NTU Journal of Agricultural and Veterinary Sciences (2024) 4 (3) : 191-201
DOI: https://doi.org/10.56286/ntujavs.v2i2

IRAQI Academic Scientific Journals

JAVS NTU

P-ISSN: 2788-9890 E-ISSN: 2788-9904
NTU Journal of Agricultural and Veterinary Sciences
Available online at: https://journals.ntu.edu.iq/index.php/NTU-JAVS/index

An Economic and Analytical Study to Estimate the Water Footprint and Virtual Water Trade for Grain Crops in Iraq

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Article Informations

Received: 17-02- 2024,
Accepted: 13-05-2024,
Published online: 28-09-2024

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Key Words:
keyword1, *strategic crops*.
keyword2, water resources
keyword3, water footprint
keyword4, virtual footprint

A B S T R A C T

Iraq is one of the most countries in the region and the world that may face a major challenge in front of its water resources, represented by the Tigris and Euphrates rivers, which are the largest rivers and sources of water due to the policies of the countries sharing with it and the upstream countries due to the construction of water dams on it, the latest of which is the Turkish Ilisu Dam on the Tigris River, which caused a decrease in the rate of A decrease of (-1.2%), The objective of the research is to examine the reality of water footprint indicators and standards and the virtual water trade of grain crops for the period (2003-2021).The results of the research during the study period indicated a decrease in water quantities from (57.38) billion m^3 cubic meters in (2003) to (22.95) billion m^3 cubic meters in (2021), The average external, internal and college water footprint of the wheat crop was (6.98, 15.18 and 22.18) billion m^3, respectively, The average external, internal and total water footprint of the rice crop was (7.49, 4.21 and 13.68) billion m^3, respectively, While the average quantity of virtual water imported for wheat crop (6.99) billion m^3, the average quantity of virtual water imported for rice crop reached (9.39) billion m^3, Researchers recommended that attention be paid to Iraq's water policy and that alternatives be found to avoid the shortage of water contained therein by focusing on the obligation of farmers to water metering, supplementary irrigation, identifying current and future water needs and conducting a comprehensive water supply survey.

Introduction:

Water is a scarce and scarce resource and Iraq faces many challenges related to its water resources, increasing population growth, climate changes, pollution and degradation of water quality, low per capita scarce water, as well as agricultural products that depend mainly on such water, This has resulted in inadequate domestic agricultural production and additional food imports to cover the growing demand for agricultural products, resulting in a water gap. Water is handled despite its scarcity away from cost-benefit calculations. This has led to increased waste and rational use of water resources. The importance of virtual water has emerged as one of the tools used to address crises resulting from the water gap and achieve water security. Virtual water trade allows water-scarce States to import water-intensive products, ensuring that water-scarce States conserve their water resources,

Applying modern concepts to evaluate water consumption for the production of various goods consumed by humans has become crucial with the severe water deficit in Iraq as it has an arid climate, the annual rainfall swallows 150 mm [1],

Climate changes and excessive us of countries are leading to a water crisis in Iraq In the light of climate change, Iraq's desertification situation and the establishment of numerous dams on the Tigris and Euphrates rivers in Turkey, Syria and Iran led to a shortage of water imports [2], Since water is vital for humans and other organisms [3], As a limited resource, water management has to be pursued because of its economic importance and must be recognized as an economic commodity, according to the US Department of Agriculture (USDA), The Agricultural Water Department knows that it seeks to use water in a way that provides crops with the amount of water they need, enhances productivity and preserves natural resources for water users and the ecosystem [4]. Tony Allan introduced the notion of virtual water in 1993 and its relationship to water security. The notion of virtual water refers to the volume of water used to produce traded goods. It focused on mitigating water scarcity in the Middle East and dry areas by importing water that is actually reflected in food commodities rather than producing them locally [5]. In 2003 (Hoekstra,) introduced the concept of water footprint, which is a comprehensive and multidimensional indicator of freshwater dependence on both sides of traditional indicators of water consumption,

This concept helps explore the risks and opportunities of water, as it includes the volume and type of pollution resulting from production processes.[6], The problem of research is the deterioration of water resources in recent years in Iraq, which has had a negative impact on the production of major grain crops, particularly wheat and rice crops, which are the focus of our study and are the pillar of Iraq's food security economy. The importance of research lies in the importance of water footprint and virtual water trade and its role in the production of strategic grain crops in Iraq, which are key crops in the domestic consumption of the Iraqi individual. Examining the issue of water and the growing demand for water resources in the light of reduced water resources, climate change and the scarcity of fresh water is very important. The research aims to study the reality of economic and productive indicators of Iraq's crops (wheat, rice) for the period 2003-2021, Examining the reality of water footprint indicators and standards and the virtual trade of grain crops because of their importance in determining the increase and decrease in the area under cultivation and evaluating the air policy of these crops by comparing the water footprint and hypothesis and working on possible solutions to address water, economic and productive problems, The research relied on the hypothesis that there were several water economic standards affecting the production of grain crops in Iraq, particularly wheat and rice crops during the period (2003-2021), and sought to establish the hypothesis if not. The research in its methodology relied on the descriptive method of economic and quantitative analysis by linking them using statistical programmers and calculating growth rates of both economic and water indicators.

