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Estimation the Virtual Water Content and the Virtual Water Transfer for Iraqi Wheat

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Abstract
The amounts of clean waters on our planet are limited by global climate change, growing population, and pollutant rates. Therefore it is important to use more effective water management strategies. The methodology of water footprint (WF) analyzes, directly and indirectly, the blue, green and gray components of water (consumed and polluted). It is also possible to calculate the virtual water contents (VWC) behind the products. In terms of the sustainability and efficiency of freshwater resources, particularly in water-scarce regions, the approach to WF contributes towards water management studies and the analysis of the total water used in the import and export products supply chain. The VWC approach provided new insights into international water transfers that give water an economic value. The objective of this research is to help to build the national water management and sustainable development strategy. In this sense, it was measured separately the WF of the imported quantities of wheat. Virtual water flow was identified in the most important countries. Savings and losses arising from wheat trading on national and global water were also noted and addressed. It was found that in 2019, the wheat WF was 1876 m³/ton of water, WF of production was 8,147,468,000 m³/year and for import was 1,184,007,630 m³/year. From importing wheat, Iraq saved 46,672,673 m³ of water but there is no global water saving.

Keywords: water footprint, virtual water, Iraqi wheat, transfer, import

1. Introduction
Although 71% of the world's surface is covered with water, the amount of water available to humans is quite limited to meet all needs such as vital activities, agricultural irrigation, and energy production. It is known that the global freshwater potential is at the level of 2.5% and most of it is stored in glaciers [1]. On the other hand, factors such as global climate change, spatial and temporal differences in rainfall and water resources, increased human activity compared to previous years, increased pollution in surface and groundwater and rapid population growth created negative pressures on the limited available water resources and caused risks to occur in many countries [2]. In line with this, the number of national and international agreements, researches, and practices have increased rapidly in recent years for the
protection of water resources and more studies have been started on water management [3]. The concepts of water footprint (WF) and virtual water transfer (VWT) are also recently introduced to the scientific literature to contribute to the sustainability of water resources in terms of quantity and quality [4]. The concepts of WF or VWC are based on measuring or estimating the amount of total water used and contaminated throughout the production process or supply chain of any product [5]. The type of water used is expressed in blue, green and gray, the surface and groundwater used in the process of obtaining any product are called blue water footprint, the total rainwater processed is called a green water footprint [4]. Unlike traditional water usage calculations, the WF is not the total water available in the product, but the total water used in the production. Therefore, blue and green WFs mostly rely on the amount of evapotranspiration from the surface and vegetation. While the concept of WF is in the [volume/year] dimension, the virtual water content (VWC) parameter is expressed as [volume/mass]. The VWC of any object means the total volume of water processed to produce one kilogram of that object. The concept of virtual water transfer (VWT) is the water in the background of imported or exported products and its effects on the water resources of the countries [5-6]. In recent studies, the VWTs of countries have been scrutinized and this has contributed to the globalization of water resources, rather than being local riches [7]. From this perspective, it is encouraged to grow or produce products in countries with low virtual water content, while countries with high virtual water content are supported to import these products from abroad. Thus, countries rich in water resources will be able to export products with high water footprints and earn a higher income, while other countries will be able to use their limited water resources for their more vital needs [6]. The agricultural sector is responsible for 80% of global water consumption, in this context, agricultural activities are among the top human activities that consume the most available water resources and the importance of agricultural water management can be better understood here [8]. It is reported that wheat, which is the most cultivated agricultural product in Iraq and in the world, has been domesticated around Ninawam Diyala and Wasit governorates, because of the nutritional culture in Iraq, the amount of production and the suitability of the climate and soil structure, the studies on the management and sustainability of the water used in the wheat production process stands out in the first plan [11]. The main purpose of this study is to calculate the virtual water transfer and water footprint of wheat consumed (produced and imported) in Iraq during 2019. The virtual water content of wheat in the countries from which Iraq is imported, the amount of trading was calculated by the amount of national and global water savings. The current study is the first analysis of virtual water transfer to Iraq and is expected to contribute to agricultural water management studies.

