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Water For Food in Euphrates–Tigris River

Abdelmoneim Bahyeldin Mohamed Metwally [1,2,*], Mai M. Yasser [3] and Merna Ahmed [3]

1 Department of Accounting, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia
2 Department of Accounting, Faculty of Commerce, Assiut University, Assiut 71515, Egypt
3 Economics Department, Faculty of Management Sciences, October University of Modern Arts and Sciences, 6th October City 12451, Egypt; myasser@msa.edu.eg (M.M.Y.); mirna.ahmed5@msa.edu.eg (M.A.)
* Correspondence: abmetwally@kfu.edu.sa

Abstract: Water scarcity is an important threat to food security in the Euphrates–Tigris river. Water scarcity is a huge worldwide problem that results from the rapid increase in water demand, which exceeds the amount of available water. The most significant problems currently affecting countries are food insecurity water scarcity. The Euphrates–Tigris river countries suffer from different political issues, such as the Syrian war and internal civil conflicts in Iraq. In addition, this area consists of only three countries: Iraq, Syria, and Turkey, but it affects the entire Middle East. Turkey has established many irrigation projects compared to Iraq, which still suffers from the previous American invasion. Therefore, this study examines the Euphrates–Tigris river (using two countries) to examine the relationship between water scarcity and food security from 1992 to 2020. This study will be conducted using a fixed and random regression approach over 18 years. The results show a negative relationship between water scarcity and food security in the short run, at a 10% significance level, and a long-term positive relationship of 1%. Thus, the use of research and development and the encouragement of investments will help policymakers to develop a nexus between water scarcity and food security.

Keywords: water; agriculture; food; Euphrates–Tigris river; urban development; development studies

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Citation: Metwally, Abdelmoneim Bahyeldin Mohamed, Mai M. Yasser, and Merna Ahmed. 2024. Water For Food in Euphrates–Tigris River. *Economies* 12: 107. https://doi.org/10.3390/economies12050107

Academic Editor: Kostas Rontos

Received: 20 March 2024
Revised: 19 April 2024
Accepted: 29 April 2024
Published: 3 May 2024

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1. Introduction

Water is not only a factor of involving food, environmental challenges, and health issues, but it now plays a significant role in economic and social activities as well. Over the past decade, conflicts over shared water resources in the Middle East have peaked. The disputes over the Euphrates–Tigris river between Turkey, Syria, and Iraq threaten the stability and peace of these countries. With the construction of dams and different water development projects since the 1950s, water sharing has become a huge conflict, particularly due to a lack of a water sharing agreement or water mismanagement. This issue has become critical, specifically for downstream countries.

As the Euphrates–Tigris river benefits all countries in the region, as shown in Figure 1, Turkey claims that the local dam is beneficial to Iraq, assuming an increase in the regulated flow of the Tigris water, and Iraqi officials stated that Iraqi farmers are facing huge uncertainty regarding their agricultural crops, as they are now subject to the whims of Ankara (Zarei 2020). Moreover, Iraq was one of the few countries in the region that was considered a grain and cereal exporter in the past, and it was planning to be a grain exporter by 2017, but it has now been transformed into a grain importer, which reflects the disastrous agricultural outcome of the current water situation (Ewaid et al. 2021).

As a result of the decrease in the amount of water flowing from the Tigris and Euphrates rivers, farmland has diminished across Iraq. The country's agricultural import bill has greatly increased because many farmers in the two river basins have been unable to grow crops for years, and some have abandoned their dried fields throughout Iraq. The water levels in Iraq's major dams that feed the irrigation system have receded sharply and shockingly, as Iraq's major reservoirs are now too shallow to operate (Dillen 2019). Due to the water shortage, Iraq's Ministry of Agriculture announced to the farmers in the river basin that they would not have the ability to plant rice for the season of 2021 (Giovanis and Ozdamar 2023).

Figure 1. Tigris–Euphrates region (source: Google Maps).

The agricultural sector has huge social and economic impacts and plays a dominant role in the national life of Turkey. It accounts for approximately 10% of exports, 47% of civilian employment, and 20% of the gross domestic product (Aamir et al. 2021). Dams have played a significant role in the growth of the Turkish economy, as they have provided huge assistance in meeting the irrigation and power needs of the country. However, in 1995, Turkey emerged as a major exporter of textile products to the EU markets, which sharply increased domestic demand for cotton. This resulted in a rapid increase in the demand for cotton in the domestic market, and the increasing cotton demand outpaced domestic production; therefore, Turkey increased its cotton imports from around the world and became a cotton importer, giving Turkey seniority in the Euphrates–Tigris river countries in regards to the value of agricultural production, which increased by 90% in Turkey compared to Iraq, which only increased by 1.4%, as shown in Figure 2. This can be explained by the different wars that Iraq experienced in 1998, 2003, as well as the Syrian conflicts that ultimately affected Iraq. (Al-Muqdadi 2019) reported that cotton production increased, and in 2010, the share of Southeastern Anatolia was 60%, an increase of 52% from 1980. In 2013, Turkey exported 25.8 billion tons of textiles, approximately 2 billion more than in 2012, which is the reason for the increase in agricultural production in 2013.

