Assessing The Impact of Water Resources and Arable Land on Agricultural Production in Iraq

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Abstract: - This work aims to estimate the impact of water resources, arable land, and several control variables on agricultural output in Iraq during 2004–2024. Econometric methodology, specifically the Autoregressive Distributed Lag model. This method was used to estimate the relationship between variables based on semi-annual data. The results showed a cointegrating relationship among the variables and a significant long-term positive relationship between arable land (X1), agricultural credit (X4), central bank independence (X5), and the inflation rate (X7) on agricultural output (Y). Conversely, significant long-term negative relationships were found between water resources (X2), agricultural investment (X3), the parallel exchange rate (X6), the interest rate (X8), and agricultural output (Y) at a significance level of 1%. The study recommends preserving arable land by addressing salinity, halting erosion and desertification, preventing subdivision or use for residential or industrial purposes, and utilizing digitalization and sustainable modern management practices to protect it. It developed a strategy that adopts water management and includes modern irrigation methods, water recycling, well water regulation, rainwater and snow storage, and regulates domestic and industrial use, and adopts a disciplined long-term monetary policy whose tools are directed and guided by the results of its indicators to support inputs of agricultural and animal production factors.

Key-Words: - Water Management, Land Sustainability, Monetary Policy, Agricultural Investment, Agricultural Credit, Agricultural Production**,** ARDL Model.

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1 Introduction

Agricultural production is a robust pillar of economic and social evolution in Iraq. Its function extends further, reaching food security to include being a significant source of job creation, enhancing the trade balance, and stimulating related activities, including manufacturing, marketing, and logistics for other sectors, [1]. Despite Iraq's substantial agricultural potential, including productive land, water resources, and a diverse climate, the agricultural sector's contribution to GDP has decreased sharply over the past three decades, resulting in a regular agricultural trade deficiency, [2]. This necessitates a thorough scientific analysis of the causes for this decrease, in light of the country's economic, environmental, and water-related challenges. The demand has appeared to examine and investigate the economic aspects influencing the value of agricultural production, including arable land, water resources, and certain control variables. Water resources and arable land are closely linked to the security and stability of agricultural production, and the degree of compatibility between them has a temporal and spatial impact, and a direct effect on agricultural productivity and sustainable agricultural development, [3].

The average total area of arable land in Iraq during the study period is approximately 4,985,637.5 million hectares. The total area of land available for irrigation is approximately 22.86 million hectares, and the irrigated area is approximately 13.24 million hectares. The arable land accounts for approximately 26.1% of the country's total land area, [4]. Fluctuations in land area in some years have contributed to fluctuations in agricultural production, indicating the agricultural sensitivity to changes in natural, economic, and social resources, [5]. The efficient use of agricultural land requires considering the impact of all factors and the degree of their impact on the technological, social, and economic efficiency of land use and the resource potential of agricultural enterprises. Renewable freshwater resources are estimated at approximately 2,000 cubic meters per capita annually, obtained from the Tigris and Euphrates, and these resources have declined significantly over the past 20 years. Before

1990, Iraq produced about one-third of its basic food needs annually, and in 2023, it spent about US$2 billion to import its food needs. Despite the focus on increasing food production, the agricultural sector continues to deteriorate.

Agricultural production remains limited due to shortages of high-quality seeds, herbicides/pesticides, fertilizers, animal vaccines, machinery, irrigation equipment, and flawed economic policies (monetary and fiscal). The Iraqi economy is characterized by numerous transitional phases and periods, marked by severe economic, political, and security upheavals in most cases, and periods of relative calm and instability in the fewest. Likewise, water resources in arid lands are declining due to extreme drought, which has harmed crops in 70% of the country's rain-fed agricultural land. Iraqi farmers struggle to plant under unfavorable environmental situations, lacking the instruments to combat drought, pests, salinity, and a lack of agricultural inputs and applicable technologies, [6]. Furthermore, mismanagement and weak revenue collection have made Iraq one of the countries with high corruption rates, according to the Corruption Perceptions Index issued by Transparency International, [7]. The availability of arable land and the lack of water resources pose a prior hazard to Iraq's future food security. A growing population is accompanied by rising food demand. Nevertheless, production is slowly declining due to diminished arable land and the scarcity of unrestricted water, both of which are attributed to its modification to commercial, industrial, and residential uses, [8].

The significance of this investigation lies in its examination of two of the most vital inputs for agricultural production: water resources and arable land. These inputs play a direct function in sustaining farmers and agricultural assets, and in determining the magnitude of agricultural output. Considering the influence of water resources and arable land allows for determining and analyzing the characteristics influencing improved agricultural production, thereby keeping self-sufficiency and lowering reliance on imports. The examination of these variables has become a priority for investigators, international institutions, and forums, especially in relation to global food security and environmental modifications. This article hypothesizes that water resources, arable land, and management variables have a considerable and positive effect on the agricultural production index in Iraq, with statistically significant and influential correlations between them. The investigation problem is handled through several inquiries: What is the extent of the influence of water resources and arable land on agricultural production? Does the influence of water resources and arable land conflict in the short term correspond to the long term? Is there a reduction in the magnitude of water resources and arable land? Are there other aspects that influence the drop in agricultural production? The purpose of this investigation is to calculate the influence of water resources and arable land on agricultural outcomes in Iraq for the period 2004-2024, and to examine the association between water revenues, arable land, agricultural production, and selected control variables employing quantitative methods, including tests and standard models.