2. Materials and Methods

2.1 Study area and data
The study area (Iraq) is positioned at longitude (38° 48'E), latitude (29°37 N), with an area of 438,317 in the Middle East which categorized by its water shortage. Iraqi terrestrial can be divided into 4 areas: 1- The mountain area in the north occupied 5% of the whole area. 2- Hills area represents 15%. 3- The alluvial plain area is restricted between the Euphrates and Tigris and occupies 20%. 4- Western Plateau and Jazeera form 60% of the total zone [9]. About 11.5 million ha (26%) of the total county is
cultivable and the entire cultivated area is about 6 million ha, of which approximately 50% in rain-fed conditions in the north [10]. The total annual water withdrawal is approximately 42.8 billion m³/yr, for agriculture (85%), domestic (7%), and for industry (8%) purposes [11-12].

The climate is a semi-arid subtropical type. The usual daily temperature during winter is about 16 °C. It is very warm in summer with a typical temperature above 45°C. The total annual average rain is 213 mm per year. The rainy season starts in October and finishes in April [13-14].

2.2 Data
In large-scale studies on WF and VWT, climate, vegetation, evapotranspiration, and other data are used. However, the number of national or local studies in the literature on this subject is absent. In the present study, the national production of wheat and cropland values was obtained from the Iraqi Central Statistical Organization yearly statistics [15].

On the other hand, the virtual water content of the wheat production in other countries, along with Iraq, were taken from the work done by [12]. In these studies, blue, green, and gray water footprints of agricultural products produced in many countries were calculated for the 1996-2005 time period based on global forecasts. Finally, international trade (import and export) statistics (tons/year) of the wheat were obtained from the Trade Map database of the International Trade Center (ITC), [16].

2.3 Water footprint method
This method has been systematized by the calculation process of the water footprint of agricultural products [8]. In order to estimate the blue and green WFs, it is necessary to determine the amount of evapotranspiration (ET) from the vegetation. However, evapotranspiration values differ from crop to crop. Crop evapotranspiration (ETc) can be estimated using the reference evapotranspiration value (ET0) and crop coefficients (Kc) (Equation 1). Reference evapotranspiration is known as the total evaporation of the standard grass plant under certain conditions, and modeling this value by the FAO-Penman Monteith method has been generally accepted (Equation 2) [17]. Different models such as CWR (crop water requirement), IR (irrigation requirement) have been developed to estimate blue and green evapotranspiration amounts. ET blue and ET green assessed in this study using the FAO CROPWAT model:

\[
ETc = Kc \times ET_0 \tag{1}
\]

\[
ET_0 = \frac{0.408d(Rn-C)+0.900u^2(es-ea)}{\Delta+\gamma(1+0.34u^2)} \tag{2}
\]

Where ET0 is the reference evapotranspiration (mm/day), T is the mean daily air temperature (°C) at 2 m height, u2 is the wind speed at 2 m height (m/s), es and ea are the saturation and actual vapor pressure (kPa), respectively. Rn; net radiation on the plant surface (MJ/m²/day), G; heat exchange intensity of the ground (MJ/m²/day), \(\Delta\); the slope of the vapor pressure curve (kPa/°C), \(\gamma\); is the psychometric constant (kPa/°C), Kc; plant coefficients, ETc; The annual evapotranspiration value of the crop as (mm/year), [10].

For the transition from blue and green ET values to virtual water contents (VWC) accounts, the yield (ton/ha) and total production amount (Equation 3) is used. Finally,
the total VW (m³/ton) is the product of the virtual water content (m³) of vegetative production (ton) and the total production amount (ton) (Equation 4).

\[
VWC_{blue, green} = 10^{\frac{\sum_{i=1}^{n} \text{ET}_{blue, green}}{\gamma}}
\]

(3)

\[
WF = VWCi \times Ci
\]

(4)

Where, \(Y\); yield, \(ci\); crop production by tons

### 2.4 Virtual water transfer method

The virtual water transfer method described by [18-19] was used in this study. The total virtual water transfer (VWT) on the background of any product is equal to the quantity (ton) of that product in imports or exports multiplied by the virtual water content (VWC) (m³/ton) (Equation 5). National water saving (NWS) is an indicator of how much a country maintains its own water resources and is calculated by multiplying the difference of imported and exported product quantity by virtual water content (Equation 6). Global water saving (GWS) is an indicator of the effect of the trade between the two countries on global water resources. GWS is equal to the net trade volume and the product's difference between the virtual water content of the importing country and the virtual water content of the exporting country (Equation 7). Negative NWS or GWS values mean national or global water loss. The land saving (LS) by (ha) is equal to imported crop quantity (ton) multiplied by land (ha) divided by production (ton) (Equation 8). Importing crops can reduce the local WF and affect any country’s savings in water and land use [20-21].

\[
VWT = P \times VWC
\]