Turkey has less freshwater available domestically, per person, than any other country in the world (Dillen 2019), with an average of 112.5 billion m^3 of economically exploitable freshwater annually, or 1519 m^3 per person. While Iraq is facing water shortages owing to decreasing annual flow, Turkey intends to enhance its water resources throughout the nation, specifically through the GAP project, which is particularly important for producing agricultural products and hydropower generation (Uzlu et al. 2014). Hydropower generation is another significant water use sector. Although Turkey has a gross hydropower potential of 433 billion kWh/year, only 125 billion kWh/year can be used economically (Al-Idami and Faraj 2021). After the construction of new hydropower plants, 36% of the country's economic potential would be tapped. Electricity production reached 16.9 TWH in 2013, accounting for 28.5% of the total hydroelectric power. In 2004, it reached 22.4 TWH, accounting for 14.9% of total Turkish electricity production, which decreased by 11.8%. Therefore, an increase in the usage of water in irrigation systems was not effective in producing electricity (Uzlu et al. 2014), as shown in Figure 3.

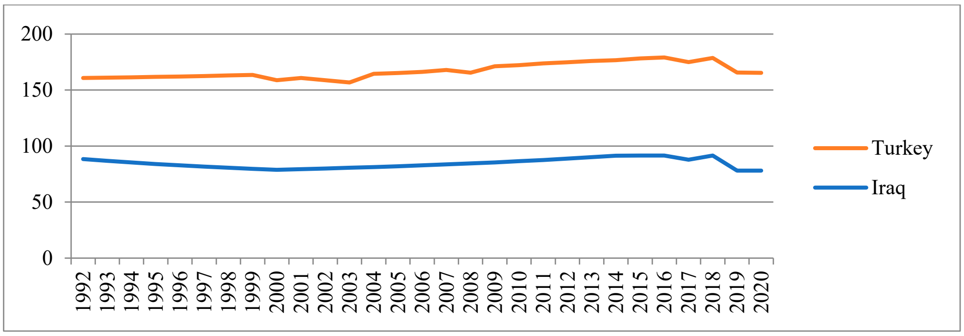

Figure 2. The value of agriculture production in Iraq and Turkey (1992–2021). Source: the authors, according to data from the Food and Agriculture Organization (FAO).

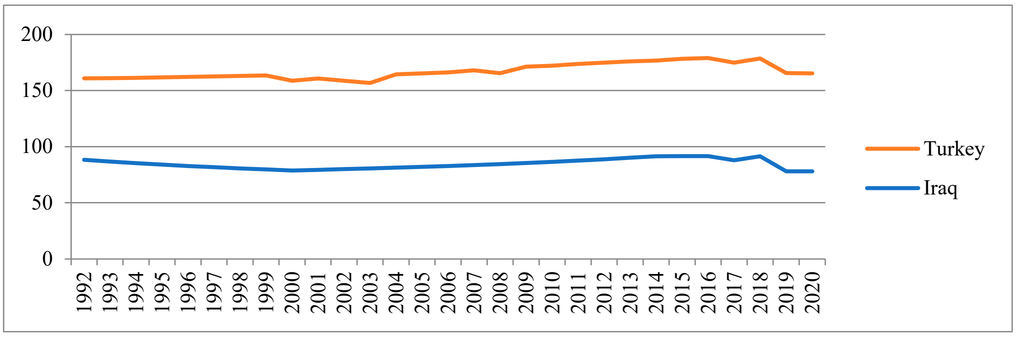

Figure 3. Created by the authors, according to annual freshwater withdrawals (agriculture) in Turkey (1992–2020). Source: World Bank data.

According to (Abd El Mooty et al. 2016), Iraq relies on the Tigris and Euphrates Rivers as the main sources of freshwater. These two rivers originate from Turkey, and they account for more than 90% of Iraq's surface water. Turkey controls the total annual flow of rivers, with 65.7 BCM from a total of 80 to 84.2 BCM of annual flow (Al-Bayaa and Mashhad 2023). Iraq's fresh water supply has decreased as a result of the dams built by both Turkey and Syria, which have a storage capacity of 14.1 BCM, and 138 BCM of water, respectively. In addition, the agricultural watering method in Iraq involves flooding the land, which has low efficiency and causes other losses of water.

