Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

THE AGRICULTURAL WATER FOOTPRINT OF AL-NAJAF GOVERNORATE, IRAQ

Doaa Swadi Kashmer 1
Salwan Ali Abed 2
1,2 College of Science, University of Al-Qadisiyah,
Diwaniyah, P.O.Box. 1895, Iraq.
salwan.abed@qu.edu.iq ; doaa.swadi@gmail.com

Abstract

Improving methods of measuring, managing, and making decisions on regional water resources became necessary due to rising water use, pollution, and urbanization rates, as well as the effects of climate change. In the same vein as ecological and carbon footprints, the notion of water footprint (WF) has just recently made its way into the scientific literature. An item's water footprint (WF) is the sum of all the water resources that are either used up or polluted in some way throughout its manufacturing. This is the first research to examine the blue and green water footprints of agricultural output in Al-najaf governorate, southern Iraq, from 2013 to 2023, and to explore the impact on the governorate's water supply. We have employed the recently created WF technique. Crop water requirement (CWR) in CROPWAT 8.0 software was used to determine the quantities of blue and green evapotranspiration. Use of statistical data has been made, which includes data on weather, rainfall, local crop coefficients, cultivation area, crop production quantities, and animal statistics. For the period from 2013 to 2023, the average yearly agricultural water flow (WF) in the Al-Najaf governorate was calculated to be 1,315,201,621 Mm3/yr. Agriculture uses the most water of all economic activities (56%). Consumption of water is mostly caused by cereal and feed crops. The most important crops grown using water from rivers are rice and wheat, which together account for over half of all WF. Just 12% of agricultural WF goes into vegetable cultivation. Just 16% of the WF for crop production was green. Broiler chickens account for 42% of all animal production water demand, while dairy cattle account for 35%. There is plenty of arable land in the research region. Unfortunately, the region's paucity of water supplies and other factors hinder agricultural activity. Cutting back on WF and blue water content might help the governorate's freshwater supplies last longer. Authorities at the national level should be able to use this study to inform the creation of more precise policies for the management of irrigation water.

Keywords: Iraq, water footprint, Al- Najaf, water management, irrigation, environment.

Introduction

Every industry relies on water, making it the most vital resource. Important rivers like the Nile, Euphrates, and Tigris were the sites of the foundation of great civilizations. In modern times, water resources play a pivotal role in ensuring a steady supply of water for human consumption, agricultural irrigation, commercial use, and long-term energy production sustainability [1, 2]. Nevertheless, the current water supplies are starting to face a challenge from the rising demand of water [3]. Within this framework, there has been a meteoric rise in the number of global studies urging better water management in terms of both quantity and quality, as well as in the efficiency of the water that is already being utilized [4, 5]. Estimation, modeling, accurate planning, and management of regional water resources and consumption are of utmost significance, particularly

Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

at this era of significant global climate change impacts.[6]
The topic's significance becomes clear when one considers that just 2.5% of the world's water is freshwater potential and that only 0.3% of the world's water resources are fit for human use [7, 8]. Regional and national water management initiatives are becoming more important due to rising water demand and pollution and shrinking or nonexistent supplies [9, 10]. Research into more efficient distribution and operation of water resources, better control and manipulation of water quality criteria, and better use of water resources as a whole are all part of water management) [12 ,11]
The idea that water is a national treasure rather than a commodity that needs proper care and management is central to international water management strategies [13,14]. This strategy states that all countries are required to disclose the ecological state of their water bodies.
A water footprint (WF) is a relatively new notion that has just made its way into the scientific literature, joining the ranks of carbon and ecological footprints. In order to manage water resources, determine how humans affect local supplies, and protect ecosystems from degradation, regional WF accounting are useful .[15]
The research of Hoekstra et al. [16] forms the foundation of the water footprint idea. Mekonnen and Hoekstra [20], Hoekstra and Hung [19], and Chapagain and Hoekstra [17, 18]. Any product, process, or area's total WF may be determined using the WF technique. The water footprint (WF) of a product is the sum of all the water that goes into making that product, whether that water is eaten, utilized, or contaminated. Total treated or contaminated water up to a specific geographical scale is what the water flow (WF) in any given location is.
Traditional methods of calculating water usage just include surface and groundwater use [21]. A more comprehensive strategy is required in today's more globalized society, however, and this method is no longer advised [22]. By include not only the kind and quantity of water used, but also its volume, the WFf approach deviates from traditional water consumption accounting.
Water flow theory primarily considers three types of water: blue, green, and gray. The overall amount of surface and groundwater consumed is shown by the blue WF, whereas the total volume of rainfall used is represented by the green WF [23]. Green and blue WF components also include evapotranspiration (ET) and water transfer to neighboring basins and regions. Thus, the more the blue water footprint is elevated in relation to any human-made operation, the greater the consumption of both surface and groundwater, and the consequent worsening of water stress issues [15]. A product's manufacturing is supplied with rainwater contributions if its green water footprint is high [24]. A greater green WF than a lower blue WF is preferable as a sustainability metric, and this is especially true for agricultural goods [25]. Lastly, according to environmental criteria for contaminants in the same location, the gray WF is the amount of clean water needed to manufacture any product [26]. All three colors—blue, green, and gray—contribute to the overall WF. In places where industrial capacity is minimal, the gray WF is particularly low. Thus, in order to depict the overall WF of any place, the computation of blue and green WFs is enough.[27 ,17]
There hasn't been nearly enough research on WF since there's a lot of data that has to be collected, the analyses that need to be run, and the fact that WF is still a relatively new parameter [28]. Mekonnen and Hoekstra [29] performed one of the earliest country-based WF studies; their calculations of the WFs of several nations as a result of production and consumption were done at a rather low level of detail. Similarly, Chapagain and Hoekstra [17] investigated the idea of

international virtual water transfer in depth and used a broader resolution to compute WFs on a country level. Using varying geographical resolutions, Mekonnen and Hoekstra[30,31] examined the WF of agricultural goods once more. A large number of studies [32, 33, 34] have examined agricultural goods since they account for a substantial component of regional WF estimations. The agricultural WF is very sensitive to local climate and weather, hence regional estimates are essential [35, 36, 37, 38]. Urban areas account about 2% of the global landmass, although they are home to 50% of the world's population. By 2050, this ratio is projected to reach 70% [39]. Domestic WF analyses are critical for more consistent and efficient water resource use [42] due to the fact that population density is a characteristic that directly impacts water resource usage [40, 41]. In this light, a notable uptick in recent years can be seen in the demographic characteristics of Al- Najaf governorate. Not only does the region's dry environment make water extraction from blue water an absolute need, but so does the region's rapid population growth and increased agricultural output. Lots of research have shown that the governorate's water capacity is going down, albeit [2, 5, 43]. So, to help with water management and planning, the governorate can conduct a comparative study of water-using industries and activities.