The concept of water footprint and virtual water trade

The notion of virtual water is based on everything we eat, dress and use in our daily lives that needs water to produce. It is called water that is used in the process of agricultural, industrial and service production and that is used in the production of virtual water. Hence, when a country with water scarcity decides to import products that require a lot of water in their production or removal (water-intensive products), this means importing their own virtual water, importing the water used in their production rather than importing the very expensive real water, This relieves the pressure on its water resources [7]. This concept, created by Allan, helped to understand some of the problems of water scarcity and how to overcome them, through international trade and the export of water-abundant crops that possess a comparative advantage in their water ownership to water-scarce countries that will import virtual water as they import crops [8], Both scientists [9] that showing and estimating the hidden water behind the products can help understand the global nature of freshwater, and measure the effects of consumption and trade on the use of local and global water resources. water resources It is important to work to improve the management of water resources. Water footprint is defined as an indicator of the use of freshwater not only in direct consumer and commodity use but in indirect use [10]. Previous studies in this area include [11] in their research aimed at estimating the water footprint of a range of plant and animal agricultural crops and estimating Brazil's virtual water, The results showed that the total water footprint exported for each crop (wheat, barley, corn, rice) was about (847, 9 .7, 6462, and 967) million m^3/year, respectively, The total water footprint imported for each crop (wheat, barley, maize, rice) was approximately (7,678, 290, 763, and 1865) m^3/year respectively. Both [12] in their research aimed at Estimating the water footprint and virtual water and the extent to which local food and water security can be achieved for the period (1998-2015), the researchers indicated that (26%) of virtual water is due to the import of rice crop from India and Pakistan. (12%) of virtual water is for importing wheat crop, green water is twice as much as blue water, and (80%) of virtual water is for importing food commodities such as (rice, wheat, meat and dairy) The researchers recommended attention to water harvesting processes, Qatar's reliance on the cultivation of less water-consuming crops and the adoption of modern techniques in agriculture such as hydroponics and greenhouses. [2] In their research aimed at estimating the water footprint of the wheat crop for the period (2016-2017) in Iraq's 15 governorates, The results of the research showed that the water footprint of the wheat crop (1876) m^3/ton, that the green water footprint is twice the blue water footprint, and the governorates showed 15 differences in the water footprint due to the difference due to climate and production, and that the highest water footprint and output were in Nineveh governorate Followed by Muthanna, Anbar and Basra, the study recommended in Muthanna, Anbar and Basra governorates that wheat yields be replaced with other crops that require less water and provide more economic benefits. According to [13] in their search for the target of estimating the volume of virtual water trade for 20 crops in Saudi Arabia for (2000-2016) the research results showed that the rate of water footprint of crops in Saudi Arabia was (503.1) billion m^3/year, and the rate of virtual water trade was about (289.2) billion m^3/year. Researchers recommended producing crops with low water consumption, and pursuing a water and trade policy that maintains water security. [14] Published In his research aimed at estimating the blue, green and college water footprint for the production and consumption of wheat crop between (2008-2019) in Turkey, The researcher found that the green, blue and total water footprint of the crop was about (239,154 and 393) m^3/ton respectively, and the green, blue and total water content of the crop was about (1161,748 and 1909) m^3/ton, respectively. The researcher recommended increasing agricultural diversity and pursuing agricultural planning that takes into account economic return and the protection of regional and national water resources. [15] Published His research aimed at a comprehensive assessment of Germany's virtual water trade with the world through the trade in crops and animal products for the period (1991-2016) ,The results of the research indicated that the total rate of virtual water for imported food was about (2316.55, 131.67, 165.34 and 2613.56) green, blue, grey and college Bm^3 respectively. and that the total rate of virtual water for exported food was about (1322.29, 52.29, 190.1 and 1564.68) green, blue, grey and college Bm^3 respectively, the researcher recommended further studies to analyses virtual water trade because it provides useful insights into agriculture and water resources and helps to modify foreign trade and economic policies. [6] in their research aimed at assessing the water footprint of the crops between (2019-2020) in Iraq's governorates, The research results showed that the water footprint of the spelt crop was about (908, 747) m^3/ton respectively, and the barley crop was about (2849, 4198) m^3/ton, The study recommended calculating the water footprint of other crops is an important way to know the water content of various crops in order of self-sufficiency and food security. [16] Published In their research aimed at estimating Egypt's water footprint for wheat and rice crops for the period (2000-2019), researchers found that the total water footprint of wheat ranged from (2.57-5.06) billion m^3 to the total water footprint of rice ranged from (3.98-10.08) billion m^3, The researchers recommended the importance of introducing the notion of virtual water when developing a future strategy for the agricultural sector to ensure the adoption of less water-use agricultural production systems. [17] Published In its study, the study found results, including the water footprint of wheat and rice (20.27, 13.89) billion m^3. The average dependence on the external water resources of the crops was (20.49%, 67.98%) respectively. The study recommended attention to the concepts of water footprint and virtual water in order to achieve water efficiency.