The decrease in water availability has a negative impact on the agricultural sector, which accounts for 60–80% of the total water consumption, particularly in southern Iraq, where farmers rely on fresh river water for irrigation (Al-Bayaa and Mashhad 2023). However, inefficient irrigation practices, including furrow irrigation and flooding, contribute to high evaporation, runoff, and waste (Al-Muqdadi 2019). Advanced systems, such as drips systems and sprinklers, can reduce water waste, but their high cost and financing make adoption difficult. Furthermore, heavy pollution and byproducts of industrial, agricultural, and human activities along the border and domestic waterways have harmed Iraq's agricultural sector. Waterways are also contaminated because of the discharge of untreated wastewater and agricultural runoff into rivers, resulting in an increase in the prevalence of illnesses, including cancer, hepatitis, and cholera epidemics. Natural ecosystems have been adversely affected by the depletion of water supplies, pollution, and increased salinization. This has resulted in a loss of habitat, biodiversity, and agricultural livelihood in high-value cultural areas, such as Iraq's southern marshes. This study aims to demonstrate the effect of water scarcity on food security in the Euphrates–Tigris river and its effect on agricultural output.

Therefore, this paper will be divided into three main parts, with the first being the theoretical handling of the literature background. The methodology is discussed in the second part, and the results are explained in the third part. Finally, the final section comprises the Conclusion and References.

2. Literature Review

The theoretical background is made up of the connections and definitions of the topics, as they connect theories with real-life practices. The literature review consists of two parts: both theoretical and empirical.

2.1. Theoretical Literature

2.1.1. Malin Falkenmark Theory

Water accessibility is a prerequisite to habitability. The water cycle provides a nation or region with both visible and invisible water resources. The amount is governed by the country's physical location, which controls any exogenous supply imported by international rivers or aquifers from upstream nations in the same river basin, as well as the endogenous supply from rainfall across the territory. Consequently, there is a limited amount of renewable fresh water. However, this can vary significantly from year to year owing to variations in the climate. (Falkenmark et al. 1989) found that the four modes of water scarcity tend to be superimposed on each other. The first two are natural and are related to the hydroclimate. First, aridity represents a lack of moisture or precipitation, which significantly affects plant growth and agricultural productivity. Second, intermittent droughts refer to periods of limited rainfall or water scarcity that occur sporadically within a region or over a specific period, which can lead to recurrent drought years, increasing the risk of crop failure (Metwally et al. 2024). These periods can have severe impacts on agricultural productivity and food security. The remaining two factors are the result of human activity. Third, landscape desiccation is referred to as a "man-made drought" and is caused by soil deterioration that decreases local water accessibility. Fourth, water stress refers to the excessive number of people per unit of water accessible from the water cycle.

2.1.2. Marxist Theories

Marxist theories emphasize that conflicts regarding the ownership of natural resources arise between specific groups, and each group has more or less control over natural resources, such as water, and has the same interest in this resource (Sandler 1994). Scarcity can cause conflicts due to its social and negative effects, such as when freshwater and agricultural land become exhausted, which results in conflicts regarding resource shares between these groups. The Marx theory of economic development and natural resources emphasizes that the scarcity of natural resources is very dangerous for economic development. Moreover, (Zhu and Zhu 2018) have been pointed out that the utilization of natural resources in agriculture is very important from its earliest stages, and that labor productivity is connected to the quality of natural resources. Consequently, the scale of agricultural production is highly dependent on natural conditions.

2.1.3. Malthusian Theory

One of the most important theories is the Malthusian theory, which explains that war, famine, and diseases are a result of human overconsumption of natural resources that exceed the available amount, in addition to population growth (Ashraf and Oded 2008). Supply-induced scarcity theory complements Malthusian theory, which is the result of the degradation of environmental resources. As the amount of any natural resource declines owing to environmental degradation, the amount available to each person also decreases. Iraq faces water insecurity due to Turkish water imperialism, political and socioeconomic conflicts, and a decrease in water discharge from the Euphrates and Tigris rivers. Moreover (Ewaid et al. 2021) stated that the Iraqi government faces great fear due to the outcomes of restricted water flow from upstream riparian areas, with enormous effects mainly on the country's agricultural production and its dealings with food security due to drought. Among the ongoing Middle East crises, Turkey is allegedly manipulating the present regional instability to further its agenda in the crisis-ridden Middle East, especially by continuing in its ambitious plans to become a regional "water superpower" that may give it the main and primary control over the region's waters (Glass 2017). Turkey has also exploited the weak situation in Iraq and made the most of its geographical position.

First, the main aim of these projects was to prevent floods and maintain and control river flows, as population growth has caused high water needs. However, it rapidly turned into a plan for hydropower generation, giving Turkey the ability to limit its dependency on oil for energy (Giovanis and Ozdamar 2023). Ankara recently began filling the Ilisu Dam, the largest dam in the network. As a result, attention has been focused on Turkey's actions, and tension has been inflamed with neighboring countries. It is estimated that Turkey's various dam and hydropower construction projects have reduced Iraq's water supply along the two rivers by 80% since 1975, with the Ilisu Dam reducing the Tigris waters in Iraq by an additional 56% (Asaad 2023). For Iraq, the dam is likely to put greater pressure on agriculture and natural habitats, increasing desertification in regions as far away as Iraq's southern marshes.