Analyzing the agricultural WF of Al-Najaf governorate based on output is the major goal of the present study. It was within this framework that the blue and green WFs of the cattle and agriculture industries were determined. The scarcity of data on water contamination has prevented any studies on Gray WF [44]. Using data collected relatively recently, this analysis covers the years 2010–2020. However, all of Najaf's districts were considered simultaneously while determining the agricultural WF, and a diverse range of crops were utilized. This is the first research that the authors are aware of that examines WF in a provincial level in Iraq. The World Forests (WFs) of our nation and the research region may be inferred from a number of studies that simulate the WFs of other countries or basins on a global scale. Although one of the earliest analyses on the issue is Chapagain and Hoekstra's [17] work, the inputs utilized to predict WFs (crop characteristics, evapotranspiration levels, crop production statistics) are not of high resolution, and average data from nations between 1997 and 2001 are utilized. Mekonnen and Hoekstra [31, 45] worked using approximated data from global databases to create high-resolution spherical WF maps. Mekonnen and Hoekstra studied fundamental statistics from a number of nations, including Iraq, using WF of production and consumption .[29 ,21]

Focusing on a specific location, using up-to-date data supplied by local authorities, and selecting a large timeframe (10 years) are the key benefits of this study compared to the previous studies. Data created by local authorities, such as geographical precipitation averages (both measured and computed), crop coefficients, crop productivity, and information on water usage in animal husbandry, were therefore carefully considered. When compared to studies focusing on basins or countries, the number of WF studies conducted at the governorate level is quite small. Vanham and Bidoglio [46] examined the water flow (WF) of the Milan governorate and discovered that external factors greatly influenced the quantity and percentage of total water utilized for agriculture, industry, and households. The specifics of the water that the Berlin, Delhi, and Lagos governorates imported were covered in the context of virtual water commerce by Hoff et al .[42] . Moreover, the literature covered a variety of water footprints (WFs) for various governorates and cities, including: industrial water footprints and optimal water use [47], WFs concerning the energy sector in big cities [48], how urbanization affects WFs [49–51], WFs of areas with low rates of urbanization and abundant water resources [52, 53], WFs of urban agriculture [54], home plumbing [55], groundwater footprints [56], gray and green WFs [57], and direct water use [58].

1. Data and Method

2.1. Study Area

Najaf is one of the governorates in central Iraq, located on the edge of the western plateau of Iraq, southwest of the capital, Baghdad, about 161 km away from it. The city rises 70 meters above sea level. It is bordered to the north and northeast by the city of Karbala, which is about 80 km away, and to the south and west by the Bahr Al-Najaf depression. The governorates of Babel and Qadisiyah to the east, Muthanna to the south, Karbala and Anbar to the north, and the international border with Saudi Arabia to the west encircle the central region of Iraq, which is home to the Najaf Governorate. Twenty-eight thousand square kilometers, or 6.6% of Iraq's total land, make up the Al-Najaf Governorate. According to Figure 1 (Iraqi CSO, 2019), it consists of ten administrative divisions, or districts, that make up four districts .

Najaf has a hot, dry summertime climate. In the winter, the temperature can drop below zero degrees, and it can occasionally exceed 45 degrees Celsius. From one to five droplets of rain per trickling fall on average in Najaf each year. (Iraqi CSO, 2019).

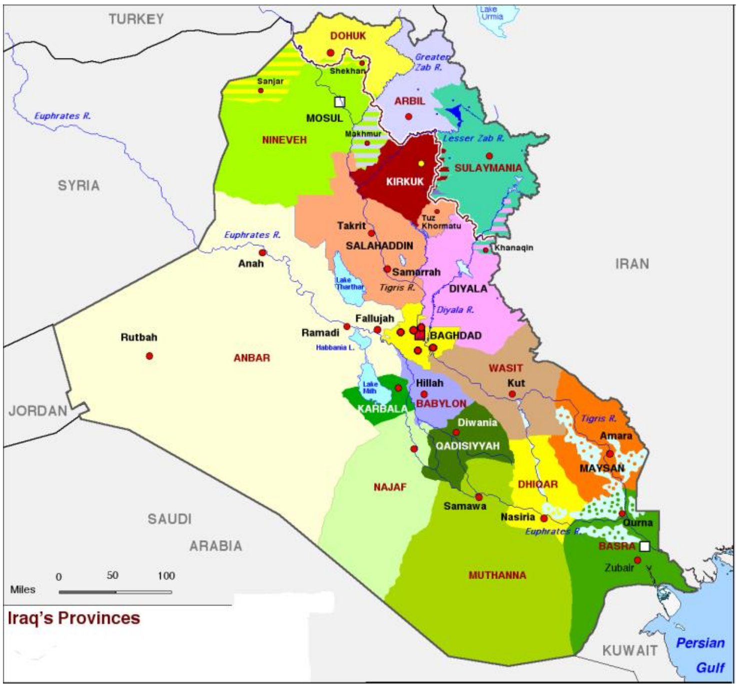

Figure 1. Iraqi map showing Najaf governorate (in light green).

2.2. Data

Many different types of data must be entered into water footprint investigations. Using high-quality data is closely correlated with accurate analysis while studying the WF of any location. Data for the Najaf governorate were culled from a number of sources, including [59, 61, 62, 63]. In regards to research area-specific concerns, such as climatic and agricultural features, Real data that has been measured on-site has been preferred above estimated data. In order By utilizing data collected from the Iraqi Meteorological Organization and Seismology (IMOS) and the CLIMWAT 2.0 programmer, we were able to estimate the reference evapotranspiration (ET0), model the effective rainfall (Peff), and determine the blue and green evapotranspiration values. This data was utilized from 2013 to 2023. Along with average and maximum temperatures, wind speeds, sundial times, solar radiation, relative humidity, and monthly rainfall averages were included in the statistics.. Crop coefficients (Kc), planting and harvesting dates, and the lengths of the first, second, third, and fourth stages of crop growth are obtained by consulting the relevant national reports [61]. In conclusion, the information has been furnished about the overall population, total production amounts (tons), total cultivated area (ha), number of cattle, sheep, and poultry kept across the governorate, and total cultivated area .[63 ,59]

The present study looked at 27 crop groups, including cereals (wheat, rice, millet, and sesame). The crops utilized as fodder include alfalfa, barley, clover, maize, and sorghum. Zucchini, green peas, green onions, crusty onions, carrots, green pepper, okra, cucumber, tomatoes, turnips, lettuce, radish, spinach, and turnip greens are among the veggies on this list. Fruits, such as golden melons, watermelons, and date palms ...