2 Literature Review

Several investigations have examined characteristics of this subject, including investigation [9], which studied managing irrigation water and food security in Nigeria in 2023. This investigation analyzes the multifaceted association between irrigation water management and food security, highlighting the influence of water availability, quality, and accessibility on crop yields, livestock production, and overall agricultural outcome. The investigation utilizes a mixed-methods strategy, incorporating a complete literature review, field examinations, discussions, and focus group discussions with key stakeholders, including growers, water resource managers, policymakers, and specialists. The results indicate meaningful gaps in Nigeria's recent irrigation water management system, including outdated infrastructure, inadequate water distribution, inflexible access to irrigation technology, and inefficient coordination among applicable government agencies and agricultural extension assistance. Another investigation [10] examined water scarcity and future challenges to food production. It studied present and future topics associated with water scarcity to highlight the demand for a more sustainable strategy for managing water resources. Water scarcity and drought, climate change, and improved irrigation water usage are anticipated to advance particularly amidst intense competition between the agriculture sector and other economic sectors. Likewise, the projected growth in global population rates suggests an inevitable rise in future food demand, which will instantly influence water usage in agriculture. Given the close association between a country's water resources and its food production capability, considering irrigation requirements is critical for water resource planning to fulfill food essentials and avoid extreme water consumption.

Investigation [11] examined abandonment of arable land in Europe, 1990–2006. The investigation aimed to study specific areas of arable land abandonment and expansion, utilizing logistic regression. It concluded that areas near road networks are associated with high rates of both abandonment and expansion, suggesting that abandonment is not restricted to areas marginal to agricultural production. Investigation [12] also showed the influence of water control on production, employment, and capital growth in an agricultural economy, in Pakistan, during 1980–2008. The observed outcomes demonstrate that capital and work in the agricultural sector have a particular impact on production growth. Enhancing capital through mechanization, enhanced seeds, fertilizers, and pesticides, as well as enhancing labor skills, strategies, and management, will have a considerable positive influence on farming production.

Likewise, any progress in control procedures by the authorities will considerably improve agricultural production. This study [13] examined the state of arable land worldwide and its impact on agricultural production from 1961 to 2019. It aimed to gather information on the extent of arable land and related agricultural approaches. The study reviewed the latest scientific findings in soil carbon, soil health, land degradation processes, greenhouse gas emissions, threats to biodiversity, and the key socio-economic aspects of arable land. Although agriculture's share of global GDP has declined significantly since 1960, it remains a crucial employer in rural areas. Therefore, enhancing agricultural production performance remains a pressing priority for poverty reduction worldwide.

The similarities and differences between this study and previous studies reviewed lie in its general focus on several impacts of economic variables on agricultural output, which was used to develop a suitable scientific methodology for analysis. This study differs from its predecessor is determined by the choice of economic region, which is the Iraqi economy, and the time period 2004-2024, the difference of most of the independent variables and the mechanism of their description, and its use of the descriptive analytical method and the standard method through several tests and models such as the ARDL model, as well as the difference in the theoretical presentation of the variables according to the logic of economic theory, and the difference in the results, discussion, conclusions and recommendations.

3 Theoretical Framework

3.1 Agricultural Output

Agricultural output is a part of the gross domestic product in the economy, as it represents the total market value (prevailing market prices) of final goods and services produced within a specific economy during a year. The agricultural gross domestic product is the total market monetary value of all final goods and services produced in the agricultural sectors within the country's borders during a specified period (usually a year). This indicator represents the net added value from agricultural activity, after deducting the value of intermediate inputs (such as seeds and fertilizers) from total production, and it is a fundamental measure of agriculture's contribution to the national economy, [14].

The agricultural gross domestic product usually consists of the following activities:

- Plant production: grain crops, vegetables, fruits, and fodder.
- Animal production: livestock breeding, dairy production, poultry, eggs.
- Forestry and wood: activities related to the production of wood and forest resources.
- Fishing and aquaculture: exploitation of aquatic resources.

Agricultural output is affected by a complex and large set of interrelated factors that determine the quantity, quality, and economic value of production. These factors can be classified into the following main categories:

- Natural and environmental factors, including: climate, water, soil, agricultural land, terrain.
- Economic and financial factors, including: tools and indicators of monetary and financial policy, and infrastructure.
- Technological factors, including: modern technologies, genetic engineering, and artificial intelligence.
- Human factors, including: skill and experience, education level, number of workers, population size.
- Political, institutional, and security factors, including: political stability, legislation, terrorism, violence, and administrative and financial corruption.
- Biological factors, including: pests, insects, parasitic plant and animal diseases.

This paper focuses on natural and environmental factors and economic and financial factors as determinants of agricultural output. The following presents these variables and their impact on agricultural output according to economic theory and applied studies.

3.2 Natural and Environmental Factors

3.2.1 Arable Land

Arable land represents the total area cultivated with temporary crops, temporary meadows and pastures, temporarily fallow land, land with permanent crops, and unused arable land, [3]. The impact of arable land on agricultural output is positive. There are also factors affecting the area of arable land, such as weather conditions, including reduced water revenues, rainfall, groundwater, desertification, soil degradation, and destruction of vegetation cover due to rising temperatures. A decrease in rainfall levels leads to the migration of arable land, its non-use, and makes it susceptible to desertification.

Wars and armed conflicts lead to severe deterioration in cultivated areas through a series of direct and indirect effects that extend for years after the conflict ends. The most prominent effects of wars on agricultural land are the destruction of infrastructure and vegetation cover, soil contamination with chemicals and debris, mines and war remnants, labor displacement and land abandonment, and a shortage of agricultural inputs. For example, when conflicts intensified and lasted for several years, ending in the early 1990s and early 2000s—in Cambodia, Mozambique, the southern highlands of Peru, Rwanda, Sierra Leone, and northern Uganda—making agricultural lands extremely hazardous for farming, [15]. Similarly, what happened in Iraq, Yemen, Syria, Ukraine, and Russia all had a significant impact on the wastage of vast areas of agricultural land.