2.2. Empirical Literature

In studying the effects of water scarcity on agricultural productivity, most studies use the terms water scarcity and water stress as synonyms. Water stress is used to measure the number of water withdrawals compared to the availability of water, whereas water scarcity refers to the pressure on water resources (Damkjaer and Taylor 2017; Doeffinger and Hall 2020; OhIsson 2000). Although there are many metrics used to study water stress, some indicators were missed owing to the use of non-renewable water, the lack of environmental flows, and alternatives to water (Wada and Bierkens 2014).

The nexus between water security and GDP was studied in the context of economic growth and agricultural value added in Gambia from 1970 to 2017 (Ceesay et al. 2021). After conducting an autoregressive distributed lag model (ARDL) in the short run and long run, along with Granger causality, a negative relationship was found between GDP growth rates and agricultural production. Climate change also plays a vital role in studying this relationship, as indicated by (Ahmed et al. 2023) using the average temperature, NO_2, methane gas emissions, CO_2 emissions, and food production from 1990 to 2019 in India using the ARDL model. This study found a positive relationship between food production and methane emissions, while the relationship between food production and other variables was negative.

In a study conducted by (Saidmamatov et al. 2023), they found a positive relationship between water, agricultural production, and GDP. This relationship was studied using the fully modified ordinary least squares regression model (FMOLS) and ARDL from 1992 to 2020 in Central Asia. This positive relationship was also observed in Pakistan from 1975 to 2017 (Soharwardi et al. 2021). This study uses variables such as the food production index, water availability, remittances, fertilizers, and the number of tractors, depending on the ARDL method.

Doeffinger and Hall (2020) reported a statistically significant relationship between freshwater withdrawal from internal resources and water productivity. The water productivity expression was used to refer to the number of yields that can be produced, which has a positive relationship with GDP. Moreover, developing countries face greater water stress than other developed countries. This study concludes that there is a negative relationship between water stress and productivity, depending on variables such as population, political stability, and agricultural lands, using OLS regression and its fixed and random effects.

By examining the relationship between water scarcity and food security (Mperejekumana et al. 2023), we tested variables such as water withdrawals, the use of energy in agricultural activities, planted area, the use of pesticides, the use of fertilizers, and annual agricultural yield in Burundi. This study concluded that there is a positive impact of all variables, including water withdrawals, on the agricultural yield per year, depending on the ARDL and ARIMA tests. Finally, the application of the ARDL model to study this relationship was conducted in 15 developing countries between 1993 and 2016, depending on variables such as GDP per capita, water withdrawals, food production index, CO_2 emissions, total population, renewable energy waste, financial aid, and foreign direct investment (FDI). (Hanif et al. 2019) concluded that all factors have a significant positive relationship with the food production index, except CO_2 and renewable wastes, which have negative impacts.

Wang et al. (2020) studied the nexus between water stress, food production, energy and CO_2 emissions, and GDP growth from 2004 to 2017 in 30 Chinese provinces. This was analyzed using the GMM model. This study found a significant positive relationship between the variables. (Ozturk 2015) studied this relationship in BRICS from 1980–2013, depending on the food index, energy use, water productivity, CO_2 emissions, health expenditure per capita, gross capital formation, and labor force participation rate. This was performed using the GMM model, showing the positive relationship between water and food production. A summary of the main empirical literature is shown in Table 1.

Table 1. Summary of the literature.

Literature	Application	Model	Expected Relationship
(Ahmed et al. 2023)	1990–2019 in India	ARDL	-
(Doeffinger and Hall 2020)	179 developing countries over different periods	OLS (fixed & Random)	-
(Mperejekumana et al. 2023)	1993–2016 Burundi	ARDL-ARIMA	+
(Ozturk 2015)	1980–2013 BRICS	GMM	+
(Wang et al. 2020)	2004–2017 in 30 provinces in China	GMM	+

Therefore, this study examines the nexus between water, energy, and food in the Euphrates–Tigris river, as no previous literature has economically evaluated the nexus in that area. Therefore, the ARDL statistical method is useful for testing the following hypotheses:

H0. *There is no relationship between water scarcity and food security.*

H1. *Water scarcity affects food security positively.*

H2. *The increase in the rate of urbanization will have a positive relationship with food security.*

H3. *The increase in GDP per capita will increase food security.*

3. Methodology

This study aimed to investigate the main aspects affecting the relationship between food security and water scarcity in the Euphrates–Tigris river. This will be done by using macroeconomic variables such as GDP per capita growth (GDP), freshwater withdrawals (WATER), total population (POP), planted land (LAND), and agriculture production (AGR). These data were obtained from the World Bank, except for the values for agricultural production, obtained from the FAO from 1992 to 2020, as explained in Table 2. These variables were logged because of the large distance between the maximum and minimum values of these data and the decrease in heterogeneity. These data were applied to the Euphrates–Tigris river countries, with evidence from Iraq and Turkey only.

Table 2. List of variables.

Variable	Symbol	Unit	Definition	Source
Gross domestic product per capita (growth rate)	GDP	%	The gross domestic product divided by the total population	World Bank
Fresh water withdrawals	Water	%	The amount of water obtained by the agricultural sector	World Bank
Value of agricultural production	AGR	$	The sum of agriculture production whatever its kind; crops, fruits, or vegetables	FAO
Total population	POP	%	Total population	World Bank
Planted land in regards to total land	LAND	%	Total amount of planted agricultural lands	World Bank

Before testing the relationship between food security and water scarcity, it was important to check the stationarity of the data. Thus, this will be done by running an augmented Dickey–Fuller test (ADF) and Phillips–Perron test. These two tests will be useful in solving the robustness and autocorrelation issues (Koondhar et al. 2021). Therefore, the proposed model is expressed in Equation (1) as follows:

$$\text{WATER} = f(\text{AGR}, \text{GDP}, \text{POP}, \text{LAND}) \quad (1)$$

The autoregressive distributed lag model (ARDL) is reliable because most of the literature depends on its analysis, and it is efficient for use in long- and short-run tests using panel data (Anderson and Hsiao 1982). One of the main advantages of the use of ARDL is the unbiased long-run results in small samples (Zhou and Li 2022). The equation applied is as follows:

$$\Delta \text{LogAGRt} = \alpha 0 + \sum \beta 1 \Delta \text{Log water t} + \sum \beta 2 \Delta \text{LogGDPt} + \sum \beta 3 \Delta \text{Loglandt} + \sum \beta 4 \Delta \text{Logpopt} + \varepsilon t \quad (2)$$

4. Results

The results of the descriptive data for the two countries (Iraq and Turkey) used by the authors in examining the relationship between food security and water scarcity in the Euphrates–Tigris Region are shown in Table 3. After logging the data to decrease the gap between the maximum and minimum, the highest mean was found for land (35.81799) compared to the lowest mean for GDP (4.215761).

Table 3. Summary of descriptive data.

	AGR	WATER	GDP	LAND	POP
Mean	16.50515	4.424127	4.215761	35.81799	17.59087
Median	16.49841	4.426913	3.691211	35.78604	17.68570
Maximum	18.14346	4.516339	49.03164	53.56210	18.22927
Minimum	14.86283	4.283150	−38.56172	18.07423	16.69731
Std. Dev.	1.291629	0.053057	11.41301	15.57054	0.491350
Observations	58	58	58	58	58

Source: authors' compilation.

The correlation matrix is estimated in Table 4 to show the significance at 1% of AGR with POP, AGR with POP, and LAND with POP. This matrix shows a negative relationship between the AGR and water, but this is insignificant. This does not reflect the fact that there are other factors that affect it in the Euphrates–Tigris river region. Thus, more tests should be performed; a unit root test was conducted to test stationarity, and the results are shown in Table 5.

Table 4. Correlation matrix.

Correlation	AGR	WATER	GDP	LAND	POP
AGR	1.000000				
WATER	−0.175341	1.000000			
GDP	−0.114417	0.055942	1.000000		
LAND	0.980232 ***	−0.229640 *	−0.103674	1.000000	
POP	0.923699 ***	−0.022379	−0.210826	0.910488 ***	1.000000

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

The results of the unit root test show that the data are stationary at the 1st difference (I1), whether using the PP or ADF test, as shown in Table 5. GDP is stationary at the level (I0) and 1st difference (I1). This means that the data are more stationary in the long run than in the short run.

Table 5. Unit root test results.

Variables	ADF		PP	
	Level	1st Difference	Level	1st Difference
		AGR		
None	1.359381	−6.771341 ***	1.239064	−6.808791 ***
Intercept	−0.707011	−6.912605 ***	−0.800432	−6.910657 ***
Intercept and trend	−1.910261	−6.856515 ***	−2.169996	−6.854374 ***
		WATER		
None	−0.078612	−4.132244 ***	−0.079009	−8.874709 ***
Intercept	−2.791689 *	−4.093315 ***	−2.641475 *	−8.804276 ***
Intercept and trend	−2.837755	−4.072185 **	−2.683552	−8.803629 ***
		GDP		
None	−7.324519 ***	−6.153025 ***	−7.340477 ***	−27.11373 ***
Intercept	−8.062800 ***	−6.224865 ***	−8.427984 ***	−29.51464 ***
Intercept and trend	−8.156119 ***	−6.506810 ***	−8.706517 ***	−36.30344 ***
		LAND		
None	0.422345	−7.350134 ***	−2.064512 **	−7.350190 ***
Intercept	−0.989429	−7.382757 ***	−0.989429	−7.382780 ***
Intercept and trend	−1.833363	−7.314182 ***	−1.877115	−7.314216 ***
		POP		
None	5.447589	−4.982327 ***	5.299877	−5.161148 ***
Intercept	−1.798575	−6.991655 ***	−1.792188	−6.991192 ***
Intercept and trend	−0.911975	−7.270856 ***	−0.943827	−7.270987 ***

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

A diagnostic test was performed to assess the functionality of the model. Table 6 shows the results of the diagnostic test to examine heteroscedasticity and correlation. The results show the significance of the absence of serial correlation and heteroscedasticity between the data.