The animal statistics, which comprised the total yearly number of cattle, buffalo, sheep, goats, camels, and poultry, were checked with a department of the Iraqi Ministry of Agriculture responsible for planning and following up on agricultural projects [63] and the Iraqi Central Statistical Organization [59]. Each animal species' average annual water footprint was calculated using national data, with global average data being utilized in situations where regional data was not available [65].

2.3. Methods

There are three primary components to area-based water footprint estimates, as stated by Hoekstra et al.'s water footprint technique [16]: agricultural, livestock, and household and industrial (Eq. 1). Consideration of the overall blue and green water requirements of the cultivated crops is used to determine the agricultural WF, which is the greatest component of the total WF on any geographical scale [66]. The water footprint of animal husbandry, on the other hand, is based on the regional total volume of water handled by animals, both directly and indirectly [67]. The manufacturing of animal feed accounts for 98% of the overall water use, whereas direct water consumption, which includes potable and drinking water, accounts for around 2%. Polluted water or water used in agricultural operations to produce barley, maize, and alfalfa is what most of the water used by the livestock sector is, in this sense, comparable to agricultural WF. Last but not least, the proportion of WF attributable to homes and businesses is the lowest overall [68]. As a matter of fact, hardly 10% of the total water operated by humans is really used by municipalities to satisfy industrial and urban water demands, which goes against what is known from conventional water usage reports [69].

$$TWF = WF_A + WF_L \qquad (1)$$

Here, TWF is the total water footprint; WF_A, agricultural WF and WF_L is the WF of livestock.

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

2.3.1. Crops water footprint

The first step in estimating the agricultural WF is to find the green and blue ET values. The term "green ET" refers to evapotranspiration from precipitation, whereas "blue ET" refers to evapotranspiration from surface and groundwater. In order to determine the evapotranspiration value of each crop, this study employed CROPWAT 8.0, a program created used by the FAO to model the amount of water that crops would require for irrigation [70]. The algorithm considered average rainfall over extended periods of time, agricultural traits, and long-term weather data. Equation 2 of the Penman-Monteith method was applied to long-term data in order to establish the reference evapotranspiration, or ET0. climatic data using the aforementioned application. Equation 3 shows how crop coefficients (Kc), growth cycle durations, and ET0 values were used to determine crop evapotranspiration (ETc) values in the CROPWAT 8.0 software. The associated software's crop water requirement (CWR) option was chosen, and blue and green ET values were estimated. To simulate the effective precipitation (P eff), we utilized the same program that was used to calculate crop water usage (CWU) (Eq. 4 and 5). We also used the USDA-SC approach [71].

$$ET_0 = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}u^2(es-ea)}{\Delta+\gamma(1+0.34\,u2)} \quad (2)$$

$$ET_c = K_c \times ET_0 \quad (3)$$

$$ET_{blue} = \max\,(0, ET_c - P_{eff}) \quad (4)$$

$$ET_{green} = \min\,(ET_c, P_{eff}) \quad (5)$$

Here, ET_0 stands for the reference evapotranspiration in millimeters per day, Rn denotes the net radiation, G stands for the soil heat flux in megajoules per square meter per day, Δ denotes the slope of the vapor pressure curve in kPa/°C, and Ɏ is the psychometric constant in kPa/°C. The equation gives the following values: T represents the average daily air temperature (°C) at 2 m height, u2 stands for the wind speed at 2 m height (ms−1), and es and ea stand for saturation and actual vapor pressure (kPa), respectively. And lastly, evapotranspiration measurements in green (mm/year) and blue (mm/year) are referred to as ETblue and ETgreen, respectively. Plant coefficients (Kc), annual evapotranspiration value (ETc) in millimeters per year (mm/year), and effective rainfall (P. eff) in millimeters are the abbreviations used.
Equations 6-7 were used to calculate the crop water utilization (CWU) values, and then Equations 8-9 were used to evaluate the crops' virtual water contents (VWC). Commonly expressed as the amount of water expended per unit of product (m3/ton), virtual water content refers to the overall amount of water used or operated in the background of a product or process. The agricultural water usage efficiency (WFE) of the Najaf governorate was determined by adding up the blue and green VWC values of all crops cultivated in the study region (Eq. 10), and then calculating the water production of each crop using the crop cultivation areas and production amounts (Eq. 11). It was subsequently. The foundation of livestock and poultry production's WF are fowl, goats, lambs, camels, and cattle [65, 72].

Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

$$CWU_{blue}\left(\frac{m3}{ha}\right) = 10\sum ET_{blue} \quad (6)$$

$$CWU_{green}\left(\frac{m3}{ha}\right) = 10\sum ET_{green} \quad (7)$$

$$VWC_{blue}\left(\frac{m3}{ha}\right) = \frac{CWU_{blue}}{Y} \quad (8)$$

$$VWC_{green}\left(\frac{m3}{ha}\right) = \frac{CWU_{green}}{Y} \quad (9)$$

$$VWC = VWC_{blue} + VWC_{green} + VWC_{grey} \quad (10)$$

$$WF\,(m^3) = \sum VWC_i\left(\frac{m3}{ton}\right) xc_i(ton) \quad (11)$$

2.3.2. WF of date's production

The water flow rate (WF) was calculated using the following assumptions: rainfall accounts for 15% (10.5 m3/tree), irrigation for 85% (59.5 m3/tree), and total annual net usage of date palm water is around 70 m3/tree [73, 74, 75].

2.3.3. Water footprint of livestock and poultry production.

Gathering the density of a given animal kind (or weight in tons of fowl) and multiplying it by the category's yearly water footprint (m^3/yr) was how the total WF was determined in the governorate .[65]

In rural Iraq, most cows have a dual function, therefore the total number was distributed equally between beef cattle and dairy cattle [63]. Dairy cattle were considered buffalo, whereas camels were considered horses [76], Table 6.

In [17], the following technique for calculating the WF of cattle was described, based on equations (12, 13, and 14):

$$WF_a = WF_{direct} + WF_{indirect} \quad (12)$$

Where WF_a is the water footprint (m3/ton) of the living thing, and WFdirect is the amount of water used for various purposes all during the animal's existence, such as drinking, bathing, and other necessities. The quantity of water utilized in the manufacturing of animal feed is denoted as WFindirect .

Direct WF contributes a meager 1% of overall livestock WF [77]. Direct and indirect WF in live animals are calculated in the following ways, using the procedures of [78]:

\

$$WF_{direct} = \frac{\int_{birth}^{slaughter} q_a\,dt}{W_a} \quad (13)$$

Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

$$WF_{indirect} = \frac{\int_{birth}^{slaughter} \{\sum_{c=1}^{n} WF_{c\_}Feed_{a,c}\}dt}{W_a} \quad (14)$$

In this context, qa represents the daily water consumption volume (m3/day), WFc stands for the water footprint of feed (m3/ton), c represents the daily crop intake (ton/day) by animals, and Wa represents the normal weight of an animal right before slaughter (tons). The water usage per day was culled from [65] and the fundamental data needed for animal production was sourced from [63].