3.2.2 Water Revenues

Water revenues refer to the available sources of fresh water (river water) used for drinking, agriculture, and industry. The relationship between water revenues and agricultural production is direct, as water revenues affect the area, and a shortage of water revenues leads to a direct reduction in cultivated areas.

3.3 Economic and Financial Factors

3.3.1 Agricultural Investment

Agricultural investment is the process of employing or operating funds and then converting them into their real form represented by agricultural goods and services with the aim of making a profit, which is primarily the return on risk, [16]. Studies have proven a strong positive relationship between the size of investment and growth in agricultural GDP, as investment is considered a flow variable that revitalizes the sector. Establishing agricultural and service projects and infrastructure directly and indirectly leads to an increase in agricultural output, farmers' income, the introduction of innovations and agricultural technology, achieving competitiveness, providing job opportunities, and enhancing exports, [17].

3.3.2 Agricultural Credit

Agricultural credit, in its two forms of loans and advances, constitutes the largest proportion of credit granted by government and commercial banks, which includes the agriculture and fishing sectors. Directing this credit towards agricultural investments increases the added value of agriculture and fishing. Agricultural credit has a direct and vital impact on agricultural output by providing the necessary cash liquidity for farmers to overcome capital shortage obstacles, which positively reflects on increasing cultivated areas and improving production rates, [18].

3.3.3 Independence of the Central Bank

It is the management of monetary policy without political pressures and interventions. Independence has indirect effects on many economic sectors, including the agricultural sector. The monetary policies adopted by the central bank, such as controlling interest rates and exchange rates (the competitive advantage of agricultural goods), determining the money supply, employing farmers' savings, and reducing inflationary pressures, can affect agricultural financing, investment in this sector, as well as the prices of agricultural products, which in turn reflect on agricultural output. The existence of central bank independence means there is control over monetary policy tools, which generates monetary and financial stability and makes it easier to achieve the set goals for developing the agricultural sector and achieving an acceptable growth rate, [19].

3.3.4 Parallel Exchange Rate

The exchange rate directly and fundamentally affects agricultural output through multiple channels, including production costs (a decrease in the value of the local currency leads to an increase in the costs of these inputs priced in foreign currency, which raises the total production cost and reduces farmers' profit margins, possibly pushing them to reduce cultivated areas), and export competitiveness (the exchange rate is the main determinant of the price of local crops in international markets through either depreciation or appreciation of the currency).

3.3.5 Inflation Rate
Inflation is generally defined as a continuous rise in the general level of prices of goods and services in an economy over a period of time. Inflation has significant effects on the agricultural sector. Rising inflation usually increases the cost of agricultural inputs, such as fertilizers, seeds, and machinery, reducing farmers' profit margins and may discourage them from investing in agriculture. This cost-driven inflation often leads to declines in agricultural productivity and production. Conversely, inflation in agricultural product prices may benefit farmers in the short term by increasing their revenues. However, this is often offset by rising input costs and the general economic instability generated by high inflation. Empirical studies have shown an inverse relationship between inflation and agricultural production, indicating that inflationary pressures significantly constrain agricultural production by increasing production costs and reducing farmers' purchasing power, [20].

3.3.6 Interest Rate
The interest rate is generally defined as the cost of borrowing credit for investment purposes and plays a pivotal role in shaping economic activity. As a fundamental macroeconomic variable, it has attracted considerable attention from economists, policymakers, lenders, and borrowers due to its profound impact on investment decisions and capital allocation. Essentially, interest rates exhibit an inverse relationship with agricultural investment, where high rates tend to discourage borrowing, thereby reducing investment and subsequently lowering agricultural output, while low rates stimulate agricultural investment by lowering the cost of financing, [21].

4 Materials and Methods
To estimate the impact of arable land and water resources on agricultural output in the Iraqi economy, a time series model for the period 2004–2024 was used. Control variables were added to ensure unbiased and spurious results, improve the accuracy of the estimates, and avoid omitted variable bias. The control variables help reduce standard errors, thus increasing the statistical significance of the model. Data were collected from the Geographic Information Systems Authority [22], the Central Bank of Iraq [23], and the World Bank and Food and Agriculture Organization [24]. The time series data were converted from annual to semi-annual in their original format, with 42 observations, to use the Autoregressive Distributed Lag (ARDL) model, which allows for highly precise association accounting, [25].

The general form of the (ARDL) model, consisting of a dependent variable and K explanatory variables (X1, X2, …, Xi), is written in the form (P, q1, q2, …, qk) as follows, [26]:

$$\begin{aligned}\Delta Y_t = C &+ \propto_1 Y_{(t-1)} + \propto_2 X_{1(t-1)} \\ &+ \propto_3 X_{2(t-1)} \\ &+ \cdots \ldots\ldots + \propto_{(k+1)} X_{K(t-1)} \\ &+ \sum_{t=1}^{p-1} \emptyset_{1_i}\ \Delta Y_{(t-i)} \\ &+ \sum_{i=0}^{q_1-1} \emptyset_{2_i}\ \Delta X_{1(t-i)} \\ &+ \sum_{i=0}^{q_2-1} \emptyset_{3_i}\ \Delta X_{2(t-i)} \\ &+ \sum_{i=0}^{q_k-1} \emptyset_k + l_i\ \Delta X_{K(t-i)} \\ &+ E_t\end{aligned} \tag{1}$$

This model is optimal for analyzing the dynamic relationship between these variables because it can process first-order integrated data and analyze short-term and long-term correlations simultaneously, [27]. Nine variables were considered, with agricultural output being the dependent variable and the others being independent variables. The economic model was formulated as follows:

$$\begin{aligned} Y_t = \beta_0 + \beta_1 X_t 1 + \beta_2 X_t 2 + \beta_3 X_t 3 + \beta_4 X_t 4 \\ + \beta 5 X_t 5 + \beta_6 X_t 6 + \beta_7 X_t 7 + \beta_8 X_t 8 + E_t \end{aligned} \tag{2}$$

where: (Y) agricultural output, (X1) arable land, (X2) water revenues, (X3) agricultural investment, (X4) agricultural credit, (X5) central bank independence, (X6) parallel exchange rate, (X7) inflation rate, (X8) interest rate, (β_o) intersection, (Et) random error variable, and (t) time. Unit root tests are used to establish data stability over the research period, determine the optimal lag period for later time intervals, estimate short-term and long-term associations between variables, and test the model's validity through a number of tests, [28].