(5)

\[
NWS = \text{imported crop quantity} \times \text{blue VWC}
\]

(6)

\[
GWS = P \times (VWC_{import} - VWC_{export})
\]

(7)

\[
LS = \text{imported crop quantity} \times \text{land (ha)} / \text{production (ton)}
\]

(8)

### 3. Results and Discussion

Iraq, the major importer of wheat, needs about five million tons every year and imports about two million tons on average in previous years [19]. The production of wheat was estimated at 4,343,000 tons for the winter season 2019, an increase of 99.4% compared to the production of the previous year when it was estimated 2,178,000 tons [19]. Nineveh Governorate occupied the first position in terms of production (19.6%) of the total production, followed by the province of Diyala, which estimated its production 557,000 tons at a rate of (12.8%) of the total production, followed by the province of Wasit, where it was estimated to produce 515,000 tons, at a rate of (11.9%) of the total production while the rest of the governorates constituted 55.7% of total production (ICSO, 2020). The production of wheat in irrigated land was 3,396,000 tons at (78.2%), while the production of wheat in lands irrigated by rain was 947,000 tons at (21.8%).
The cultivated area of the wheat crop was estimated at 1,582,750 ha for the winter season 2019, an increase of 100.7% compared to the previous season, which amounted to 788,500 ha [23]. The harvested area for this season was estimated at 1,543,250 ha, at 97.5% of the total cultivated area. The cultivated area in the irrigated lands was estimated at 1,113,250 ha (70.3%). Whereas, the cultivated area in the lands irrigated by rain was estimated at 469,500 ha (29.7%) of the total cultivated area. While the cultivated area in the lands with semi-guaranteed rains was estimated at 334,750 ha at a rate of (71.3%) of the lands irrigated by rain, while the cultivated area in the lands with guaranteed rains was estimated at 84,500 ha (18%) of the cultivated area in the cultivated area [19].

The average yield per ha was estimated on the basis of the total cultivated area (2744.4) kg for the winter season 2019, a decrease of 0.6% compared to the year 2018, when it was (2762) kg. The average yield per ha of wheat yield was estimated based on the cultivated area in irrigated lands (3050.8 kg).

Total wheat import corresponds to about 11.2% of total consumption (Figure 1). Finally, with the consideration of import figures, the total national wheat consumption in Iraq was realized as about 5 million tons [23].

![Figure 1](image_url). Iraq's 2019 wheat consumption, import, and production (tons).

To calculate the total water footprint of national wheat production, the virtual water content of the wheat consumed in Iraq in 2019 was found to be approximately 9,331,475,630 m³ (Table 1, Figure 2). Wheat imports related to Iraq from USA, Turkey, Canada, Spain, Belgium, France, Italy, and UK, respectively, approximately (1,020,060,571), (82,367,761), (80,621,750), (513,450), (247,968), (144,834), (46,440), and (4,856) m³ of water has been imported. Looking at the total figures, it is revealed that the water footprint of wheat imports in 2019 was approximately 1,184,007,630 m³ (mostly green water). This situation reveals the importance of virtual water transfer among countries. It was found that the WF wheat in m³/ton was 1876 m³/ton and the total WF for production is 8,147,468,000 m³, (Table 1, Figure 2).

### Table 1. Iraqi 2019 wheat total water footprint values (m³).

| Parameter               | Quantity | Green WF  | Blue WF  | Total WF  |
|-------------------------|----------|-----------|----------|-----------|
| National total production | 4,343,000 | 5,324,518,000 | 2,822,950,000 | 8,147,468,000 |
| Imports                 | 560,499  |           |          | 1,184,007,630 |
| National consumption    |         |           |          | 9,331,475,630  |
In 2019, approximately 11.2% of the WF of our country's wheat consumption is outsourced. This is a good thing because Iraq is used to importing more than that annually. The USA, Turkey, and Canada are our most important virtual water suppliers in terms of wheat. Virtual water imports from the USA account for approximately 86.15% of total imports. The effects of imported virtual water on national and global water resources can be understood by looking at the amount of VWC in the country where wheat is produced. The wheat production in Iraq and countries where the wheat trade green, blue, gray, and total virtual water content are compared in (Table 1 and Figure 2).