3. Results and Discussion

3.1. Comparison of WFs of Different Sectors

Agricultural agriculture and animal husbandry have a combined annual average water flow (WF) of 995,020,883 m3/yr from 2013 to 2023. Table 1 and Figure 2 show the water quantities in each region. Thus, 383,668,376 m3 (crops and dates without fodder) of Najaf's water is utilized for agricultural purposes, making up 31.3% of the overall agricultural water consumption .

By far, the most significant water user in the region is the agricultural WF. The plant has a high ET need, which is why this is the case. The majority of the world's freshwater supply—more than 70%—is derived from human activities [79]. On a global scale, 90% of all clean water consumption occurs in agriculture [80]. The WF of agricultural operations is very high, according to comparable research [17, 36], particularly in dry locations with continental climates.

Table 1. The agricultural WF components of Najaf Governorate (m^3/yr) (2013-2023).

Agricultural				
Crops without fodder	Date Palms	Livestock	Poultry	Total
826,541,976	70,595,981	233,878,242	184,185,426	1,315,201,625

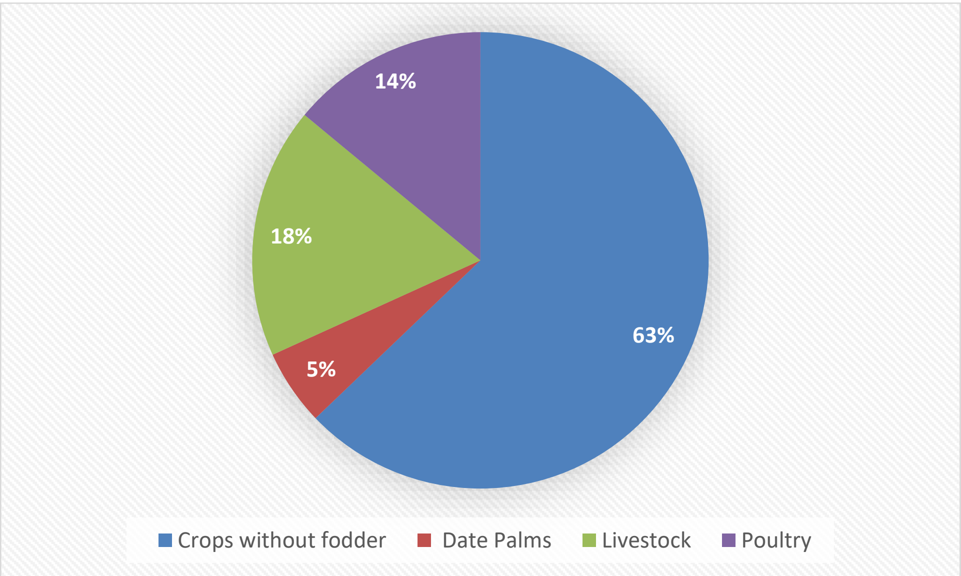

Figure 2. The percentages of agricultural WF components of Najaf Governorate (2013-2023).

Water is utilized both directly and indirectly in animal husbandry with the goal of producing meat, milk, and other goods from animals such as cattle, sheep, goats, camels, and poultry [81, 82]. According to the current study, the total water required for the production of fodder crops accounts for almost one-third of all agricultural operations worldwide [84]. This information is derived from the livestock water footprint (WF). Table 1 and Figure 2 show that animal husbandry's total WF—including both cattle and poultry—accounts for 311,027,797 m3. This is 31.2% of the overall WF. Traditional water use estimations just include water immediately collected from surface and subsurface deposition systems; however, the WF technique considers the overall amount of water utilized in all activities. By disaggregating water use into its component parts, WF studies have an advantage over more conventional methods of water consumption estimation. Rainwater evaporation, or green water, and surface and groundwater evaporation, or blue water, are two different things. This study used the CROPWAT 8.0 program's blue water with the CWR option to account for the quantity of irrigation that has to be done within the context of agricultural operations, taking into account the crops' irrigation water demand (IWR). Based on the average data from 2010 to 2020, it was determined that 83% of the total crop WF is blue, and 17% is green (Table 3). Due to the significant significance of irrigated agriculture, the blue component of the WF has high values. Agricultural activities, including irrigation, consume over 75% of Iraq's water [14]. This part addresses the water consumption concerns of agricultural production in the study region, as it is the largest water-consuming industry compared to others .

The average rainfall season in Qadisiyah yielded 446,683,192 (or 83% of the total) and 90,235,105 (17%) million m3 of WF blue and green components, respectively, for the crop output. On a worldwide basis, agricultural operations are reported to have a green water ratio of 78% [32]. Despite the high blue WF predicted for continental climates, this leads to over-distribution of surface water, which in turn restricts agricultural activity, particularly in regions where water is scarce. So, to lessen the amount of blue ET, better watering techniques should be implemented.

Table 3 displays the average yearly WF and rate for each of the 27 crops that were included in this study from 2010 to 2020. The cultivation of cereal crops, including rice, wheat, and barley, accounts for the bulk of the governorate's water use .

The research region has a specific emphasis on wheat production [85]. Based on the calculations, the wheat crop accounts for 25.6% of the crops in the area and 13.8% of the total water processing capacity (WF), with a total of 137,286,724 million m3 in the study area. A ratio of 23.84% was determined for the research area's wheat production using green water. Taking into account the global average, this percentage is said to be around 70%.[30]

Barley, wheat, and alfalfa are the crops that use the most blue water. Together, they use 264,644,191 million m3 of freshwater, which is roughly 26.6% of the total water utilized in the region. This accounts for 59.2% of the surface water used for agricultural irrigation. Consequently, the appropriate authorities should prioritize making these items more efficient during irrigation. But while thinking about the future, it's important to consider the virtual water content of these items as well. The virtual water content (VWC) is the amount of clean water (in cubic meters) utilized to make one unit of product (in tons) and stands for the overall amount of water consumed by the items. There is a clear correlation between the yield in the location where a product is cultivated and its high VWC [86]. Consideration of all relevant factors, such as the VWCs of various goods throughout Iraqi areas, their yields, economic returns, reliance on other nations, etc., should go into the development of product-based policies for the sustainability of water resources.

3.2. Agricultural water footprint

3.2.1. Crops water footprint

The governorate agricultural production WF was forecast for the years 2013–2023, with 27 distinct crop kinds taken into consideration (see section 2.2). The crops that are being studied have their matching annual WFs displayed in Table 3. When including in crops used for feed, the average yearly WF of Qadisiyah is 536,918,297 Mm3/yr. The highest water-holding capacity (WFC) is found in fodder crops, which account for over 42% of the total WF crop at 225,679,481 Mm3/yr. The largest water holding capacity (WF) is held by barley at 139,575,569 Mm3/yr, followed by wheat at 137,286,724 Mm3/yr, date palms at 72,429,560 Mm3/yr, and alfalfa at 51,726,725 Mm3/yr. In this study, fodder crops are included in the livestock WF. The inclusion of other crops was based on their comparatively small water footprints, as seen in Table 3 and Figure 3.