Virtual water: defined as the amount of water contained in the product or commodity, which refers to the water needed to produce the product or commodity, the virtual water imported by a state, which means the use of such water in the importing country and is added to the water available in the country**,** There are two different approaches or methods applied [10]:

The first approach: The virtual water content is defined by the size of the water used to produce the product, commodity or service, and depends on the conditions of production, including the place and time of production and water efficiency. For example the production of one kilogram of grain in the arid country requires two to three times more water than is needed to produce the same amount in the wet country.

The second approach: takes the calculation process from the end user's perspective of the goods rather than the product's perspective, and the user determines the virtual water content of the product and the amount of water required to produce the product, commodity or service somewhere where the product is needed.

Virtual water is divided into:

(a) Blue virtual water: refers to river water and groundwater consumed, lost or wasted in various production lines, phases and operations of a commodity or crop state [18].

(b) Green virtual water: means the consumption of water resources, mostly rain, in crop production or livestock development through natural pastures and any other [10].

(c) Grey virtual water: defined as the amount of fresh water needed to reduce pollution resulting from a specific process, and gives basic information about the nature of the basic concentrations and existing water quality standards in the surrounding area[19].

Water footprint: defined as the total volume of freshwater used in the production of goods and services consumed by the individual or society. Through the concept of water footprint, actual consumption can be determined in both agricultural, industrial and domestic purposes. The water footprint is divided into:

(a)Total water footprint: The total water footprint is divided into two sections: internal and external water footprint.

(b) Inland water footprint: estimate the amount of virtual water used for agricultural purposes less the amount of virtual water exported through agricultural products to other countries.

(c) External water footprint: estimate the quantity of virtual water imported from abroad less the quantity of virtual water re-exported from imported products [20].

Three types of water footprint can be separated [21].

(a) Blue water footprint: It refers to the volume of blue water actually consumed in the entire lines and stages of production operations for any product.

(b) Green water footprint: indicates the amount of water evaporated from green water resources during the growth stages of the product.

(c) Grey water footprint: the volume of water contaminated associated with the production of the commodity, service or crop.

Materials and methods

-Methods of calculating economic indicators of the crop:

1- Available consumption = net production + net foreign trade (exports-imports) [22].

2- Size of the food gap = production – consumption [23].

3- Offshore dependence ratio = import consumption * 100 [24].

-Methods of calculating water indicators [25]:

1-Indicator of river water scarcity = (average per capita river water - 1000/1000) * 100.

2-Agriculture's share of river water = (average per capita water - water poverty per capita/water poverty per capita) * 100.

- Methods of Calculating Water Footprint and Virtual Water and Indicators [26], [20]:

1-Internal water footprint = quantity of water used in production - quantity of virtual water exported.

2-External water footprint = quantity of imported virtual water - quantity of exported virtual water.

3-Total water footprint = inner water footprint + outer water footprint.

4-Ratio of dependence on external water resources = (external water footprint/total water footprint) × 100.

5-Quantity of water used in production = quantity of crop production × water needs per ton.

6-Quantity of imported virtual water = quantity of crop imports × water needs per ton.