This study differs from our previous studies in that it examines the effect of (water revenues from arable lands, agricultural credit, central bank independence, inflation rate, parallel exchange rate, and interest rate) on agricultural output in Iraq using semi-annual data for the period 2004-2024. Our previous study [3] examined the effect of public savings on agricultural and fishery investments in the government and private sectors for the period 2005-2021, where (public savings, government investments, private sector investments in forestry and fishing, and GDP) represented the dependent variables, while public savings was the independent variable. The current study also differs from our previous study [25], which aimed to measure and estimate the effect of domestic public debt on government agricultural investment and economic growth using quarterly data for the period 2004-2022, where domestic public debt was the independent variable, while economic growth and government agricultural investment were dependent variables. Additionally, the current study differs from our previous study [28], which aimed to measure and analyze the effect of inflationary pressures on foreign trade of agricultural goods and live animals for the period 2004-2022 using the VECM econometric methodology. In that study, inflationary pressures were the independent variable, while the agricultural trade balance for agricultural goods and live animals was the dependent variable.

5 Results and Discussion

5.1 Unit Root Tests

Table 1 (Appendix) shows the unit root test results using the Extended Dickey-Fuller Test (ADF) (14).

The augmented Dickey-Fuller test is the most common unit root test. It is a regression of the first difference of the variable on its lagged level, in addition to additional lags of the first difference. The Dickey-Fuller test was built on the assumption of a normally distributed, independent error distribution.

This test is based on three equations[29]:

1- The first equation without a constant term and a time trend.

$$\Delta Y_t = (\rho - 1)Y_{t-1+\sum_i^k=1\rho i\Delta Y_{t-1}+vt} \quad (3)$$

2- The second equation with a constant term and without a time trend.

$$\Delta Y_t = c + (\rho - 1)Y_{t-1} + \sum_{i=1}^{n} \Delta Y_{t-i} + e_t \quad (4)$$

3- The third equation with a constant term and a time trend:

$$\Delta Y_t = c + \beta T + (\rho - 1)Y_{t-1} + \sum_{i=1}^{n} \rho i \Delta Y_{t-i} + e\,_t \quad (5)$$

The results in Table 1 (Appendix) indicate that some of the variables under investigation exhibit a unit root, meaning they are not stationary at the original data level. The first difference was then used, and most of them became stationary at the 1% level, meaning they are of integral order [1][I]. Here, we accept the alternative hypothesis (HI), which assumes that the time series are stationary at the first difference, and reject the null hypothesis (H0), which assumes that the time series are not stationary at the first difference. Therefore, these results justify the use of the Arrhythmic Delay Model (ARDL), in addition to cointegration tests and error-correction vector analysis, to study the short- and long-term association among the variables under investigation.

5.2 County Integration Test for the Study Variables

Because not all study variables are stationary at the same level, as indicated by the root tests, the model indicates cointegration among the variables, suggesting a long-term equilibrium association. The bounds test will be utilized. According to this test, the first step is the bounds test, which estimates the Unbounded Error Correction Model (UECM) to determine whether a stable long-term equilibrium association exists between the dependent variable and the independent variables. The estimated F-statistic is then compared with the critical (tabbed) values provided by Besran. Table 2 shows the cointegration results between variables.

Table 2. Bounds Test according to the ARDL methodology

The results	K	F-Statistic	
There is integration	8	34.43763	
The critical (tablodic) value of the F statistic at K = 8			
	The Minimum I(0)	**The Maximum I(1)**	**Significance level**
There is mutual integration	1.85	10%	2.85
There is mutual integration	2.11	5%	3.15
There is mutual integration	2.33	2.50%	3.42
There is mutual integration	2.62	1%	3.77

Source: Prepared by the authors based on the outputs of the EViews program.

Table 2 shows that the calculated F-statistic is 34.43763, which is greater than the upper critical values in the model estimated by Bessran's test at 1% and 5% levels, which are 3.77 and 3.15, respectively. This result supports rejecting the null hypothesis at these significance levels, corroborating the existence of a long-term equilibrium association between agricultural output (the dependent variable) and the independent variables under study.

5.3 Determining the Distributed Lag Length Periods:

The lag order in the ARDL model is selected using the Akaike information criterion. We determine the optimal lag scores before estimating the specific model to eliminate serial or self-correlation in random errors. The optimal lag period is chosen as the one with the lowest value. The results in Figure 1 indicate that the optimal lag period for the first difference is (2,0,0,2,0,2,2,2,2), as it corresponds to the lowest value of the used criterion (14).

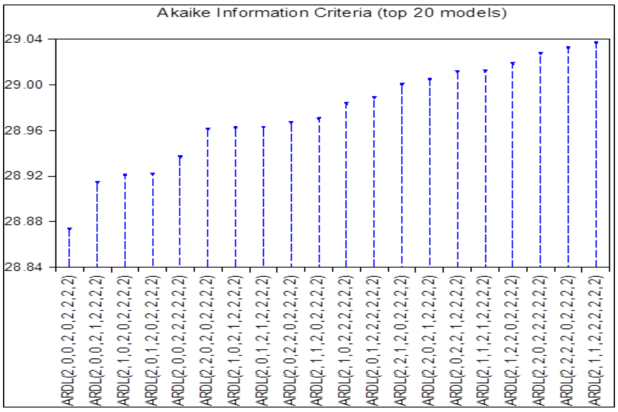

Fig. 1: The (AIC: Akaike) Standard for The Time Lag of The Model
Source: Prepared by the authors based on the outputs of the EViews program.