It is possible to obtain a more realistic and sustainable approach by using this data together with wheat trade data. For example, in Iraq, the wheat virtual water content of about 1876 m$^3$/ton, while this amount is 2369 m$^3$/ton in the USA [11-12]. Water and soil shortages may be caused by poor trade management. Therefore, water and land needs for the production of the same quantity as imported crops were analyzed in this study. The need for moving from agricultural imports to local production was thus indicated by water and land savings. The amount of blue water and land required to replace imported crops with local production was indicated by national water and land savings.
As a result of the virtual water trade (import only) Iraq saved 46,672,673 m³ of water as a national water-saving (NWS), but there is no global water saving (GWS) because Iraq imports wheat from countries (at most from the United States of America and Turkey) which are countries that have more water for wheat than Iraq and it is a green water footprint on mostly. The land saving (LS) as a result of importing wheat in 2019 was around 204266.6 ha (Table 2).

This indicates the importance of attention that Iraq can work like neighboring countries like Jordan and refrains from cultivating crops that consume a lot of water and replace them with crops that have more economic returns and consume less water [3].

**Table 2.** Iraqi 2019 wheat import, virtual water transfer, and its background detail.

| Country | Wheat Import (ton) | Virtual water content (m³/ton) | Virtual water imports (m³) | Other (m³) | NWS | GWS |
|---------|--------------------|--------------------------------|---------------------------|------------|-----|-----|
| USA     | 472,469            | 1.842                          | 89                        | 228        | 2,159 | 42,049,74 |
|         | 98                 | 1.072                          | 32                        | 1,020,060,5 | 1    | -147,882,797 |
| Turkey  | 34,769             | 2.052                          | 125                       | 192        | 2,369 | 71,345,98 |
|         | 71                 | 6,765                          | 648                       | 82,367,761 | 1    | -21,070,014 |
| Canada  | 52,250             | 1.338                          | 5                         | 200        | 1,543 | 69,910,50 |
|         | 8                  | 261                            | 250                       | 80,621,750 | 1    | -15,831,750 |
| Spain   | 350                | 1.221                          | 36                        | 210        | 1,468 | 427,350 |
|         | 12,600             | 73,500                         | 0                         | 80,621,750 | 1    | -15,831,750 |
| Belgium | 378                | 558                            | 4                         | 656        | 82    | 210,924 |
|         | 12,600             | 73,500                         | 0                         | 80,621,750 | 1    | -15,831,750 |
| France  | 239                | 591                            | 3                         | 12         | 606   | 141,249 |
|         | 144,834            | 247,968                        | 0                         | 247,968    | 1    | +64,530 |
| Italy   | 36                 | 1121                           | 20                        | 149        | 1290  | 40,356 |
|         | 720                | 46,440                         | 0                         | 46,440     | 1    | 21,096 |
| UK      | 8                  | 455                            | 1                         | 151        | 607   | 3,640 |
|         | 1,518             | 4,856                         | 0                         | 4,856      | 1    | +2,152 |
| Total   | 560,499            | 1,012,367                      | 46,672,67                 | 124,967,0  | 1,184,007,6 | 46,672,67 |
|         | 905                | 52                            | 30                        | 46,672,67  | 3    | -152,807,323 |

Water footprint and virtual water transfer calculations have been used in many countries especially in agricultural product management processes in recent years. Pursuant to include a new perspective on the subject, these concepts have not yet been adequately studied in Iraq. In the present study, the international wheat trade in 2019 was Iraq's examination of the impact on the national and global water resources. This study is aimed to set an example for other agricultural products or sectors other than wheat and to support water management studies in our country. The fact that the virtual water content of the products in different regions is different has led to the understanding that the transfer of goods or services will create different stress or gain in each country. In this context, the concept of globalization of water has come to the fore. Some countries that suffer water scarcity are trying to protect their water resources, especially by importing blue virtual water content products from other countries. It has begun to be discussed in international scientific studies and platforms that this situation will be transformed into an opportunity by the countries with rich water resources and low virtual water content and it will be an economic value to water.

Comparison with the previous study [12] provided a general assessment reporting wheat’s annual water footprint of the majority of large basins and nations for 1996–2005. The result of the current study regarding Iraqi wheat green and blue WF of production 8,147,468,000 m³ in 2019 is compatible with [11] which having an overestimation. The difference can be clarified with the quality and the period of used data, changes in rainfall, yield, and production features, as well as the used model.
The conclusions of this study and earlier studies show that the wheat water footprints can meaningfully vary Mekonnen and Hoekstra 2014 within and around regions. This variation is created from the mutual influences of region-specific climatic and agricultural conditions. It has been well-known that the variability of wheat production largely depends on the water use and yield amount by 21% and 45%, respectively [24]. It is also stated that the wheat WF could increase up at various locations around the world to five or six times [24].