Just about one-fifth of all WF crops are blue, with the remaining 83.2% being green. Irrigated agriculture, together with other agricultural uses, accounts for over 75% of Iraq's water consumption, which is why the blue portion of the WF has such high numbers.

Table 3. The WF annual average values of crop production in Najaf Governorate (2013-2023).

	Production		Area	Water footprint (m^3/ton)			WF of production (Mm^3/yr)		
	ton/yr	**ton/ha**		**blue**	**green**	**total**	**blue**	**green**	**total**
Cereals (60% of the TWF)									
Wheat	270,625	2.544	106,344	796	297	1,093	215,417,500	80,375,625	295,793,125
Rice	100,108	4.373	22,898	3,319	8	3,326	332,155,027	900,964	333,055,990
Sesame	1,638	1.075	1,527	9,116	415	9,528	14,939,486	678,545	15,618,032
Millet	756	0.528	1,432	7,796	841	8,636	5,885,226	634,202	6,519,426
Fodder crops (24% of the TWF)									
Barley	120,112	1.763	68,166	1,084	402	1,485	130,080,214	48,164,512	178,244,725
Maize	3,887	2.407	1,616	2,541	192	2,732	9,870,442	742,227	10,612,667
Sorghum	2,158	1.07	2,035	634	359	992	1,365,382	772,208	2,137,588
Alfalfa	40,492	14.339	2,825	1,198	78	1,277	48,467,728	3,198,788	51,726,725
Clover	9,095	9.533	955	1,802	119	1,920	16,378,295	1,073,093	17,451,387
Vegetables (10% of the TWF)									
Eggplant	5,016	6.006	836	844	64	907	4,277,646	315,946	4,543,591
Green peas	1,755	3.078	571	1,391	59	1,449	2,438,061	101,733	2,539,793
Green onion	1,183	8.890	134	482	21	502	568,543	23,641	592,183
Crusty onion	2,286	4.446	515	963	41	1,003	2,198,171	91,401	2,289,571

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

Carrots	75	7.790	9.6	548	24	573	40,627	1,703	42,329
Water melons	32,747	6.018	5,443	1,159	64	1,222	37,919,869	2,062,999	39,982,867
Yellow melons	25,481	8.354	3,051	8354	47	881	21,250,321	1,172,081	22,422,401
Green pepper	175	2.24	79	3,108	201	3,308	540,967	3,4801	575,767
Cowpea	2,463	4.105	601	1,234	93	1,326	3,035,647	226,505	3,262,151
Okra	5,009	6.714	747	755	58	812	3,776,033	285,457	4,061,489
Cucumber	11,107	9.785	1,136	519	38	558	5,752,909	433,135	6,186,043
Tomatoes	6,368	12.785	499	849	29	876	5,399,217	171,910	5,571,126
Turnip	605	1.968	308	1,349	175	1,523	814,193	105,097	919,289
Lettuce	6,051	2.319	2,611	1,145	148	1,292	6,921,201	889,351	7,810,551
Radish	66	1.626	41	3,114	234	3,347	202,346	15,146	217,491
Spinach	277	1.587	175	1,673	215	1,889	461,473	59,617	521,089
Zucchini	1,103	1.752	631	2,890	215	3,106	3,183,679	238,033	3,421,711
Date palms (m^3/tree) (6% of the TWF)									
	ton/yr	**ton/tree**	**Dates**	**blue**	**green**	**total**	**blue**	**green**	**total**
	33	0.033	1,008,515	58	12	70	59,502,325	11,093,655	70,595,981
Total			233,126				932,792,504	153,862,352	**1,086,654,855**
WF without fodder crops							726,630,449	99,911,528	**826,541,976**

In most parts of the world, crops use green water as their primary source of water [84]. However, in this governorate, the blue water content of crops was found to be 83.2% and the green water fraction to be 16.8%. Due to the high evapotranspiration levels, hot weather, and lack of precipitation, agricultural output uses more water than usual [88]. Because there isn't enough rain in Iraq's dry regions, particularly in the summer, irrigation is necessary to prevent crop blue water from becoming too high. With the exception of winter crops like wheat and barley, which use less blue water, every crop in the research region depends on it to some extent .

In 2017, the World Federation for Rice (WFF) for Iraqi rice was 3091 m3/ton, according to the study by Ewaid et al. [89], which is greater than the global average of 1325 m3/ton. During the dry and hot season, when rice is grown, green water vapor is almost nonexistent and blue water vapor is dominating; about 821,737,881 Mm3/yr of water has been utilized to irrigate rice-growing regions, yielding 265,852 tons.

One of the most widely grown crops, wheat, was domesticated in Iraq [85]. On a worldwide scale, green water accounts for 70% of wheat flour (WF) [45]. The proportion of green water used in wheat production is far lower than the world average, according to this study. There is a little less dependence on blue water in the region as 27% of the overall water need for wheat production comes from the green water. Estimates put Iraq's annual wheat harvest at 4,120,160,334 Mm3 [85]. The Najaf governorate is also a major wheat-growing region. A total of 137,286,724 Mm3/yr of wheat is produced per year.

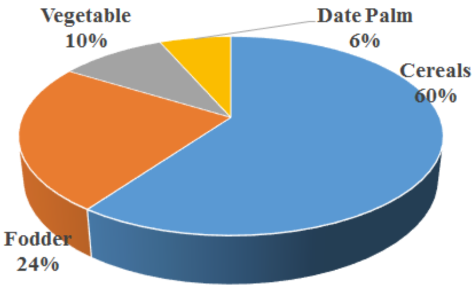

Figure 3. The primary percentages of the crops WF in the governorate (2013-2023).

In order to improve water management techniques, policymakers should thoroughly examine each crop's blue, green, and total water factor. To make a better decision on agricultural management of the study area, it is practical to encourage crops with lower water-use factors (WFs), such as vegetables, in order to preserve limited freshwater resources. However, it is also important to consider topics such as the nutritional and economic worth of crops, concerns about food safety, and the amount of virtual water in the country [88].