5.4 Estimating the Error Correction Parameter for the Model:

The results in Table 3 imply the presence of cointegration between the independent and dependent variables, as the error correction parameter reached -0.50652, which is negative and statistically significant at 1%. The error-correction coefficient expresses the rate of adjustment from the short to the long-term, so it must be negative and significant to provide evidence of cointegration between variables. The results show that the value of the error correction coefficient is significant and negative, which means that statistical significance is achieved, as the error correction parameter takes a negative sign and is statistically significant at 1%. This indicates that (0.50) of the short-term errors caused by shocks to the independent variables can be corrected by the agricultural output within a unit of time (14).

Table 3. Results of the Error Correction Model (ECM) estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Y(-1))	-0.46861	0.048387	-9.68461	0.0000
D(X3)	0.130352	0.179748	0.725197	0.4788
D(X3(-1))	3.978718	0.26091	15.24936	0.0000
D(X5)	683349	134415.3	5.083865	0.0001
D(X5(-1))	4987590	274596.4	18.16335	0.0000
D(X6)	1121.506	948.9267	1.181868	0.2545
D(X6(-1))	45084.24	2179.108	20.68931	0.0000
D(X7)	205335.1	13197.09	15.55912	0.0000
D(X7(-1))	-228349	13079.1	-17.4591	0.0000
D(X8)	257947.7	23854.31	10.81346	0.0000
D(X8(-1))	836270.1	43372.12	19.28128	0.0000
CointEq(-1)*	-0.50652	0.021836	-23.1967	0.0000
R-squared	0.960641		Mean depend var	196563.2
Adjusted R-squared	0.943323		S.D. dependen	1304591
S.E. of regressic	310583.7		Akaike infc criterion	28.3869
Sum squa resid	2.41E+12		Schwarz criteı	28.90936
Log likelih	-513.158		Hannan-Quii criter.	28.57109
Durbin-Wa stat	1.679723			

Source: Prepared by the authors based on the outputs of the EViews program.

5.5 Estimating the Short-Term and Long-Term Relationship of the Model

After conducting static and cointegration tests, the model is evaluated. Following an experimental approach, the study arrived at the optimal functional formula in terms of gaps, ARDL (2,0,0,2,0,2,2,2,2), Table 4 (14):

Table 4. Results of the short-term and long-term association between independent and dependent variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.14E+08	36035602	0.0000	0.0000
Y(-1)*	-0.506523	0.060937	-8.3122	0.0000
X1**	10.65411	1.178001	9.044232	0.0000
X2**	-30850.03	10255.21	-3.00823	0.0083
X3(-1)	-3.75534	0.31001	-12.1136	0.0000
X4**	0.022355	0.001857	12.04102	0.0000
X5(-1)	-4198202	490726.8	-8.55507	0.0000
X6(-1)	-43790.99	4200.381	-10.4255	0.0000
X7(-1)	433122.4	52426.46	8.261522	0.0000
X8(-1)	-564046.5	96330.64	-5.85532	0.0000
D(Y(-1))	-0.468605	0.083176	-5.63391	0.0000
D(X3)	-0.130352	0.322727	-0.40391	0.6916
D(X3(-1))	3.978718	0.466652	8.526092	0.0000
D(X5)	683349	277747.6	2.460324	0.0256
D(X5(-1))	4987590	413744.8	12.05475	0.0000
D(X6)	-1121.506	1798.119	-0.62371	0.5416
D(X6(-1))	45084.24	3809.027	11.83616	0.0000
D(X7)	205335.1	34993.13	5.867869	0.0000
D(X7(-1))	-228349	28213.85	-8.09351	0.0000
D(X8)	-257947.7	47554.15	-5.42429	0.0001
D(X8(-1))	836270.1	117440.2	7.120814	0.0000

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	21.03381	2.263731	9.291654	0.0000
X2	-60905.46	17071.95	-3.56758	0.0026
X3	-7.413955	0.935349	-7.92641	0.0000
X4	0.044135	0.004125	10.70057	0.0000
X5	8288271	1146912	7.226597	0.0000
X6	-86454.07	10741.81	-8.04837	0.0000
X7	855089	109246.5	7.827155	0.0000
X8	-1113565	183362.3	-6.07303	0.0000
C	620727631	86551650	7.17176	0.0000

Source: Prepared by the authors based on the outputs of the EViews program.

The short-term and long-term relationships between variables can be interpreted as follows:

Short-term relationship:
The results show a significant association between all independent variables and the dependent variable in the short term, with a clear positive relationship for the arable land variable (X1). An increase of one unit in (X1) leads to an increase in agricultural output (Y) by 10.65411. An inverse relationship is found for the water revenue variable (X2), meaning that an increase of 1 unit in (X2) leads to a decrease in (Y) by 30850.03. The results show an inverse relationship for the agricultural investment variable (X3), where a one-unit increase in (X3) leads to a decrease in (Y) of 0.130352. A direct association is seen for the farming credit variable (X4), with a 1-unit increase in (X4) associated with an expansion in (Y) of 0.022355. A direct association is obvious for the central bank independence variable (X5), where a one-unit expansion in (X5) results in an expansion in (Y) by 683349. The outcomes indicate an inverse association for the parallel exchange rate variable (X6) during the initial deceleration time, but it was not influential throughout the examination term. This indicates that an increase of one unit in (X6) leads to a reduction in Y of (43790.99). A straightforward association is evident for the inflation variable (X7), as an expansion of one unit in (X7) results in an expansion in Y by (205335.1). An inverse association is evident for the interest rate variable (X8), indicating that an expansion in (X8) results in a reduction in Y by (257947.7).