References
1. Distefano, T., & Kelly, S. (2017). "Are we in deep water? Water scarcity and its limits to economic growth". *Ecological Economics, 142*, 130–147.
2. Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2020a). Assessment of Main Cereal Crop Trade Impacts on Water and Land Security in Iraq. *Agronomy, 10*(1), 98.
3. Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019a). Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq. *Water, 11*(4), 756.
4. Xinchun, C., Mengyang, W., Xiangping, G., Yalian, Z., Yan, G., Nan, W., & Weiguang, W. (2017). "Assessing water scarcity in agricultural production system based on the generalized water resources and water footprint framework". *Science of the Total Environment, 609*, 587–597.
5. Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019b). Water Footprint of Wheat in Iraq. *Water, 11*(3), 535.
6. Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2020b). Domestic, Industrial, and Agricultural Water Footprint of two Provinces, Southern Iraq. Under press.
7. Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2011). "The Water Footprint Assessment Manual". Water Footprint Network.
8. Mekonnen, M.M., & Hoekstra, A. Y. (2011). "National water footprint accounts: The green, blue and grey water footprint of production and consumption", Volume 1: Main report. Delft, The Netherlands: Education, UNESCO-IHE Institute for Water Education.
9. Elena, G.C., & Esther, V. (2010). "From water to energy: The virtual water content and water footprint of biofuel consumption in Spain". *Energy Policy, 38*(3), 1345–1352.
10. Price, R.A. (2018) *Environmental risks in Iraq, K4D Helpdesk Report*; Institute of Development Studies: Brighton, UK.
11. Mekonnen, M.M., & Hoekstra, A. Y. (2011a). "National water footprint accounts: The green, blue and grey water footprint of production and consumption", Volume 2: Appendices. Delft, Netherlands: Unesco-IHE Institute for Water Education.
12. Mekonnen, M M, & Hoekstra, A. Y. (2010)." A global and high-resolution assessment of the green, blue and grey water footprint of wheat". *Hydrology and Earth System Sciences, 14*(7), 1259–1276.
13. Mekonnen, Mesfin Mergia, & Hoekstra, A. Y. (2010). "The green, blue and grey water footprint of crops and derived products". Volume 2: Appendices. UNESCO-IHE Institute for water education.
14. AQUASTAT. *Geography, climate and population Geography*; Food and Agriculture Organization (FAO) of the United Nation: Baghdad, Iraq, 2019.
15. Al-Ansari, N.; Knutsson, S. Toward prudent management of water resources in Iraq. *J. Adv. Sci. Eng. Res. 2011, 1*, 53–67.
16. Ewaid, S. H. (2018). Irrigation water quality of Al-Gharraf Canal, south of Iraq. In J. Phys. Conf. Ser (Vol. 1003, p. 012006).
17. Chen, W.; Wu, S.; Lei, Y.; Li, S. China’s water footprint by province, and inter-provincial transfer of virtual water. *Ecol. Indic.* 2017, 74, 321–333.
18. Adamo, N.; Al-Ansari, N.; Sissakian, V.K.; Knutsson, S.; Laue, J. Climate change: Consequences on Iraq’s environment. *J. Earth Sci. Geotech. Eng.* 2018, 8, 43–58.
19. Iraqi CSO. Iraqi Central Statistical Organization yearly statistics, Ministry of Planning Baghdad. Available online: http://www.cosit.gov.iq/en/ 10/4/2020.
20. ITC. (2020). Trade Map database. Retrieved April 28, 2020, from https://www.trademap.org/Index.aspx
21. Allen, R. G., Smith, M., Perrier, A., & Pereira, L. S. (1994). "An Update for the Definition of Reference Evapotranspiration". *ICID Bulletin*, 43(2), 1–34.
22. Muratoglu, A. (2020). Assessment of wheat’s water footprint and virtual water trade: a case study for Turkey. *Ecological Processes*, 9(1), 1-16.
23. Iraqi Central Statistical Organization (ICSO) (2020) Wheat and barley productivity 2019, Agricultural Statistics Directorate. In Arabic
24. Gobin, A., Kersebaum, K. C., Eitzinger, J., Trnka, M., Hlavinka, P., Takáč, J. ... & Lalić, B. (2017). Variability in the water footprint of arable crop production across European regions. *Water*, 9(2), 93.