Consequently, it is recommended that existing water supplies be utilized, with the primary goals being to limit water loss due to evaporation, collect rainfall, and implement more advanced irrigation systems to do this [14]. Lower WF rates for food, products, and services must be promoted by the authorities [85]. The issue may have a remedy that involves raising awareness, changing product labels, or anything along those lines. It is possible to improve water usage efficiency by ignoring manufacturing techniques with lower output levels.[88]

Because of the weather, the governorate's biggest share was Blue WF. Half of the water that the agriculture sector has to withdraw has gone into cereal cultivation. Given that blue water resources are very limited, it is suggested that rice, wheat, and barley cultivation be reduced. To further lessen the strain on water supplies, decision-makers in the agricultural sector should limit the harvest of crops with a high water-fixation factor (WF). Climate and productivity are the two main factors that determine the yield of WF crops. Cereal crops, such as rice, consume a lot of blue water, which means that their production should be restricted. Vegetables, on the other hand, don't need as much water, therefore they should be cultivated instead.

3.2.2. Water footprint of date's production

Central and southern Iraq are major producers of dates. Over the past half-century, date palm plantations have declined as a result of human carelessness and the extensive degradation brought about by the proliferation of domestic animals and humans.[90]

The date palm tree is an abundant source of many different goods and is a renewable resource in and of itself [91, 92]. Long, hot summers with little rain and extremely low humidity, as well as an abundance of surface or irrigated groundwater, are ideal for date palms, which can thrive in extremely dry, heated climates and are somewhat resistant to acidic and saline soils [93]. This study's WF dates are displayed in Table 4.

Volume 2, Issue 6, June - 2024
ISSN (E): 2938-3781

Table 4. The date palms average WF annually in Najaf Governorate (2009-2018).

Production		Trees	Water Footprint (m3/tree)			WF of Production (Mm3/yr)		
ton/yr	ton/tree		blue	green	total	blue	green	Total
Najaf	0.0	1,008,	5	1	7	59,50	11,09	71,636
32,299	33	513	8	2	0	2,327	3,653	,932

3.2.3. Water footprint of livestock and poultry production.

The amount of feed that cattle and poultry consume, both directly and indirectly, as shown in their weight. To determine the WF for cattle and poultry, this study employed the average water consumption per animal quantity or ton of animal weight for poultry [65]. Table 6 gives the province WF for livestock and poultry production, whereas Table 5 offers some data of poultry output [63]. Figure 2 shows that the average annual water flow (WF) from cattle production is around 203,043,456 Mm3/yr, or about 28 percent of the total WF.

Table 5. Statistics on poultry production in Najaf Governorate (MOA, 2023).

	projects	sets	Chickens Numbers 1000	Weight per chicken	Quantity of sold chickens (ton) poultry	breeding
Najaf	197	5	8000	1965 g	13742	132

Table 6. The WF of livestock and poultry production in Najaf Governorate (2013-2023).

Animal category	m3/yr/animal	Number of animals	WF
Beef cattle	631	75,537	47,663,847
Dairy cattle	2,057	75,537	155,379,609
Broiler chickens	27	7,001,000	189,027,000
Layer chickens	34	66,226	2,251,684
Camels	1,600	5,108	8,172,800
Sheep	69	294,284	20,305,596
Goats	32	86,827	2,778,464
Total			425,579,000

The percentages of the governorate's WF that go for livestock agriculture are shown in Figure 4. Table 6 shows that dairy cattle account for the lion's share of water utilized in animal production, at 57%.

Web of Agriculture: Journal of Agriculture and Biological Sciences
webofjournals.com/index.php/8

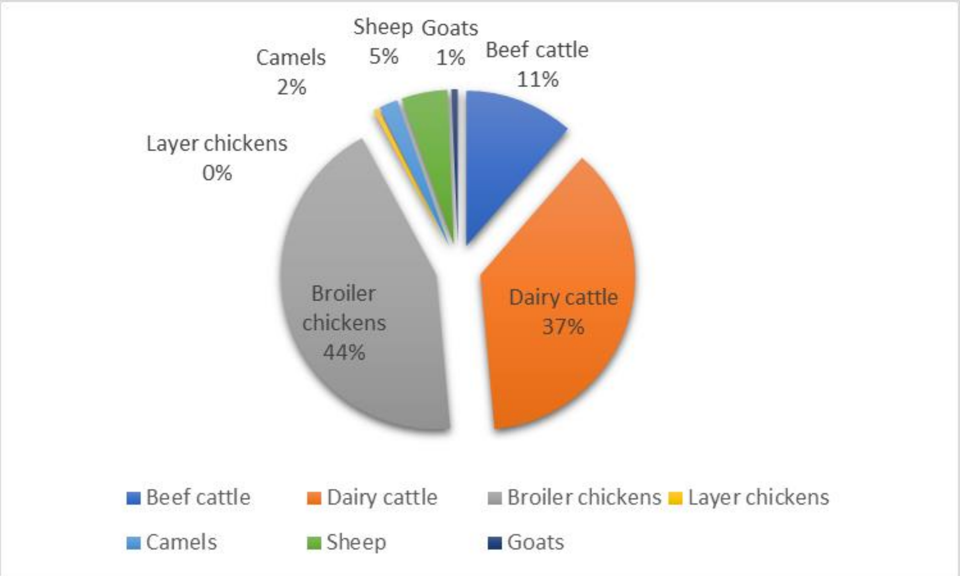

Figure 4. The percentages of the animal production WF (2013-2021).

Approximately 98% of the world's freshwater is used by animal feed, making it the most water-intensive process in animal production [72]. In the world of livestock agriculture, feed production accounts for over a third of all agronomic freshwater. Beef accounts for 33% of WF, dairy cattle for 19%, and fowl for 20%. Additionally, green water accounts for 87% of the total animal production WF [65], making it the most consumed freshwater by livestock on a global scale. The study found that blue-water ecosystems rely more on livestock activities than the typical global ecosystem. The current state of affairs and future possibilities for improved water resource utilization and increased water productivity in animal production can be better understood by calculating the water productivity of animal production.

4. Conclusions

Study findings indicate that the governorate's annual water footprint is around 995,020,883 million m^3. The majority of the water consumed is handled by agricultural agriculture, specifically date palms and fodder crops (536,918,297 m3), accounting for 54% of the total. Water footprints were computed for the study area's livestock as well as for industrial and household uses. A total of 27 plant species grown in the area had their water footprints and total water use determined. Barley, wheat, and alfalfa are the three most water-intensive agricultural crops. The majority of the crop's water use (59.2%) is caused by these items.

Based on the data collected, wheat accounts for 13.8% of the governorate's overall water footprint, making it the most important crop farmed there. There is a lot of blue water usage in the area, according to comparable research in the literature. The location of the research region in the hot climatic zone explains this condition, particularly the rise in evapotranspiration volumes.

The climate, the virtual water content of manufactured and consumed goods, the way of life of the local population, their dietary choices, and other factors all contribute to a region's high water footprint [18]. For water resource sustainability, particularly in semi-arid and dry locations, it is crucial to find ways to lessen the impact on water resources and cut down on the use of blue water in farming. Reviewing the virtual water content and usage of blue water in Iraq's primary goods will help with more effective and reasonable water management. Detailed policies regarding water and agricultural products can be advanced with the use of research that measure rising water footprints.