Results and discussion:

Economic indicators of Iraq's wheat crop for the period 2003-2021:

Wheat is a strategic and important crop because of its nutritional importance [27], and Wheat in Iraq ranks first in area [28]**,** as economic indicators of wheat crop illustrate the challenges facing its production**.** The economic indicators of the wheat crop illustrate the challenges facing its production, including the impact of the wheat crop production on climatic conditions, and weather fluctuations in particular in territories that depend on dummy agriculture and where there is no supplementary irrigation **[29]**. As well as the low rainfall rates that led to the scarcity of water resources and thus the lack of cultivated areas **[30].** Tables (1, 2) note fluctuations in economic and productivity indicators and growth rates of Iraq's crop between the period (2003-2021), The average area under wheat crop cultivation during the research period was (5978589) dunam, with a growth rate of (-1.1%), Indicating a decrease in the growth rate of the area under cultivation. The average output was (3456563) tons, with a growth rate of (7.1%), while the rate of productivity growth was (5.9 %) which means a decrease in crop productivity. The average quantities consumed by wheat crop was (4873588) tons and a growth rate of (1.5%), While the average external dependency ratio was about (36.59%) and the growth rate of the external dependency ratio was (-27.3%), as shown in the table below.

Economic and productive indicators of the rice crop:

Tables (3,4) show fluctuating economic and productive indicators and growth rates of Iraq's rice crop over the period (2003-2021), The productivity of growing the rice crop as an average production ranged from (927) kg/dunam, with a growth rate of (-1.3%), with an average production rate of (444404) tons and a growth rate of (7.8%), While the crop area growth rate was (2.5%), its average consumption was estimated at (6151411) tons and a growth rate of (9.7%), which is higher than the rate of production growth, which means that there is an increase in the quantities consumed throughout the study period

The average foreign dependence ratio (82.46%), which is a large proportion of the country's dependence on import in this crop, is very high, This indicates that the economic and productive indicators of Iraq's wheat and rice crops are deteriorating and lacking access to self-sufficiency for these two strategic crops, which are important food crops that are embedded in the daily lives of the Iraqi individual.

Water indicators:

The fluctuation in Iraq's water imports for the period (2003-2021) is noted in tables (5,6) with the lowest proportion of water imports for the Tigris River in (2008) at (18) billion m^3. This percentage then rose to the highest value, as (2019) was (76.52) billion m^3. Due to the establishment of the Aliso Dam in Turkey, water imports decreased as operations began to fill this dam on the Tigris River in July (2019) [31], at a growth rate of (-1.2%).

While the Euphrates River imports had the highest value of water imports, they reached (20.64) billion m^3 in (2006), then imports fell to (7.49) billion m^3 in (2015), With an average of (15.47) billion m^3 and a growth rate of (1.1%), the average per capita of the Tigris and Euphrates rivers in (2003) was the highest value (2774.9) m^3, It then dropped to (864.9) m^3 in (2018), with a growth rate of (-3.6%), and a scarcity index of (-3.8%) of river water due to an increase in the population growth rate by (2.4%), the population in (2021) reached (41) million, as well as the decrease in water imports of the Tigris River and Euphrates, as shown in the table below.

Water footprint and indicators for wheat and rice crops for 2003-2021

The products contain many agricultural crop ingredients as the crops are used for food, feed, oil, fiber, etc., and these products are included in their production system, often with water fingerprints, Tables (7, 8) show both the internal and external water fingerprints, the college, the ratio of dependence on external materials and the growth rates of these indicators for the grain crops being studied, as shown in table (8). With the lowest external footprint (0.01) billion m^3 in (2003), it reached a high of (34.48) billion m^3 in (2008) for the wheat crop, While the inland water footprint was the lowest value (8.04) billion m^3 in (2018) the maximum was (21.85) billion m^3 in (2020), wheat yields averaged (15.18) billion m^3 , with the highest proportion of external water resources allocated in (2008) at (70.25%). This is because external water fingerprints were the highest possible this year and their growth rate for external dependence was (32.7%). For the rice crop, the lowest value of the total water footprint was (7.54) billion m^3 in (2003), while the lowest value of the total water footprint was (23.02) billion m^3 in (2006). It was (15.82) billion m^3, for the rice crop and the growth rate of the internal, external and total water footprint of the rice crop was (3.4%, -0.8% and -1.1%) respectively as shown in table (8), while the highest value for external dependence in (2019) was (97.3%) and average (70.71%) as shown in the table below.

Virtual water and indicators for wheat and rice crops for 2003-2021

Production of any commodity or any goods or service that has to be required by water, and that water has to go into the production process whether it be agricultural or industrial or both. This is what is called virtual water, which is included in all the renewable water in the product, which is involved in or lurking in it [32].

The water footprint indicators and growth rates of wheat and rice crops are noted in tables (9, 10), noting that the lowest water requirement for wheat crops was in (2016) by (3.08) m^3/kg, While the highest value in (2008) was (11.63) m^3/kg, with an average of (5.64) m^3/kg, while an estimated growth rate of (-6.1%) was as shown in table (10) and the water used for its production was an average of (15.23) m^3, Virtual water imports averaged (6.99) billion m^3, but the lowest value in (2003) was (0.01) billion m^3 and (9.49) m^3/kg .While the average quantities used to produce the rice crop locally were (4.25) m^3, The quantity of virtual water imported for the rice crop averaged (9.39) billion m^3, with a growth rate for both the quantities used in its production rice and the quantities of virtual water (-4.7%, 11.2%) respectively, This constitutes a significant burden on water resources, especially the widespread strategic grain crops and production in Iraq during the period of research from (2003 – 2021) as shown in the table below.

Conclusions:

The Economic and Productive Indicators Study of Crops (Wheat, Rice) showed that there is a large food gap of production-consumption of these crops in Iraq This is due to the high water footprint and virtual water on the one hand and the decrease in water imports on the other, which exacerbated the gap from these crops, The high water footprint and the virtual water of the rice crop and the quantities used therein, as well as the much higher dependence on abroad than the wheat crop, place considerable pressure on Iraq's water resources. In particular, these two crops are widespread in their cultivated area and there is a decline in the total water imports available to Iraq from both the Tigris and Euphrates rivers, which makes the notion of virtual water strongly impose on Iraq's agricultural foreign trade.

Acknowledgements

The authors thank the Department of Agricultural Economics at Mosul University and the Ministry of Planning of Iraq for helping improve the quality of this work.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publishing of this article.

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Table 1. Iraq's wheat crop economic and productive indicators for the period 2003-2021

Years	Wheat Production (ton) (1)	Area (dunam) (2)	Productivity (kg/dunam) (3)	Imported quantities (ton) (4)	Quantities of domestic consumption (ton) (5)	Food Gap (tons) (6)	Foreign Dependency (rate %) (7)
2003	2329200	6854900	340	1276667	3484847	-1155647	36.63
2004	1832100	6159400	298	2501412	4097182	-2265082	61.05
2005	2228400	6410600	348	2535520	4763920	-2535520	53.22
2006	2286300	6054100	378	2838813	5120113	-2833813	55.44
2007	2202800	6279600	351	2423713	4625943	-2423143	52.39
2008	1255000	5741200	219	2963320	4217740	-2962740	70.25
2009	1700400	5049800	337	3050409	4750219	-3049819	64.21
2010	1254975	5543900	496	1854525	4708000	-3453025	40.28
2011	3650000	6542700	429	2674720	4799000	-1149000	48.77
2012	3610000	6914400	443	2643064	4925000	-1315000	46.32
2013	4178000	7376300	566	3084500	5053000	-875000	42.46
2014	5055000	8528000	593	3018237	5184000	-129000	37.38
2015	2645000	4146700	638	1042504	5274000	-2629000	28.27
2016	4589000	3697000	826	302500	5229000	-640000	9.01
2017	3617000	4216000	706	214553	5251000	-1634000	6.72
2018	4103000	3154000	691	1552301	5240000	-1137000	41.61
2019	6331116	6331000	686	14148	4357148	-1973968	0.32
2020	8573683	8574000	728	1263	6239263	-2334420	0.02
2021	4233714	6019600	703	52257	5278803	-1045089	0.99
Average	3456563	5978589	514	1791812	4873588	-129000	36.59
lowest value	1254975	3154000	219	1263	3484847	-3453025	0.02
Highest value	8573683	8574000	826	3084500	6239263	-129000	70.25

Source: Columns (1, 2, 3, 4) Central Organization for Statistics and Information Technology (Republic of Iraq).
Column (5) of the researchers' calculation (quantities available for consumption) = domestic production + imported quantities + inventory.
Column (6) of the researchers' calculation (food gap) = local production - quantities available for consumption.
Column (7) of the researchers' calculation (percentage of dependence on abroad) = quantities imported \ quantities available for consumption * 100.

Table 2. Results of estimating the growth rates of the economic and productivity indicators of the wheat crop in Iraq for the period 2003-2021

Functions	The equation	Growth rate	R2 test	F test
Production	Y= 14.217+ 0.07 X	7.1%	57.4	22.88
Productivity	Y= 5.594+ 0.059X	5.9%	77.1	57.12
cultivated area	Y= 15.676 - 0.011X	-1.1%	48.1	33.51
imported quantities	Y= 16.227 - 0.268X	-26.8%	48.3	15.86
quantities of domestic consumption	Y= 15.241+ 0.015 X	1.5%	47.5	15.37
The percentage of dependence on abroad	Y= 89.66 - o.273X	-27.3%	49.3	16.54

Source: from researcher's preparation based on statistical programmer SPSS-27.