Long-Term Relationship:
Examination of the outcomes of the association between arable land (X1) and agricultural outcome (Y): The outcomes suggest a substantial positive long-term association between arable land (X1) and agricultural outcome (Y) at 1%. The coefficient value was 21.03381, suggesting that a one-unit expansion in X1 leads to an expansion of 21.03381 in Y. This aligns with economic theory and the research hypothesis. The availability of arable land improves farming production. The area of arable land directly and seriously influences the volume and sustainability of farming production. Arable land discourages growers or investors from recycling less fertile land, therefore avoiding raised fees associated with land reclamation, higher product costs, and a loss of competitive benefit in the market. Soil quality and nutrient availability improve effective efficiency, helping agricultural development and food security.

Investigation of the association between water gains (X2) and agricultural outcome (Y): The outcomes indicate a substantial inverse association between water revenues (X2) and farming outcome (Y) in the long run at 1%, with a coefficient value of -60905.46. This suggests that an expansion of 1 unit in (X2) results in a decline of (Y) by 60905.46, which opposes the logic of economic theory and the investigation hypothesis. The association between water revenues and farming outcome is typically direct (expanded water leads to advanced production), whereas it can become inverse in typical issues associated with the following explanations First, inadequate management and optimal water usage, through decreasing waste, lowering water distribution technologies for more considerable areas, and a decline in the number of dams on rivers and water reservoirs. Second: The continuous use of traditional irrigation procedures. The failure to adopt smart irrigation approaches leads to waterlogging and expanded salinity due to advancing groundwater levels, which in turn lowers crop productivity per acre.

Investigation of the association between agricultural investment (X3) and agricultural outcome (Y): The outcomes show a considerable inverse association in the long run between agricultural investment (X3) and agricultural outcome (Y) at 1%, with a coefficient of -7.413955. This suggests that an expansion of 1 unit in (X3) leads to a reduction in (Y) of 7.413955, which opposes economic theory and the investigation hypothesis. The association between the two variables is fundamentally direct, as investment improves production and extends agricultural land. Investment is the prior driver of improved production, and any decrease in production despite investment suggests a defect in the efficiency of investment control, not the economic association between investment and production. The explanation for the difference in this association is due to the following: First, the lower volume of agricultural investments (both governmental and private). The average rate of farming investment in the Iraqi economy did not surpass 2%, and the average comparable importance of agricultural investment in the GDP did not surpass 1% during the analysis period (2004-2023). This low volume of agricultural investment and the diversion of accounts to other sectors suggest a decline in agricultural exhibition, thereby disrupting the association between the two variables. Second: The failure to direct investments towards cash crops (for export) and critical imported food crops. Third: Inadequate infrastructure and a deficient business environment, associated with a lack of technological expertise in addressing current investments.

Analysis of the association between agricultural credit (X4) and agricultural outcome (Y): The result reveals a significant positive association between agricultural credit (X4) and agricultural outcome (Y) in the long run at 1%, with a coefficient of 0.044135. This implies that an expansion of one unit in X4 leads to an expansion of 0.044135 in Y. This outcome agrees with the logic of economic theory and the research hypothesis. Supplying capital to farmers allows them to buy modern inputs (enhanced seeds, fertilizers, pesticides, machinery, and livestock), which improves the productivity of farming units. Farming credit lowers time and effort and improves the efficiency of farming procedures, thereby expanding the total agricultural outcome.

Investigation of the association between central bank independence (X5) and agricultural outcome (Y): The result showed a significant positive correlation between central bank independence (X5) and agricultural outcome (Y) in the long run at the 1% level. The coefficient value was 8288271, suggesting that an expansion of one unit in X5 leads to an expansion of 8288271 in Y. These outcomes agree with economic theory and the investigation hypothesis. Central bank independence implies that monetary policy is steady and capable of accomplishing its objectives according to economic concerns without intervention. Monetary policy independence rescues growers' earnings from the shocks of dual instabilities (price volatility and currency devaluation). It has an indirect effect on key agricultural variables, including the stability of the general farming cost level, farmers' decisions, enhanced agricultural credit management, exchange rate stability, the competitiveness of farming exports, and the attraction of investment. This reflects a sound economic policy that encourages farming production expansion.

Investigation of the association between the parallel exchange rate (X6) and agricultural outcome (Y): The results demonstrate a significant inverse association between the parallel exchange rate (X6) and agricultural outcome (Y) in the long run at 1%, with a coefficient of -86454.07. This implies that an expansion of one unit in (X6) leads to a decline of 86454.07 in (Y). This result agrees with the economic theory and the investigation hypothesis. An expansion in the market exchange rate implies a decline in the value of the local currency (the dinar). This currency devaluation has the opposite effect: an expansion in GDP. This makes local agricultural goods more affordable for foreign importers, which in turn impacts exports, imports, farm production fees, and finally, the development of farm production.

Analysis of the association between the inflation rate (X7) and agricultural output (Y): The result showed a significant positive association between inflation (X7) and agricultural output (Y) in the long run at a level of 1%. The parameter value reached 855089, meaning that an increase in X7 by 1 unit leads to an increase in Y by 855089. This result contradicts economic theory and the study's hypothesis, as it leans towards an inverse relationship. This is because agricultural production is negatively affected by a rise in the general price level. High inflation rates lead to increased costs of agricultural inputs, prompting farmers to reduce cultivated areas or cease production altogether, thus lowering profit margins and eroding their incomes, ultimately resulting in a decrease in agricultural GDP.

Investigation of the relationship between interest rate (X8) and agricultural outcome (Y): The results indicate a significant inverse association between interest rate (X8) and agricultural outcome (Y) in the long run at the 1% level, with a coefficient of -1113565. This suggests that an expansion of one unit in (X8) leads to a decline of 1113565 in (Y). The results agree with economic theory and the study's hypothesis. The interest rate is the fee for borrowing funds invested in the farming sector, and higher interest rates usually lead to a decrease in investment and production, and vice versa.

5.6 Model Integrity Test

5.6.1 ARCH Reliability Test

The outcomes indicate that the model does not suffer from heterogeneity of variance, as the estimated F-value of 2.566028 at a probability level of 0.1184 is not significant at 5% (14).

5.6.2 LM Test

The estimated model was found to be free of serial correlation, as the calculated F-value of 0.326021 at a probability level of 0.7251, which was not statistically significant at the 5% level. Therefore, the model is free from serial autocorrelation (14).

5.6.3 Testing the Validity of the Functional Model using the Ramsey Test

The calculated t-value (0.926709) and its p-value (0.3687) were not significant at the 5% level. Similarly, the calculated F-value (0.858789) and its p-value (0.3687) were also not significant at 5%. This implies the validity of the functional model (14).

5.6.4 Testing the Structural Stability of the Estimated Model Parameters

To detect its stability and to evaluate the reliability and consistency of the estimated model (ARDL) estimation of long-term and short-term parameters throughout the study period, two tests were conducted:

First: Cumulative Sum of Residuals (CUSUM) test.

Second: Cumulative Sum of Residuals (CUSUMSQ) test.

According to these tests in Figure 2, the structural stability of the estimated parameters is accomplished, as the graph for both tests falls within the critical limits (upper and lower limits) at the 5% level. Therefore, the long-term and short-term parameters, in light of the statistical test, are considered stable for the estimated model (ARDL). Consequently, the null hypothesis is accepted, stating that all estimated parameters are structurally stable in the short and long term, and that structural stability is achieved between the dependent and independent variables (14).

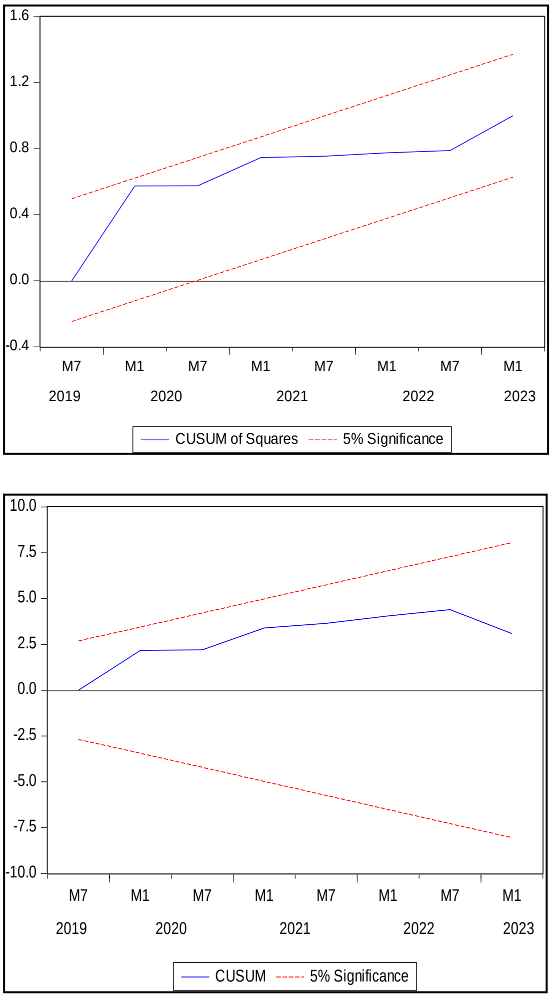

Fig. 2: Structural Stability Test for The Estimated Model Parameters

Source: Prepared by the authors based on the outputs of the EViews program.

5.6.5 Normality of Residue Test

The test for the distribution of residue in the model depends entirely on the probability result (Bera). If this probability is greater than 5%, the model is free of the normality assumption for the residual distribution problem. However, if it is less than 5%, the model has a problem with the residual distribution. Figure 3 shows the probability result (Bera), which was greater than 5%, reaching 47%. Therefore, the model is free of the normality assumption for the residual distribution problem (14).

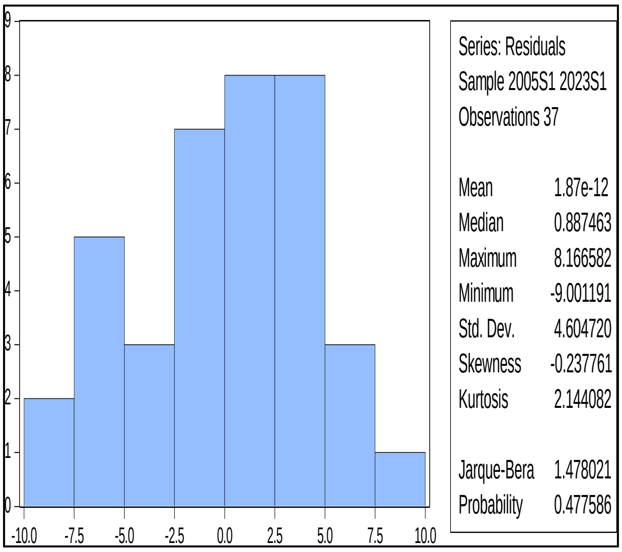

Fig. 3: Normality Test For Residues

Source: Prepared by the authors based on the outputs of the EViews program.

6 Conclusions

Considering the influence of water resources, arable land, and control variables on farming outcomes in Iraq is essential for determining the determinants and controlling factors of farming production. This encourages economic policies to be directed toward reducing inequalities in the farming sector. The investigation indicated that the area of arable land is distinguished by fluctuations and volatility, experiencing comparable increases and reductions. It indicated an inability to maintain pace with the growth in domestic demand for farming products during the investigation period. Similarly, it was seriously influenced by the sharp decrease in water resources, which in turn led to a decline in agricultural output. The highest contribution of farming outcome to the GDP did not exceed 3% during the investigation period. The study successfully achieved its objective of assessing the impact of water resources, arable land, and control variables on agricultural output and confirmed most of the research hypotheses. Most of the data became stationary at a significance level of 1%, meaning they were of order, [1] (I). This confirms the alternative hypothesis (HI), which assumes that the time series are stationary at the first difference, and rejects the null hypothesis (H0), which assumes that the time series are not stationary at the first difference. The estimated model is statistically significant because the error-correction parameter has a negative sign and is statistically significant at 1% level. Furthermore, agricultural output can correct 0.50 of the short-term errors caused by shocks to the independent variables within a given time period. The results of the ARDL model for the long-run association between arable land (X1) and agricultural output (Y) show a significant positive relationship at a 1% level, meaning that arable land increases agricultural output.

The relationship between water revenues (X2) and agricultural output (Y) in the long run was significantly inverse at the 1% level. This opposes the investigation hypothesis, as the availability of water revenues allows the usage of more extensive farming areas, which in turn leads to expanded farming production. The association between farming investment (X3) and farming output (Y) was significantly inverse in the long run, opposing economic theory, since the flow of farming investment contributes to expanded production volume. The association between farming credit (X4) and farming outcome (Y) was significant and positive, meaning that agricultural loans encourage growers and investors to establish projects and implement modifications, consequently accomplishing growth in farming and livestock production. The long-run results reveal a significant positive association between the central bank independence (X5) and farming output (Y). This association is logical because the independence and discipline of monetary policy protect growers' earnings from corrosion and preserve cost stability. Investigation of the association between the parallel exchange rate (X6) and agricultural outcome (Y) indicates a significant inverse association in the long run. This consequence strengthens agricultural outcomes because the exchange rate influences the competitiveness of farming and livestock exports and imports, as well as farming production fees. Evaluating the association between the inflation rate (X7) and farming output (Y) revealed a significant positive association in the long run at a 1% level. This is unlikely, as high inflation has a negative impact and undermines farming expansion. Assessing the long-term association between the interest rate (X8) and farming output (Y) aligns with economic theory, offering a significant inverse association. High capital fees prevent farming investment.

Based on these outcomes, the article suggests maintaining arable land by managing salinity, preventing erosion and desertification, and avoiding its division for housing or industrial purposes. It recommends digitization and modern sustainable management to protect it, and developing a strategy that adopts water management and includes modern irrigation methods, water recycling, regulating well water, storing rainwater and snow, and regulating domestic and industrial use. Finally, it recommends adopting a disciplined long-term monetary policy that directs its tools and is guided by the results of its indicators to support the inputs of agricultural and animal production factors.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The author wrote, reviewed, and edited the content as needed and verifies that no artificial intelligence (AI) tools were used. The authors take full responsibility for the content of the publication.

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The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

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APPENDIX

Table 1. ADF test results

At Level										
		Y	X1	X2	X3	X4	X5	X6	X7	X8
With Constant	t-Statistic	-1.7753	-0.8575	-3.8596	-1.2882	-2.053	-4.8264	-1.0346	-1.6474	-2.0031
	Prob.	0.3867	0.7881	0.0054	0.6251	0.2641	0.0004	0.731	0.4487	0.2843
		n0	n0	***	n0	n0	***	n0	n0	n0
With Constant & Trend	t-Statistic	-2.0021	-6.0771	-3.8282	-1.4134	-1.964	-3.843	-1.1602	-2.1884	-2.5821
	Prob.	0.5815	0.0001	0.0267	0.8408	0.6016	0.0266	0.9045	0.4818	0.2901
		n0	***	**	n0	n0	**	n0	n0	n0
Without Constant & Trend	t-Statistic	0.2747	0.2664	-1.1817	-0.7637	-0.9891	0.0743	0.1313	-1.2205	-0.9331
	Prob.	0.7604	0.757	0.2121	0.3788	0.2834	0.6988	0.7182	0.1998	0.3061
		n0	n0	n0	n0	n0	n0	n0	n0	n0
At First Difference										
		d(Y)	d(X1)	d(X2)	d(X3)	d(X4)	d(X5)	d(X6)	d(X7)	d(X8)
With Constant	t-Statistic	-6.0505	-3.3626	-5.5899	-5.9154	-5.9274	-3.6195	-5.8684	-3.3224	-5.7707
	Prob.	0	0.0213	0	0	0	0.0113	0	0.0216	0
		***	**	***	***	***	**	***	**	***
With Constant & Trend	t-Statistic	-6.0316	-3.54	-5.5337	-6.1589	-5.8852	-3.5268	-6.5174	-3.2806	-5.676
	Prob.	0.0001	0.0543	0.0004	0.0001	0.0001	0.0545	0	0.0866	0.0002
		***	*	***	***	***	*	***	*	***
Without Constant & Trend	t-Statistic	-5.9944	-2.355	-5.5129	-5.9994	-5.9961	-3.7761	-5.9445	-4.1623	-5.8551
	Prob.	0	0.0201	0	0	0	0.0005	0	0.0001	0
		***	**	***	***	***	***	***	***	***

*** Significant at the 1%, ** Significant at the 5%, * Significant at the 10%, no (not significant).

Source: Prepared by the authors based on the outputs of the EViews program.