References

[1] Hoekstra, A. Y., Mekonnen, M. M., Chapagain, A. K., Mathews, R. E., & Richter, B. D. (2012). Global monthly water scarcity: blue water footprints versus blue water availability. PloS one, 7(2), e32688.

[2] Rahi, K. A., Al-Madhhachi, A. S. T., & Al-Hussaini, S. N. (2019). Assessment of Surface Water Resources of Eastern Iraq. Hydrology, 6(3), 57.

[3] Ewaid, S. H., Abed, S. A., & Kadhum, S. A. (2018). Predicting the Tigris River water quality within Baghdad, Iraq by using water quality index and regression analysis. Environmental technology & innovation, 11, 390-398.

[4] Al-Ansari, N., Knutsson, S. (2011). Toward prudent management of water resources in Iraq. J. Adv. Sci. Eng. Res. 2011 (1), 53–67.

[5] Al-Ansari, N. (2013). Management of water resources in Iraq. Engineering, 5(6), 667-684.

[6] Distefano, T., & Kelly, S. (2017). Are we in deep water? Water scarcity and its limits to economic growth. Ecological Economics, 142, 130-147

[7] Salman, D. A., Amer, S. A., & Ward, F. A. (2014). Water appropriation systems for adapting to water shortages in Iraq. JAWRA J. of the American Water Resources Association, 50(5), 1208-1225.

[8] Mekonnen, M.M., Hoekstra, A.Y. (2016). Sustainability: Four billion people facing water scarcity. Sci. Adv. 2.

[9] Almamalachy, Y. S., Al-Quraishi, A. M. F., & Moradkhani, H. (2020). Agricultural drought monitoring over Iraq utilizing MODIS products. In Environmental Remote Sensing and GIS in Iraq (pp. 253-278). Springer, Cham.Abed, S. A., Ewaid, S. H., & Al-Ansari, N. (2019). Evaluation of Water Quality in the Tigris River within Baghdad, Iraq using Statistical Techniques. Journal of Physics: Conference Series (Vol. 1294, No. 7, p. 072025). IOP Publishing.

[10] Ewaid, S.H.; Kadhum, S.A.; Abed, S.A (2019a). Development and evaluation of irrigation water quality guide using IWQG V.1 software: A case study of Al-Gharraf Canal, Southern Iraq. Environ. Technol. Innov. 2019, 13, 224–232.

[11] Joint, F. A. O. (2018). Challenges and Opportunities for Crop Production in Dry and Saline Environments in the ARABIA Member States (No. IAEA-TECDOC--1841). Joint FAO/IAEA Division of Nuclear Tech. in Food and Agri.

[12] Clark, G. (2007). Evolution of the global sustainable consumption and production policy and the United Nations Environment Program's (UNEP) supporting activities. Journal of cleaner production, 15(6), 492-498.

[13] Ewaid, S. H., Abed, S. A., and Al-Ansari, N. (2019b). Crop Water Requirements and Irrigation Schedules for Some Major Crops in Southern Iraq. Water, 11(4), 756.

[14] Veettil, A. V., & Mishra, A. K. (2018). The potential influence of climate and anthropogenic variables on water security using blue and green water scarcity, Falkenmark index, and

freshwater provision indicator. Journal of environmental management, 228, 346-362.

[15] Hoekstra, A. Y., Chapagain, A. K., Mekonnen, M. M., & Aldaya, M. M. (2011). The water footprint assessment manual: Setting the global standard. Routledge.

[16] Chapagain, A.K., Hoekstra, A.Y. (2004). Water footprint of nations. Volume 1: Main report. Value Water Res. Rep. Ser. 1, 1–80.

[17] Hoekstra, A. Y., & Chapagain, A. K. (2006). Water footprints of nations: water use by people as a function of their consumption. Integrated assessment of water resources and global change (pp. 35-48). Springer, Dordrecht.

[18] Hoekstra A.Y., Hung P.Q. (2002). A quantification of virtual water flows between nations in relation to international crop trade, Water Research, 49 (11), 203–209.

[19] Mekonnen, M. M., & Hoekstra, A. Y. (2010a). 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.

[20] Oki, T., & Kanae, S. (2006). Global hydrological cycles and world water resources. science, 313(5790), 1068-1072.

[21] Vanham, D. (2012). A holistic water balance of Austria–how does the quantitative proportion of urban water requirements relate to other users?. Water Science and Technology, 66(3), 549-555.

[22] Ercin, A. E., & Hoekstra, A. Y. (2014). Water footprint scenarios for 2050: A global analysis. Environment international, 64, 71-82.

[23] Quinteiro, P., Rafael, S., Villanueva-Rey, P., Ridoutt, B., Lopes, M., Arroja, L., & Dias, A. C. (2018). A characterization model to address the environmental impact of green water flows for water scarcity footprints. Science of the Total Environment, 626, 1210-1218.

[24] Novoa, V., Ahumada-Rudolph, R., Rojas, O., Munizaga, J., Sáez, K., & Arumí, J. L. (2019). Sustainability assessment of the agricultural water footprint in the Cachapoal River basin, Chile. Ecological indicators, 98, 19-28.

[25] Johnson, M. B., & Mehrvar, M. (2019). An assessment of the grey water footprint of winery wastewater in the Niagara Region of Ontario, Canada. Journal of cleaner production, 214, 623-632.

[26] Muratoglu, A. (2019). Water footprint assessment within a catchment: A case study for Upper Tigris River Basin. Ecological Indicators, 106, 105467.

[27] Qasemipour, E., & Abbasi, A. (2019). Virtual Water Flow and Water Footprint Assessment of an Arid Region: A Case Study of South Khorasan Governorate, Iran. Water, 11(9), 1755.

[28] Mekonnen M.M., Hoekstra A.Y., (2011a) National water footprint accounts: The green, blue and grey water footprint of production and consumption, Volume 1: Main report 50, Education, UNESCO-IHE Institute for Water Education, Delfth, The Netherlands.

[29] Mekonnen, M.M., and Hoekstra, A.Y. (2010a). The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands.

[30] Mekonnen, M. M., & Hoekstra, A. Y. (2011b). The green, blue, and grey water footprint of crops and derived crop products. Hydrology and Earth System Sciences, 15(5), 1577-1600.

[31] Mekonnen, M. M., & Hoekstra, A. Y. (2014). Water footprint benchmarks for crop production: A first global assessment. Ecological indicators, 46, 214-223.

[32] Zhang, Y., Huang, K., Yu, Y., Hu, T., & Wei, J. (2015). Impact of climate change and drought regime on the water footprint of crop production: the case of Lake Dianchi Basin, China. Natural Hazards, 79(1), 549-566.