Table 6. Diagnostic tests.

Test	t-Statistic	Result
Breusch–Godfrey serial correlation LM	84.33489 ***	No serial correlation
Ramsey test	4.113254 ***	Correct function
Breusch–Pagan–Godfrey test	5.011080 ***	No heteroskedasticity

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

CUSUM and CUSUM squared tests were also used to investigate the stability of the model in Figures 4 and 5. These two tests showed the significance of the variables, which is significant below 5%.

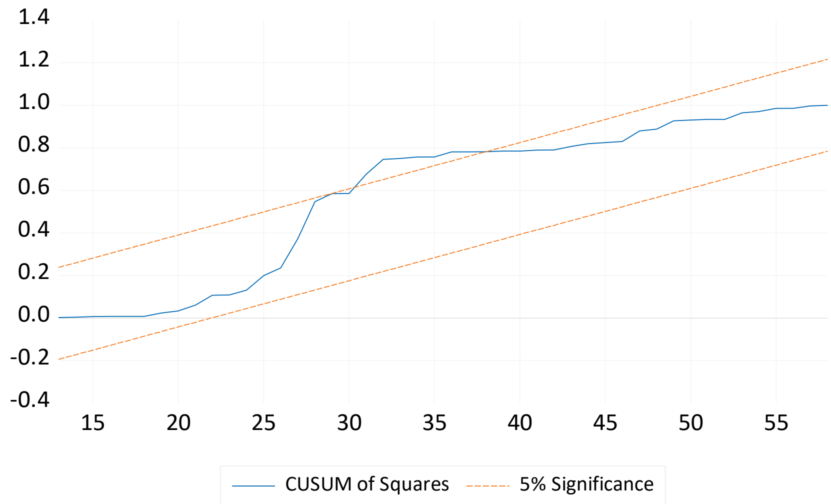

Figure 4. CUSUM squared test results.

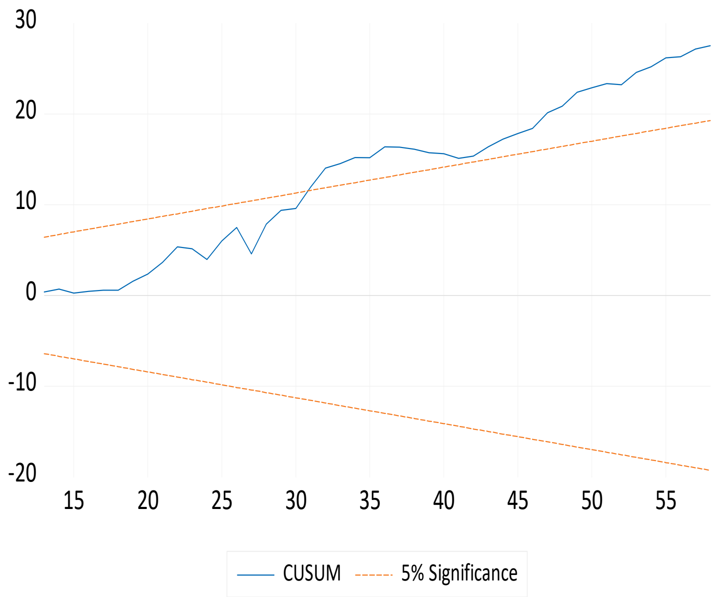

Figure 5. CUSUM test results.

Before running the ARDL test, a VAR model is used to estimate the optimal lag that the model will use. This model uses AGR as a dependent variable, whereas the other variables are independent variables. The lag length results are displayed in Table 7, which shows that all the optimal lag length criteria were accepted until the fifth lag (0, 1, 2, 3, 4, and 5). According to Schwarz (SC) and Hannan–Quinn (HQ) information criteria, the optimal lag is accepted at lag 1, whereas it is accepted for sequential modified LR (LR), final prediction error (FPE), and Akaike (AIC) test statistics at lag 5. Thus, lag 5 will be used at the AIC, which will be reliable when using the ARDL model.

Then, the ARDL test is run in Table 8, beginning with the results of the ARDL bounds and the results of the ARDL test itself. The coefficient is greater than the values of the bounds test at I(0) and I(1), which indicates the fitness of the ARDL model. ARDL was then conducted over the short and long run. In the short run, WATER and LAND at the 10% level were significant at the 1% level, except for GDP at the 5% level. Compared to the long run, the relationship was not significant for all variables, as WATER, POP, GDP, and LAND were significant at the 5% or 1% level.

Table 7. Lag length criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−299.9753	NA	0.068504	11.50850	11.69438	11.57998
1	27.46961	580.7513	7.61×10^{-7}	0.095487	1.210746 *	0.524362 *
2	50.05293	35.79245	8.55×10^{-7}	0.186682	2.231324	0.972953
3	79.90079	41.67437	7.61×10^{-7}	0.003744	2.977769	1.147410
4	106.0894	31.62392	8.31×10^{-7}	−0.041108	3.862301	1.459955
5	146.2183	40.88608 *	5.92×10^{-7} *	−0.612011 *	4.220781	1.246448

Source: authors' compilation; * significant at 1%.

Table 8. ARDL results.

Panel I: ARDL bounds			
F-statistic	Level of significance	Bound test critical values	
		I(0)	I(1)
	10%	3.03	4.06
5.164196	5%	3.47	4.57
	2.5%	3.89	5.07
	1%	4.4	5.72
Panel II: ARDL results			
short run	Coefficient	Long run	t-statistic
AGR(-1)	0.953055 ***	AGR(−1) *	−0.046945
GDP	0.002125	WATER	−1.297425 **
GDP(-1)	0.002288 **	GDP(−1)	0.004413 *
WATER	−1.297425 ***	LAND(−1)	−0.003734
POP	0.277114	POP	0.277114 **
LAND	0.055072 ***	D(GDP)	0.002125
LAND(-1)	−0.064499 ***	D(LAND)	0.055072 ***
LAND(-2)	0.005693	D(LAND(−1))	−0.005693
C	1.775286	C	1.775286

Source: author' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

Moreover, the effects of causal cointegration were evaluated for the region as a whole and for each country separately, depending on the Granger causality test, as shown in Table 9. These findings show that the relationship between food security and water scarcity is correlated in each country, but not in the whole region, as it can be expressed by the abundance of planted lands in Iraq and the dams that were established in Turkey.

Table 9. Granger causality results.

Null Hypothesis	F-Statistic	F-Statistic (Iraq)	F-Statistic (Turkey)
WATER does not Granger Cause AGR	0.90762	1.67489	1.11091
AGR does not Granger Cause WATER	1.37674	5.19937 **	4.06070 **
GDP does not Granger Cause AGR	0.79083	0.16823	0.24246
AGR does not Granger Cause GDP	0.67793	3.03053 *	0.27178
LAND does not Granger Cause AGR	1.64139	2.74314 *	0.83844
AGR does not Granger Cause LAND	0.95671	0.51805	1.83964
POP does not Granger Cause AGR	4.18893 **	0.20775	2.96132 *
AGR does not Granger Cause POP	2.32595 *	0.22651	2.27115
GDP does not Granger Cause WATER	0.11011	0.09452	1.48315
WATER does not Granger Cause GDP	0.51314	0.33689	1.60061
LAND does not Granger Cause WATER	0.68419	3.03756 *	2.00947
WATER does not Granger Cause LAND	1.35656	2.84103 *	1.28914
POP does not Granger Cause WATER	0.49777	0.04711	2.96982 *
WATER does not Granger Cause POP	0.30713	1.29988	0.23293
LAND does not Granger Cause GDP	0.07909	0.37754	0.09587
GDP does not Granger Cause LAND	1.65306	0.22632	0.02659
POP does not Granger Cause GDP	0.43081	0.87105	0.84535
GDP does not Granger Cause POP	1.29729	0.70634	0.88166
POP does not Granger Cause LAND	2.13183	21.5074 ***	1.38282
LAND does not Granger Cause POP	2.39560	0.87243	5.08094 **

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

5. Discussion

This study is the first to address the relationship between water scarcity and food security in the Euphrates–Tigris river region. This evaluation achieved by applying only two out of the three countries in that region because of a lack of data for Syria. In addition to a limited number of empirical studies, this relationship has been studied worldwide. Thus, the study depends on the autoregressive distributed lag model (ARDL) that has been employed in different studies using the data offered for Iraq and Turkey by the FAO and the World Bank from 1992 to 2020.

The results estimated by the model, whether in the short or long run, were consistent with the literature review conducted in Section 1, showing that the nexus between water scarcity and food security is controlled by other factors (Ahmed et al. 2023; Doeffinger and Hall 2020; Saidmamatov et al. 2023; Wang et al. 2020). As shown in the results of our model, water scarcity is negatively significant, whether in the short or the long run, and the relationship is fixed, as it resulted in the same coefficient in both runs, as concluded by (Ahmed et al. 2023; Doeffinger and Hall 2020).

Therefore, this study aimed to examine the relationship between water scarcity and food insecurity in the Euphrates–Tigris river countries from 1993 to 2020. Unfortunately, the study was limited to only two out of the three countries because of the lack of transparency of data for Syria. This study concludes that there is a clear negative relationship between water scarcity and food security, as the increase in demand for food puts a significant burden on the use of water, which has led to huge demand for water. Second, there is a significant positive relationship between the agricultural production value from one side and GDP, population, and the amount of planted land from the other side. These results were significant at the 1% level for the value of agricultural products, water, and planted land in the short run, while in the long run, only land was significant at the 1% level.