Table 3. Iraq's rice crop economic and productive indicators for the period 2003-2021

Years	Wheat Production (ton) (1)	Area (dunam) (2)	Productivity (kg/dunam) (3)	Imported quantities (ton) (4)	Quantities of domestic consumption (ton) (5)	Food Gap (ton) (6)	Foreign Dependency (rate %) (7)
2003	81300	122500	664	433500	513600	-432300	84.40
2004	250300	351800	711	651641	899731	-649431	72.42
2005	308700	428200	721	830639	1137639	-828939	73.01
2006	363300	502600	723	1329089	1692389	-1329089	78.53
2007	392800	497400	790	735900	1128700	-735900	65.19
2008	248200	339000	732	1051916	1300116	-1051916	80.90
2009	173100	219700	788	1099560	1272660	-1099560	86.39
2010	155800	191900	812	1854525	681500	248157	92.25
2011	334784	263800	891	2674720	12099000	334784	91.92
2012	361000	318800	1133	2643064	12332000	361000	87.97
2013	631000	383800	1177	3084500	12656000	631000	87.22

2014	403000	317200	1270	3025581	12985000	403000	88.24
2015	1092000	110400	988	1059008	13321000	1092000	90.65
2016	608000	154200	1176	1720905	13153000	608000	90.48
2017	850000	222100	1197	1164431	13237000	850000	81.40
2018	729000	21700	838	2783889	13195000	729000	99.35
2019	574700	511400	1124	1636011	2210711	574700	74.00
2020	464200	594481	1141	2103691	2781891	464200	75.62
2021	422500	578651	730	1869851	289876	422500	66.81
Average	444404	322612	927	1671180	6151411	9372	82.46
lowest value	81300	21700	664	433500	2781891	-1329089	65.19
Highest value	1092000	594481	1270	3084500	13321000	1092000	99.35

Source: Columns (1, 2, 3, 4) Central Organization for Statistics and Information Technology (Republic of Iraq).
Column (5) of the researchers' calculation (quantities available for consumption) = domestic production + imported quantities + inventory.
Column (6) of the researchers' calculation (food gap) = local production - quantities available for consumption.
Column (7) of the researchers' calculation (percentage of dependence on abroad) = quantities imported \ quantities available for consumption * 100.

Table 4. Results of the estimate of growth rates of economic and productive indicators of Iraq's rice crop for the period 2003-2021

Functions	The equation	Growth rate	R2 test	F test
Production	Y= 12.069+ 0.078 X	7.8%	47.4	11.32
Productivity	Y= 12609 - 0.013 X	-1.3%	8.3	1.44
cultivated area	Y= 6.554+0.025 X	2.5%	41.1	11.85
imported quantities	Y= 13.541+ 0.065 X	6.5%	41.5	12.13
quantities of domestic consumption	Y= 13.960+ 0.097 X	9.7%	16.1	3.25
The percentage of dependence on abroad	Y= 4.383+ 0.002X	0.2%	2.21	12.1

Source: from researcher's preparation based on statistical programmer SPSS-27.

Table 5. Total water imports of the Tigris and Euphrates rivers in Iraq and their water scarcity per capita indicators for the period 2003-2021

Years	Euphrates River imports (billion m^3) (1)	Imports of the Tigris River (billion m^3) (2)	Total river imports (billion m^3) (3)	Population (million person) (4)	Average water per capita for rivers (Tigris and Euphrates) (m^3) (5)	River water scarcity index% (6)
2003	15.71	57.38	73.09	26.34	2774.87	267.48
2004	20.54	44.42	64.96	27.12	2395.28	229.52
2005	17.57	37.08	54.65	27.96	1954.58	185.45
2006	20.64	41.85	62.49	28.81	2169.04	206.90
2007	19.33	37.09	56.42	29.22	1930.87	183.08
2008	14.70	18.00	32.70	30.58	1069.33	96.93
2009	9.30	22.99	32.29	31.50	1025.08	92.50
2010	12.45	37.68	50.13	32.44	1545.31	144.53
2011	14.62	32.94	47.56	33.40	1423.95	132.39
2012	20.47	28.63	49.10	34.40	1427.33	132.73
2013	15.15	40.60	55.75	35.42	1573.97	147.39
2014	15.50	21.70	37.20	36.49	1019.46	91.94
2015	7.49	27.36	34.85	36.58	952.71	85.27
2016	15.15	39.54	54.69	36.88	1482.92	138.29
2017	13.16	27.37	40.53	37.13	1091.57	99.15
2018	9.56	23.41	32.97	38.12	864.90	76.49
2019	16.95	76.52	93.47	39.09	2391.15	229.11
2020	20.20	29.39	49.59	40.22	1232.97	113.29
2021	16.79	22.95	44.74	40.86	1094.96	99.49
Average	15.47	35.77	51.24	33.42	1573.63	147.35
lowest value	7.49	18.00	32.29	26.34	864.90	76.49
Highest value	20.64	76.52	93.47	40.86	2774.87	267.48

Source: Columns (1, 2, 3, 4) Central Organization for Statistics and Information Technology (Republic of Iraq) Department of Water Resources.
Column (4) Central Organization for Statistics and Information Technology (Republic of Iraq) Human Resources Department.
Column (5) of the researchers' calculation (the water scarcity index of the two rivers) = (the average per capita share of the water of the two rivers - 1000/1000) * 100.
Column (6) of the researchers' calculation (the share of agriculture from the water of the two rivers) = (the average per capita share of water - the level of water poverty per capita / the level of water poverty per capita) * 100

Table 6. Results of the estimate of the growth rates of water roses of the Tigris and Euphrates rivers in Iraq for the period 2003-2021

Functions	The equation	Growth rate	R2 test	F test
Euphrates River imports	Y= 2.820 - 0.011 X	1.1%	49.1	18.67
Tigris River imports	Y= 3.626 – 0.012X	-1.2%	38.1	6.78
The total imports of the two rivers	Y= 4.003 – 0.011 X	1.1%	49.2	8.68
Population	Y= 3.270 + 0.24 X	2.4%	98.0	85.49
The average per capita water supply of the two rivers	Y= 7.641 – 0.036 X	-3,6%	32.3	8.11
The scarcity index of the two rivers	Y= 5.288 - 0.038 X	-3.8%	32.2	8.74

Source: from researcher's preparation based on statistical programmer SPSS-27

Table 7. Iraq's total water footprint and indicators for wheat and rice crops for the period 2003-2021

Crops	Water footprint and its indicators for wheat crop				Water footprint and its indicators for rice crop			
Years	External water footprint (billion m^3) (1)	Inland water footprint (billion m^3) (2)	Total water footprint (billion m^3) (3)	Dependence on external water resources% (4)	External water footprint (billion m^3) (5)	Inland water footprint (billion m^3) (6)	Total water footprint (billion m^3) (7)	Dependence on external water resources % (8)
2003	0.01	16.54	16.55	0.06	5.62	1.92	7.54	74.54
2004	0.02	13.64	13.66	0.16	7.89	5.02	12.90	61.12
2005	0.02	16.31	16.33	0.11	9.92	6.15	16.06	61.73
2006	0.02	14.03	14.05	0.14	15.82	7.20	23.02	68.72
2007	0.02	15.99	16.01	0.11	8.02	7.14	15.16	52.90
2008	34.48	14.60	49.08	70.25	12.42	4.86	17.28	71.88
2009	23.06	12.86	35.92	64.21	12.04	3.15	15.19	79.26
2010	9.53	14.12	23.65	40.29	11.91	2.75	14.66	81.24
2011	17.16	16.68	33.84	50.70	10.84	3.79	14.63	74.09
2012	13.95	17.61	31.56	44.20	10.52	4.58	15.09	69.69
2013	10.09	18.81	28.90	34.92	9.64	5.51	15.15	63.63
2014	4.84	21.72	26.56	18.22	6.31	4.55	10.86	58.10
2015	1.69	10.56	12.25	13.81	8.62	1.58	10.20	84.51
2016	0.54	9.42	9.96	5.42	6.76	2.21	8.97	84.51
2017	1.76	10.74	12.50	14.10	6.26	3.19	9.45	75.36
2018	6.90	8.04	14.94	46.21	11.56	0.31	11.87	66.24
2019	2.12	16.13	18.25	11.61	9.88	7.34	17.22	97.36
2020	3.74	21.85	25.59	14.62	7.58	3.50	11.08	57.38
2021	2.97	18.89	21.86	12.76	8.43	5.32	13.75	61.31
Average	6.98	15.18	22.18	23.25	7.49	4.21	13.68	70.71
lowest value	0.01	8.04	9.96	0.06	5.62	0.31	7.54	52.90
Highest value	34.48	21.85	49.08	70.25	15.82	7.34	23.02	97.36

Source: Columns (1, 5) calculated by researchers based on equation No. (1) in the methods of calculating the water footprint, virtual water and its indicators shown above.
Columns (2, 6) are calculated by the researchers based on equation No. (2) in the methods of calculating the water footprint and virtual water and its indicators shown above.
Source: Columns (3, 7) calculated by the researchers based on Equation No. (3) in the methods of calculating the water footprint, virtual water and its indicators shown above.
Columns (4, 8) are calculated by the researchers based on equation No. (4) in the methods of calculating the water footprint and virtual water and its indicators shown above.

Table 8. Results of the estimate of growth rates of indicators Water footprint of Iraq's wheat and rice crops for the period 2003-2021

wheat crop				
Functions	The equation	Growth rate	R2 test	F test
External water footprint	Y= 8.607 – 0.167 X	-16.7%	11.3	17.31
Inland water footprint	Y= 14.957 + 0.023 X	2.3%	11.2	19.54
total water footprint	Y= 23.623 – 0.144 X	-14.4%	11.2	10.91
Percentage dependence on external water resources	Y= 19.988 + 0.327X	32.7%	16.6	10.9
rice crop				
Functions	The equation	Growth rate	R2 test	F test
External water footprint	Y= 2.295 – 0.008 X	-0.8%	28.1	4.89
Inland water footprint	Y= 1.600 - 0.034 X	3.4%	66.3	12.01
total water footprint	Y= 2.689 – 0.011 X	-1.1%	49.4	8.73
Percentage dependence on external water resources	Y= 4.203 + 0.004 X	0.4%	24.2	4.24

Source: from researcher's preparation based on statistical programmer SPSS-27.

Table 9. Iraq's virtual water and its wheat and rice crop indicators for the period 2003-2021

Crops	Virtual water and its wheat crop indicators			Virtual Water and Indicators for Rice Crop		
Years	Water requirements for wheat crop (m^3/kg) (1)	Quantities of water used in local production of wheat crop (m^3) (2)	Quantity of imported virtual water for wheat crop (billion (m^3) (3)	Water requirements for rice crop (m^3/kg) (4)	Quantity of imported virtual water for rice crop (billion m^3) (5)	Quantity of imported virtual water for rice crop (billion m^3) (6)
2003	7.49	17.45	0.01	12.96	1.94	5.62
2004	8.55	15.66	0.02	12.11	5.04	7.89
2005	7.32	16.31	0.02	11.92	6.15	9.92
2006	6.74	14.06	0.02	11.90	7.20	15.82
2007	7.26	15.99	0.02	10.89	7.14	8.02
2008	11.63	14.60	34.48	11.76	4.18	12.42
2009	7.56	12.86	23.06	10.92	3.15	12.04
2010	5.14	14.12	9.53	10.60	3.79	11.91
2011	5.94	16.68	17.16	9.66	4.58	10.84
2012	5.75	17.61	13.95	7.60	5.51	10.52
2013	4.50	18.81	10.09	7.31	4.55	9.64
2014	4.30	21.72	4.84	6.78	4.58	6.31
2015	3.99	10.56	1.69	8.70	5.51	8.62
2016	3.08	9.42	0.54	7.32	1.58	6.76
2017	3.61	10.74	1.76	7.19	2.21	6.26
2018	3.69	8.04	6.9	10.27	3.19	11.56
2019	3.71	16.13	2.21	7.66	0.31	9.88
2020	3.50	21.85	3.74	7.58	7.34	7.58
2021	3.41	16.85	2.84	7.29	2.93	6.91
Average	5.64	15.23	6.99	9.49	4.25	9.39
lowest value	3.08	8.04	0.01	6.78	0.31	5.62
Highest value	11.63	21.85	34.48	12.96	7.34	15.82

Source: Columns (1, 4) calculated by the researchers based on Equation No. (5) in the methods of calculating the water footprint, virtual water and its indicators shown above.
Columns (2, 5) are calculated by the researchers based on equation No. (6) in the methods of calculating the water footprint and virtual water and its indicators shown above.
Columns (3, 6) calculated by the researchers based on Equation No. (7) in the methods of calculating the water footprint, virtual water and its indicators shown above.

Table 10. Growth rates of Iraq's virtual water and its indicators of wheat and rice crops for the period 2003-2021

Virtual water for wheat crop				
Functions	The equation	Growth rate	R2 test	F test
Water needs of wheat	Y= 2.256 – 0.061 X	-6.1%	78.1	60.60
Quantities of water used in local wheat production	Y= 2.770 – 0.008 X	-0.8%	27.1	4.67
Quantity of virtual water imported for wheat	Y= 2560 + 0.275 X	27.5%	30.7	7.54
Virtual water for rice crop				
Functions	The equation	Growth rate	R2 test	F test
Water requirements for rice	Y= 2.556 - 0.033 X	-3.3%	68.3	36.59
Quantities of water used in local rice production	Y= 1.745 – 0.047 X	-4.7%	12.8	2.51
Quantity of virtual water imported for rice	Y= 2.316 - 0.112X	11.2%	51.1	9.15

Source: from researcher's preparation based on statistical programmer SPSS-27