[33] Zhuo, L., Mekonnen, M. M., & Hoekstra, A. Y. (2014). Sensitivity and uncertainty in crop water footprint accounting: a case study for the Yellow River basin. Hydrology and earth system sciences, 18(6), 2219-2234

[34] Dumont, A., Salmoral, G., & Llamas, M. R. (2013). The water footprint of a river basin with a special focus on groundwater: The case of Guadalquivir basin (Spain). Water Resources and Industry, 1, 60-76.

[35] Aldaya, M. M., & Llamas, M. R. (2008). Water footprint analysis for the Guadiana river basin (Vol. 3). Delft, The Netherlands: UNESCO-IHE

[36] Hu, T., Huang, K., Yu, Y., Zhang, X., Xu, Y., & Wang, X. (2016). Measuring water footprint on a lake basin scale: a case study of lake dianchi, China. CLEAN–Soil, Air, Water, 44(10), 1296-1305

[37] Hoekstra, A. Y. (2019). The water footprint of modern consumer society. Routledge.

[38] Pfister, S., Bayer, P., Koehler, A., & Hellweg, S. (2011). Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. Environmental science & technology, 45(13), 5761-5768.

[39] Chen, J., Shi, H., Sivakumar, B., & Peart, M. R. (2016). Population, water, food, energy, and dams. Renewable and Sustainable Energy Reviews, 56, 18-28.

[40] Kinouchi, T., Nakajima, T., Mendoza, J., Fuchs, P., & Asaoka, Y. (2019). Water security in high mountain cities of the Andes under a growing population and climate change: A case study of La Paz and El Alto, Bolivia. Water Security, 6, 100025.

[41] Hoff H., Döll P., Fader M., Gerten D., Hauser S., Siebert S. (2014). Water footprints of cities indicators for sustainable consumption and production, Hydrology and Earth System Sciences, 18, 213-226.

[42] Abdullah, M., Al-Ansari, N., & Laue, J. (2019). Water Resources Projects in Iraq, Reservoirs in The Natural Depressions: Water Resources Projects in Iraq, Reservoirs in The Natural Depressions. Earth Sciences and Geotechnical Engineering, 9(4), 137-152.

[43] Iraqi CSO (2019). Iraqi Central Statistical Organization yearly statistics, Ministry of Planning Baghdad, at http://www.cosit.gov.iq/en/

[44] Mekonnen, M.M. and Hoekstra, A.Y. (2011 b) National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value 2 of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.

[45] Vanham, D. A., & Bidoglio, G. (2013). The water footprint of Milan. Water Science and Technology, 69(4), 789-795.

[46] Xu, M., Li, C., Wang, X., Cai, Y., & Yue, W. (2018). Optimal water utilization and allocation in industrial sectors based on water footprint accounting in Dalian City, China. Journal of cleaner production, 176, 1283-1291.

[47] Liao, X., Zhao, X., Jiang, Y., Liu, Y., Yi, Y., & Tillotson, M. R. (2019). Water footprint of the energy sector in China’s two megalopolises. Ecological modelling, 391, 9-15.

[48] Feng, L., Chen, B., Hayat, T., Alsaedi, A., & Ahmad, B. (2017). The driving force of water footprint under the rapid urbanization process: a structural decomposition analysis for

Zhangye city in China. Journal of Cleaner Production, 163, S322-S328.

[49] Zhang, F., Zhan, J., Li, Z., Jia, S., & Chen, S. (2018). Impacts of urban transformation on water footprint and sustainable energy in Shanghai, China. Journal of cleaner production, 190, 847-853.

[50] Fang, K., Zhang, Q., Yu, H., Wang, Y., Dong, L., & Shi, L. (2018). Sustainability of the use of natural capital in a city: Measuring the size and depth of urban ecological and water footprints. Science of the Total Env., 631, 476-484.

[51] Qian, Y., Dong, H., Geng, Y., Zhong, S., Tian, X., Yu, Y., ... & Moss, D. A. (2018). Water footprint characteristic of less developed water-rich regions: the case of Yunnan, China. Water Research, 141, 208-216.

[52] Luo, P., Yang, Y., Wang, H., Gu, Y., Xu, J., & Li, Y. (2018). Water footprint and scenario analysis in the transformation of Chongming into eco-island. Resources, Conservation and Recycling, 132, 376-385.

[53] Zhao, X., Tillotson, M. R., Liu, Y. W., Guo, W., Yang, A. H., & Li, Y. F. (2017). Index decomposition analysis of urban crop water footprint. Ecological Modelling, 348, 25-32.

[54] Cai, B., Liu, B., & Zhang, B. (2019). Evolution of Chinese urban household's water footprint. Journal of cleaner production, 208, 1-10.

[55] Pérez, A. J., Hurtado-Patiño, J., Herrera, H. M., Carvajal, A. F., Pérez, M. L., Gonzalez-Rojas, E., & Pérez-García, J. (2019). Assessing sub-regional water scarcity using the groundwater footprint. Ecological indicators, 96, 32-39.

[56] Ding, X., Wang, S., & Chen, B. (2019). The Blue, Green, and Grey Water Consumption for Crop Production in Heilongjiang. Energy Procedia, 158, 3908-3914.

[57] Manzardo, A., Loss, A., Fialkiewicz, W., Rauch, W., & Scipioni, A. (2016). Methodological proposal to assess the water footprint accounting of direct water use at an urban level: A case study of the Municipality of Vicenza. Ecological indicators, 69, 165-175.

[58] Iraqi CSO (2019). Iraqi Central Statistical Organization yearly statistics, Ministry of Planning Baghdad, at http://www.cosit.gov.iq/en/

[59] Bishay, F. K. (2003). Towards sustainable agricultural development in Iraq. The transition from relief, rehabilitation, and reconstruction to development.

[60] DEAT (2019). Guide to Agricultural Operations in Iraq; Department of Extension and Agricultural Training, Ministry of Agriculture: Baghdad, Iraq, (In Arabic)

[61] IMOS (2021). Iraqi Meteorological Organization and seismology (IMOS) unpublished data.

[62] MOA (2021). The Iraqi M. of Agriculture, Dept. of Statistics. Annual statistics of agricultural crops.

[63] FAO, CLIMWAT 2.0, Food and Agricultural Organization of the United Nations, http://www.fao.org/land-water/databases-andsoftware/ climwat-for-cropwat/en/.

[64] Mekonnen, M. M., & Hoekstra, A. Y. (2012). A global assessment of the water footprint of farm animal products. Ecosystems, 15(3), 401-415.

[65] Lovarelli, D., Bacenetti, J., & Fiala, M. (2016). Water Footprint of crop productions: A review. Science of the Total Environment, 548, 236-251.

[66] Ran, Y., Lannerstad, M., Herrero, M., Van Middelaar, C. E., & De Boer, I. J. M. (2016). