form and direction of the causal relationship, not just the direction, is reached by using the vector error correction method (VECM) [3]. The VECM model identifies the relationships between economic variables in the long and short term, as the differences in the variables with lags represent the causal relationships and their form in the short term. The significance of the parameters in the short term is identified by using the Wald test to verify the acceptance or rejection of the null hypothesis that states that the estimated parameter is not significant, by looking at the probability level of the chi-square value. If the probability level is less than 5%, the null hypothesis is rejected in favor of the alternative hypothesis to confirm the significance of the estimated parameter and vice versa. While joint integration embodies the form of the relationship in the long term, the VECM model can be represented by the following two equations [2]:

$$\Delta Y_t = a_1 + \sum_{i=1}^{n} a_j \, \Delta Y_{t-j} + \sum_{i=1}^{n} \beta_i \, \Delta \mathrm{X}_{t-i} + P_1 \mu_{t-1}$$

$$\Delta \mathrm{X}_t = a_2 + \sum_{j=1}^{n} \beta_i \, \Delta \mathrm{X}_{t-j} + \sum_{j=1}^{n} \beta_j \, \Delta \mathrm{Y}_{t-i} + P_2 v_{t-1}$$

Δ refers to the differences of the variables, while μ_(t-1) and v_(t-1) refer to the error correction limits. The error correction limit indicates the existence of a long-term equilibrium relationship if it is negative and significant. The error correction limit measures the amount of correction (speed of adaptation) of the imbalance that occurs in the short term to reach the equilibrium value in the long term [10].

This represents:

- The variables are:

Y2: Crop production index as the dependent variable,

(X1): Annual flow of the Tigris and Euphrates rivers ((billion m3)

(X2): CO_2 emissions (kiloton)

(X3): Methane emissions (kilotonnes of carbon dioxide equivalent)

(X4): Nitrous oxide emissions (1000 metric tons of carbon dioxide equivalent)

(X5): Average temperature (c^0)

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(X6): Rainfall rate (mm)

- k: Number of lags.

- i’sβ: Short-term parameters.

- i’sφ: Long-term parameters.

- εi: Random error.

Results and Discussion

To investigate the stationability of the study variables, the Extended Dickey-Fuller Unit Root Test (ADF) was used for the economic indicators. The results of the Extended Dickey-Fuller (ADF) in Table (1) indicate that most of the variables were not stationary at the initial level. Upon retesting after accounting for the initial difference, these variables became stationary. This result leads us to use the VECM method.

The results showed the presence of a unit root in the time series for most variables at their original levels, confirming the absence of stationarity and thus accepting the null hypothesis that a unit root exists in the time series data. However, after taking the first difference of the variables and performing the unit root test, the results indicate that stationarity is present at the first difference for all variables. This means rejecting the null hypothesis and accepting the alternative hypothesis, confirming that the time series for the variablesare stationary at their first difference.

After establishing the stationarity of the time series and confirming that most of the variables used in the study are stationary at the first difference, we can use cointegration to test for the existence of a long-term equilibrium relationship between the model variables.

Cointegration (Johansen-Joselius).

Unit root tests for time series stationarity (the augmented Dickey-Fuller test) proved that most of the model variables are stationary in the first difference, meaning they are first-order integrals (1)~l. This indicates that the time series of the variables under study are of the same degree, suggesting the possibility of a cointegration relationship between the study variables. The cointegration between the model variables will be determined using the Johansen-Joselius methodology (Johansen-Joselius 1990), which is considered one of the best methods used to estimate the cointegration vector and confirm its oneness. This is based on the trace test (traceλ) and the maximum possible values test (max), which demonstrate the existence of a long-term equilibrium relationship between the economic variables in the study sample. The results are shown in Table (2)

Table (1): Results of the ADF unit root test for the study variables

UNIT ROOT TEST RESULTS TABLE (ADF)
Null Hypothesis: the variable has a unit root

		Y2	X1	X2	X3	X4	X5	X6
	At Level							
With Constant	t-Statistic	-4.7111	-1.2010	-0.2825	-0.4539	-2.4199	-5.9279	-5.1324
	Prob.	***0.0006***	***0.6583***	***0.9174***	***0.8882***	***0.1442***	***0.0000***	***0.0002***
		***	n0	n0	n0	n0	***	***
With Constant & Trend	t-Statistic	-4.4875	-0.3025	-2.1569	-6.0924	-3.8596	-4.1258	-5.0543
	Prob.	***0.0062***	***0.9861***	***0.4972***	***0.0001***	***0.0252***	***0.0136***	***0.0013***
		***	n0	n0	***	**	**	***
Without Constant & Trend	t-Statistic	0.1013	0.4827	1.8362	0.4120	-0.5550	-0.6681	-0.0007
	Prob.	***0.7073***	***0.8125***	***0.9820***	***0.7966***	***0.4690***	***0.4197***	***0.6752***
		n0	n0	n0	n0	n0	n0	n0
	At First Difference							
		d(Y2)	d(X1)	d(X2)	d(X3)	d(X4)	d(X5)	d(X6)
With Constant	t-Statistic	-5.1660	-4.6446	-6.0963	-10.5744	-8.8672	-3.6599	-8.6189
	Prob.	***0.0002***	***0.0011***	***0.0000***	***0.0000***	***0.0000***	***0.0098***	***0.0000***
		***	***	***	***	***	***	***
With Constant & Trend	t-Statistic	-5.0625	-4.8882	-5.9245	-10.0903	-8.8981	-3.9024	-8.4789
	Prob.	***0.0016***	***0.0030***	***0.0001***	***0.0000***	***0.0000***	***0.0236***	***0.0000***
		***	***	***	***	***	**	***
Without Constant & Trend	t-Statistic	-5.2527	-4.7115	-5.1660	-9.4121	-8.7823	-3.6865	-8.7329
	Prob.	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0006***	***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.

Source: Eviews 10 software output.

Table(2). Results of the Johansen-Joselius cointegration test for the study variables for the period (1990-2024)

Date: 12/06/25 Time: 17:29
Sample (adjusted): 1992 2024
Included observations: 33 after adjustments
Trend assumption: Linear deterministic trend
Series: Y2 X1 X2 X3 X4 X5 X6
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 *	0.907188	205.8202	125.6154	0.0000
At most 1 *	0.793821	127.3734	95.75366	0.0001
At most 2 *	0.681397	75.25608	69.81889	0.0172
At most 3	0.397469	37.52035	47.85613	0.3234
At most 4	0.294842	20.80204	29.79707	0.3701
At most 5	0.241024	9.274018	15.49471	0.3407
At most 6	0.005232	0.173110	3.841466	0.6774

Trace 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

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.907188	78.44676	46.23142	0.0000
At most 1 *	0.793821	52.10736	40.07757	0.0014
At most 2 *	0.681397	37.74573	33.87687	0.0164
At most 3	0.397469	16.71832	27.58434	0.6042
At most 4	0.294842	11.52802	21.13162	0.5946
At most 5	0.241024	9.100908	14.26460	0.2778
At most 6	0.005232	0.173110	3.841466	0.6774

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level

Source: Eviews 10 software output.

After conducting the cointegration test between the variables, it was found that there are a number of cointegration vectors between these variables. The results of the trace λ test shown in Table (Trace Statistics), which is 205.820, are greater than the critical value of 125.615. Furthermore, the prop value of 0.0000 is less than 5%, which means rejecting the null hypothesis and accepting the alternative hypothesis R>1, which states that there are three cointegration vectors and that the equation is integral. The maximum eigenvalue (maximum eigenvalue) indicates that the statistical value of 78.44 is greater than the critical value of 46.28, and the probability value (prob=0.0001) is less than 5%. This means rejecting the null hypothesis (r=0) and accepting the alternative hypothesis that there are three cointegrating vectors and that the equation is integral. This indicates a long-term equilibrium relationship between the study variables, and that they move in the same direction in the long run, despite some short-term deviations. Based on the cointegrating test results, the Vector Error Correction Model (VECM) will be used.

The results of the three tests (AIC, HQ, SC), which were used to determine the optimal slowing period that achieves the best estimate for the error correction vector model, Table (3), showed that this period is the second period for all variables because its value is the lowest compared to the rest of the values in the three tests, as stipulated by those tests. Therefore, this period will be adopted in estimating this model, which means that the error correction vector model that will be used to detect the direction of the relationship between the variables under study will include the first slowing period according to the Schwartz criterion.

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Table(3) Results of the number of optimal lag times for the duration

VAR Lag Order Selection Criteria
Endogenous variables: Y2 X1 X2 X3 X4 X5 X6
Exogenous variables: C
Date: 12/06/25 Time: 17:31
Sample: 1990 2024
Included observations: 33

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-872.0426	NA	3.24e+14	53.27531	53.59275	53.38212
1	-755.6968	176.2816	5.85e+12	49.19375	51.73327*	50.04822
2	-675.8221	87.13603*	1.39e+12*	47.32255*	52.08417	48.92469*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Eviews 10 software output.

Results of the Vector Error Correction Model (VECM) Estimation:

From observing the results of Table ( ), the negative and significant impact of the Tigris and Euphrates river revenues X1 on the agricultural crop production index indicates that the availability of water alone is not sufficient to improve agricultural production, and that institutional, administrative, infrastructure, and climate variability factors play a major role in converting available water into real production. Thus, the result reflects a structural problem in the Iraqi agricultural sector, and not just a direct effect of water on production. The analysis also indicated that carbon dioxide (CO_2) emissions had a significant positive impact on the agricultural crop production index in Iraq. This result can be explained from both an economic and environmental perspective, as improved agricultural activity is often associated with increased emissions. Expanding agricultural practices, such as fertilizer use, machinery operation, and production intensification, leads to increased CO_2 emissions from fuel consumption. Therefore, the positive relationship does not necessarily mean that emissions improve production; rather, increased production is associated with increased activities that generate more emissions. In developing countries like Iraq, increased emissions often indicate increased agricultural economic activity due to reliance on traditional, emission-intensive technologies. Thus, the relationship appears statistically positive. The significant positive impact also points to the absence of low-emission technologies in the agricultural sector, making any expansion in production directly linked to increased emissions, a correlation reflected in the econometric model. Furthermore, the results indicated

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that methane emissions did not have a significant impact on the crop production index. This is attributed to the fact that methane sources in Iraq are more closely linked to the oil and waste sectors than to the agricultural sector, and its indirect climatic impact may not be significant. As mentioned in the previous model, within the model's time horizon, nitrous oxide (X4) emissions had a negative impact on the crop production index. This reflects a flaw in the management of agricultural inputs and the agro-environment, as increased emissions lead to a decline in fertility and stress on the agricultural system, ultimately resulting in reduced agricultural production in Iraq.

The results indicated that average temperature (X5) had a significant negative impact on the agricultural crop production index. High temperatures in Iraq lead to decreased crop production because excessive heat causes heat stress on plants, reducing the efficiency of growth and photosynthesis processes. Heat also increases evaporation rates and moisture loss from the soil, weakening productivity in an environment already suffering from water scarcity. Furthermore, high temperatures contribute to the increased spread of agricultural pests and diseases, shorten the crop rotation cycle, and consequently reduce the quantity and quality of production.

The results also indicated that rainfall rate (X6) had a negative impact on the agricultural crop production index in Iraq during the study period. The negative impact of rainfall rate on crop production suggests that increased rainfall in Iraq is often irregular and intense, leading to flooding. Or excessive water saturation of the soil. This saturation reduces root aeration and leads to rotting, weakens nutrient absorption, and thus limits productivity. Also, sudden heavy rains may cause soil erosion and loss of fertility, especially in areas with fragile agricultural infrastructure. In addition, Iraqi agriculture depends largely on regulated irrigation rather than rainfall, so excessive rainfall often disrupts the agricultural system rather than supporting it.

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Table (4) Results of vector error correction estimation for a long-run model for the period (1990-2024):

Vector Error Correction Estimates
Date: 12/06/25 Time: 17:49
Sample (adjusted): 1993 2024
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
Y2(-1)	1.000000
X1(-1)	14.49419
	(2.25026)
	[6.44111]
X2(-1)	-0.961352
	(0.28654)
	[-3.35501]
X3(-1)	-0.497051
	(0.41716)
	[-1.19150]
X4(-1)	3.334179
	(0.49398)
	[6.74963]
X5(-1)	66.85643
	(7.65363)
	[8.73526]
X6(-1)	4.570217
	(0.51398)
	[8.89182]
C	-3008.632

Source: Eviews 10 software output.

Note: When interpreting long-run parameters in the VECM model, the signals are interpreted inversely.

The results of Table (5) also indicate short-term parameters, the most important of which is the value of the error correction factor (ECM), which indicates that the system is being adjusted to a state of equilibrium at an adjustment rate of (5%) per annum, which is a very slow rate.

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Table (5) Results of error correction vector estimation for a short-run model for the period (1990-2024)

Error Correction:	D(Y2)	D(X1)	D(X2)	D(X3)	D(X4)	D(X5)	D(X6)
CointEq1	-0.051694	-0.020578	-0.122814	0.017235	-0.105045	-0.006347	0.192807
	(0.01498)	(0.10932)	(0.08643)	(0.03640)	(0.07451)	(0.00413)	(0.14377)
	[-3.45043]	[-0.18823]	[-1.42094]	[0.47347]	[-1.40978]	[-1.53752]	[1.34111]
D(Y2(-1))	0.439554	0.078537	-0.419956	-0.317567	0.270211	-0.005555	-0.328356
	(0.26230)	(0.03595)	(0.20738)	(0.08734)	(0.17878)	(0.00990)	(0.34495)
	[1.67575]	[2.18484]	[-2.02507]	[-3.63605]	[1.51144]	[-0.56088]	[-0.95191]
D(Y2(-2))	-0.420904	0.061594	0.095066	0.043443	-0.048683	0.013943	-0.452787
	(0.32439)	(0.04446)	(0.25647)	(0.10801)	(0.22110)	(0.01225)	(0.42660)
	[-1.29752]	[1.38554]	[0.37068]	[0.40220]	[-0.22019]	[1.13833]	[-1.06140]
D(X1(-1))	1.111512	0.250511	1.064766	-0.430086	0.836819	0.085310	-3.064776
	(1.54247)	(0.21138)	(1.21949)	(0.51359)	(1.05130)	(0.05824)	(2.02845)
	[0.72061]	[1.18511]	[0.87313]	[-0.83740]	[0.79599]	[1.46472]	[-1.51090]
D(X1(-2))	-1.871187	-0.098567	-0.386680	-1.130467	-0.885405	0.101198	-3.433495
	(1.44763)	(0.19838)	(1.14450)	(0.48201)	(0.98666)	(0.05466)	(1.90372)
	[-1.29259]	[-0.49685]	[-0.33786]	[-2.34530]	[-0.89738]	[1.85134]	[-1.80357]
D(X2(-1))	0.980844	-0.240688	-0.133297	0.042917	0.571954	-0.025394	1.993598
	(0.48993)	(0.06714)	(0.38734)	(0.16313)	(0.33392)	(0.01850)	(0.64429)
	[2.00199]	[-3.58480]	[-0.34413]	[0.26308]	[1.71283]	[-1.37266]	[3.09423]
D(X2(-2))	0.106498	-0.057237	0.238128	0.001643	0.124951	0.004978	0.021179
	(0.40721)	(0.05580)	(0.32194)	(0.13559)	(0.27754)	(0.01538)	(0.53551)
	[0.26153]	[-1.02568]	[0.73966]	[0.01212]	[0.45021]	[0.32372]	[0.03955]
D(X3(-1))	-0.973317	0.081899	0.371741	0.132390	-0.308491	0.006443	-1.964202
	(0.72136)	(0.09886)	(0.57031)	(0.24019)	(0.49165)	(0.02724)	(0.94863)
	[-1.34929]	[0.82847]	[0.65182]	[0.55119]	[-0.62745]	[0.23653]	[-2.07056]
D(X3(-2))	-0.252783	-0.090616	-1.073716	0.007962	-0.632300	0.042724	-0.097161
	(0.56458)	(0.07737)	(0.44636)	(0.18799)	(0.38480)	(0.02132)	(0.74245)
	[-0.44774]	[-1.17121]	[-2.40551]	[0.04235]	[-1.64320]	[2.00413]	[-0.13087]
D(X4(-1))	-0.484862	0.096742	0.099452	0.042339	-0.747886	0.012260	-0.343314
	(0.40191)	(0.05508)	(0.31775)	(0.13382)	(0.27393)	(0.01518)	(0.52854)
	[-1.20639]	[1.75644]	[0.31299]	[0.31638]	[-2.73021]	[0.80785]	[-0.64955]
D(X4(-2))	-0.055585	-0.054150	0.154673	0.147229	-0.141799	-0.014227	0.980085
	(0.34215)	(0.04689)	(0.27051)	(0.11393)	(0.23320)	(0.01292)	(0.44995)
	[-0.16245]	[-1.15486]	[0.57178]	[1.29232]	[-0.60805]	[-1.10117]	[2.17819]
D(X5(-1))	7.842712	-0.680886	-0.421110	0.792416	3.400456	-0.373999	3.830555
	(4.20471)	(0.57622)	(3.32427)	(1.40004)	(2.86580)	(0.15877)	(5.52946)
	[1.86522]	[-1.18165]	[-0.12668]	[0.56600]	[1.18656]	[-2.35563]	[0.69275]
D(X5(-2))	1.977574	-2.038944	-0.738271	1.404868	-2.459838	-0.070247	16.41424
	(4.82306)	(0.66096)	(3.81314)	(1.60593)	(3.28725)	(0.18212)	(6.34263)
	[0.41002]	[-3.08483]	[-0.19361]	[0.87480]	[-0.74830]	[-0.38573]	[2.58792]
D(X6(-1))	0.146662	0.140049	0.471836	-0.020970	0.231280	0.019613	-1.432568
	(0.38131)	(0.05225)	(0.30146)	(0.12696)	(0.25989)	(0.01440)	(0.50144)
	[0.38463]	[2.68012]	[1.56515]	[-0.16517]	[0.88993]	[1.36217]	[-2.85689]
D(X6(-2))	-0.055099	0.082292	-0.023293	-0.078333	-0.102666	0.014593	-0.963086
	(0.25574)	(0.03505)	(0.20219)	(0.08515)	(0.17431)	(0.00966)	(0.33632)
	[-0.21545]	[2.34803]	[-0.11520]	[-0.91989]	[-0.58900]	[1.51116]	[-2.86361]
C	-2.801295	2.059063	8.404685	3.821394	-0.799253	-0.153478	-4.910996
	(5.24988)	(0.71945)	(4.15059)	(1.74805)	(3.57815)	(0.19823)	(6.90393)
	[-0.53359]	[2.86200]	[2.02494]	[2.18610]	[-0.22337]	[-0.77423]	[-0.71133]
R-squared	0.826540	0.547252	0.710543	0.691915	0.668586	0.787029	0.754250
Adj. R-squared	0.663922	0.122800	0.439178	0.403086	0.357885	0.587369	0.523860
Sum sq. resids	118.8271	6327.237	3954.888	701.4890	2939.227	9.021298	10942.27
S.E. equation	2.725197	19.88598	15.72198	6.621409	13.55366	0.750887	26.15133
F-statistic	5.082700	1.289314	2.618398	2.395584	2.151861	3.941839	3.273793
Log likelihood	-66.39698	-129.9962	-122.4776	-94.80554	-117.7287	-25.14767	-138.7605
Akaike AIC	5.149811	9.124760	8.654849	6.925346	8.358043	2.571729	9.672530
Schwarz SC	5.882679	9.857628	9.387717	7.658214	9.090911	3.304597	10.40540
Mean dependent	-0.015625	0.670625	9.346297	4.054688	1.621875	-0.110937	1.218750
S.D. dependent	4.700865	21.23233	20.99396	8.570269	16.91414	1.168943	37.89888

Source: Eviews 10 software output.

The correlation coefficient (R^2) was 82%, and the weighted R^2 was 66%. This means that the independent variables explain 66% of the variation in the dependent variable. And 34% is due to other factors not mentioned in the model, whose effect was absorbed by the random variable. The F-value was significant, and the p-value was 0.0000, which is less than 5%, indicating the overall significance of the model.

After completing the model estimation, and to confirm the accuracy of the results obtained above, some important tests must be performed:

Serial Correlation (LM) Test: This test is used to ensure that the estimated model is free from autocorrelation. The Breusch-Godfrey test was used to detect autocorrelation, and the test results are shown in Table (6).

Table (6) Results of the Autocorrelation Test for Errors (LM Test)

VEC Residual Serial Correlation LM Tests
Date: 12/06/25 Time: 17:54
Sample: 1990 2024
Included observations: 32

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	63.92231	49	0.0746	1.363131	(49, 19.7)	0.2293

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	63.92231	49	0.0746	1.363131	(49, 19.7)	0.2293

*Edgeworth expansion corrected likelihood ratio statistic.

Source: Eviews 10 software output.

The results in the table above indicate that the probability value of the F-statistic, F(1.36) = 0.2293, which is greater than 5%. This means accepting the null hypothesis (which states that there is no autocorrelation between random residuals) and rejecting the alternative hypothesis. This indicates that the model is free from the problem of autocorrelation between random residuals, which strengthens the possibility of relying on the model's results in analysis, prediction, and policymaking.

The Heteroskedasticity Test: This test is used to detect heterogeneity of variance. The following results were obtained:

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Table (7) Results of the Heteroskedasticity Test

VEC Residual Heteroskedasticity Tests (Levels and Squares)
Date: 12/06/25 Time: 17:55
Sample: 1990 2024
Included observations: 32

Joint test:

Chi-sq	df	Prob.
865.8406	840	0.2610

Source: Eviews 10 software output.

The results above indicate that the model is free from the inconsistency of variance problem, based on the Chi-sq value of 0.2610, which is greater than 5%. This means accepting the null hypothesis (which states that there is no inconsistency of variance) and rejecting the alternative hypothesis, thus indicating that the model is free from the inconsistency of variance problem. This strengthens the acceptability of the model's results.

Model quality test (unit root test): From Figure (1), it is observed that the model achieves stability because the points fall within the circle boundaries.

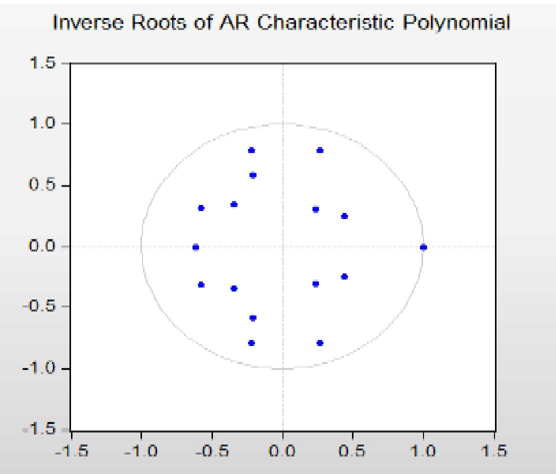

Figure (1) shows the results of the model quality test (unit root test).

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

Conclusions and Recommendations

Based on the obtained results, it can be concluded that the performance of the agricultural sector in Iraq is influenced by structural, climatic, and environmental factors that go beyond the mere availability of water resources. The negative and significant impact of the Tigris and Euphrates river revenues on the agricultural crop production index indicates the presence of institutional and administrative inefficiencies, weak agricultural infrastructure, climate variability, and poor resource management, which prevent the effective transformation of available water into actual agricultural output. The statistically significant positive relationship between carbon dioxide emissions and the crop production index reflects a pattern of agricultural expansion dependent on traditional, emission-intensive technologies, indicating that increases in production are associated with higher levels of polluting economic activity rather than improvements in environmental efficiency. In contrast, methane emissions did not show a significant effect on agricultural production,

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as their primary sources in Iraq are more closely related to the oil and waste sectors than to agriculture. The negative impact of nitrous oxide emissions, average temperature, and rainfall rates on the crop production index highlights deficiencies in input management, the adverse effects of heat stress on crops, and the consequences of irregular and intense rainfall, such as soil saturation, erosion, and reduced soil fertility. Accordingly, the study recommends adopting integrated agricultural policies focused on institutional reform, improving water resource management efficiency, upgrading agricultural infrastructure, and promoting the use of modern, low-emission agricultural technologies. In addition, strengthening climate change adaptation measures—such as developing heat- and drought-resistant crop varieties, improving irrigation systems, and enhancing early warning and climate monitoring systems is essential to improve agricultural productivity, sustainability, and food security in Iraq. The research recommends continued support for the agricultural sector to reduce import pressure and increase self-sufficiency in other goods. It also recommends rationalizing import policies during periods of high agricultural production, renewing oversight of imported products to minimize waste, reducing waste and loss is achieved by rationalizing both imports and consumption through guidelines, behaviors, and changes in dietary habits. and promoting local alternatives such as Iraqi herbal drinks, which can reduce reliance on imported beverages. Furthermore, it recommends stabilizing the exchange rate through clear monetary policies to curb speculation and unjustified import increases, strengthening border controls to prevent unregulated expansion of essential goods imports, and regulating imports through quotas or controls to prevent excessive import volumes during periods of currency fluctuation. The research also recommends raising consumer awareness to reduce the culture of excessive hoarding, which exacerbates demand when the dollar rises. The study further recommends diversifying the economy and reducing dependence on oil to lessen the sensitivity of local markets to oil price volatility. It suggests using oil surpluses to establish a strategic reserve of essential food commodities and strengthening food security policies by supporting local production of arable goods, reducing the import bill, and adopting sound fiscal policies during periods of high oil prices to avoid excessive imports that create structural imbalances.

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Appendices

YEAR	**Y2**	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**
1990	120.75	43	96.222	95.44	-20.1	29.6	162.6
1991	94.45	42	54.413	22.23	-23.2	28.9	169.3
1992	102.6	41	75.718	28.33	-8.6	27.4	177
1993	121.36	40	136.83	32.69	15	21.89	240.08
1994	118.33	39	148.845	35.02	15.3	22.81	234.53
1995	124.23	39	149.027	36.37	11.3	22.49	154.2
1996	126.33	39	138.537	34.48	11.2	22.87	238.59
1997	120.76	40	177.629	50.91	19.3	22.16	201.03
1998	130.6	41	159.285	57.89	20	23.37	171.54
1999	119.79	42	148.545	66.42	17.6	23.37	169.25
2000	112.69	42	168.338	71.44	17.3	22.86	178.36

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2001	131.67	42	182.023	72.75	26.8	23.48	187.23
2002	150.06	42	170.171	65.88	58.3	22.84	209.29
2003	123.31	42	152.254	64.07	-10.3	23.01	214.56
2004	116.69	42.3	171.04	74.23	15.1	22.88	201.31
2005	123.73	42.4	164.72	70.7	5.1	22.96	180.76
2006	126.38	43.2	164.383	72.86	4.8	23	220.15
2007	120.78	44.7	154.653	69.47	3.3	22.92	176.58
2008	104.25	46.5	171.651	73.66	11.4	23.09	134.23
2009	106.49	47.9	187.4319	82.8	28.2	23.07	174.82
2010	124.06	48.6	210.601	91.39	32.6	24.47	155.73
2011	133.51	44.5	223.8747	100.07	37.5	22.61	179.33
2012	134.28	43.7	253.4315	111.39	44.9	23.21	176.99
2013	155.09	42.9	265.3887	111.71	54.4	22.87	197.78
2014	144.82	37.7	265.5317	117.32	58.4	23.32	180.64
2015	76.18	44.6	275.9174	127.82	38.1	23.54	171.66
2016	79	42.3	322.764	157.24	52.6	23.36	212.7
2017	75.67	40	338.2099	160.17	44.9	23.38	169.78
2018	72.82	41.7	354.9466	163.4	53.8	24.18	236.69
2019	127.79	37.7	376.877	169.83	64.2	23.55	211.85
2020	158.63	38.1	331.5823	149.28	46.1	23.43	211.63
2021	127.72	54	335.7908	149.81	43.2	24.26	153.42
2022	104.22	59.7	365.296	163.12	43.5	23.84	164.88
2023	106.49	43.8	384.303	153.05	46.1	24.06	216.5
2024	124.06	40.5	374.7995	158.08	43.3	23.85	216

Source: Ministry of Planning / Central Statistical Organization