In the short run, the independent variable, that is, the value of agricultural products, was significant with D(land-2) and population and GDP per capita annual growth rate. Although an increase in GDP by 1% caused an increase in the value of agricultural products by 0.2%, a 1% increase in planted land caused a decrease in the value of agricultural production by 6.4%. This was clarified by (Mperejekumana et al. 2023), who determined that the negative relationship was due to the increase in pesticides and insecticides.

In the long run, the value of agricultural production is significant at the 1% level for planted land, at the 5% level for water and population, and at the 10% level for GDP per capita growth rate. There is a positive relationship between the value of agricultural production, GDP per capita growth rate, and planted land. If there is a 1% increase in the value of agricultural production, the GDP per capita will increase by 0.4% and 0.5% for planted land. The results are summarized in Table 10.

Table 10. Summary of results.

Hypotheses	Results in Short Run	Results in Long Run	Accept or Refuse
H0. There is no relationship between water scarcity and food security.	Negative insignificant	Negative significant	Refuse
H1. Water scarcity affects the food security positively.	Negative	Negative	Accept
H2. The increase in the rate of urbanization will have a positive relationship with food security.	Positive insignificant	Positive significant	Partially accepted, only in the long run
H3. The increase in GDP per capita will increase food security.	Positive significant	Positive significant	Accept
H4. The increase in planted land will increase food security.	negative significant	positive significant	Partially accepted, only in the long run

6. Conclusions

Ultimately, the water resources between countries have always been a source of conflict and negotiation. As the condition of the Euphrates–Tigris river system has increased water scarcity and insecurity, determining a water management plan between Turkey, Iraq, and Syria has remained a source of tension. The water insecurity caused by huge water development projects, specifically those initiated by Turkey, have impacted the agricultural sector in Iraq by a huge percentage. There are currently no official agreements to support and obtain fairly shared water resources among these countries, which could lead to progressively increasing fragility in terms of water resources, especially in Iraq. In addition, it was concluded that water shortages in the basin would enhance and support Turkey's economic and political control and leverage over Iraq. In conclusion, this study discusses the effects of GDP, population growth, PHDI, and annual freshwater withdrawals on the agricultural resources of both Turkey and Iraq.

This study showed the effect of water development projects on decreasing the flow of water for downstream countries, as well as the increase in Turkey's production and the initiation of irrigation and hydroelectricity projects. The results also showed that there is a significant positive relationship between the agriculture production (dependent variable) and the annual freshwater withdrawals (independent variable), so we rejected H0. Therefore there are some policy implications that should be adopted, as follows:

First, there is a need for research and development (R&D) to help increase opportunities for food consumption and decrease the amount of water required. In addition, this implies the need for more investments to connect the knowledge that individuals can acquire and the information available to them.

Second, there is a need for an increase in the usage of sewage water reuse after purifying, besides desalination, that will positively accept the use of water for activities other than food production.

Third, the countries in the Euphrates–Tigris river depend heavily on the public sector; thus, public–private partnerships should be introduced and developed in the fields of irrigation, energy, and food.

Fourth, more attention should be paid to individuals and human capital, as the Euphrates–Tigris river countries are characterized by a high population rate. Therefore, the development of educational systems and training, besides providing awareness campaigns regarding the importance of water, would be beneficial.

Fifth, to increase efficiency in the use of water, taxes and decreased subsidies should be imposed on those who are irrational in the usage of water.

Sixth and finally, as water is characterized by its inelastic supply, with no available substitutes (Markantonis et al. 2019), harsh legislation should be instituted against those who rationalize the use of water, in addition to imposing high penalties on them.

For further studies on the water–food nexus in Euphrates–Tigris river countries, greater attention should be focused on the area as a whole, including Syria, which appears to be an obstacle due to a lack of data for this country.

Author Contributions: Conceptualization, A.B.M.M., M.M.Y. and M.A.; methodology, A.B.M.M., M.M.Y. and M.A.; software, A.B.M.M., M.M.Y. and M.A.; validation A.B.M.M., M.M.Y. and M.A.; analysis and interpretation of the data A.B.M.M., M.M.Y. and M.A.; drafting of the paper A.B.M.M., M.M.Y. and M.A.; revising it critically for intellectual content A.B.M.M., M.M.Y. and M.A.; funding acquisition, A.B.M.M., M.M.Y. and M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia. [Project No. GRANT5851].

Data Availability Statement: Data are available upon request from researchers who met the eligibility criteria. The corresponding author can be contacted privately through e-mail.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

ADF	augmented Dickey–Fuller test
ARDL	autoregressive distributed lag
CUSUM	cumulative sum of recursive residuals
FMOLS	fully modified ordinary least squares regression
GDP	gross domestic product
PP	Pearson—Perron unit root test
VAR	vector autoregression

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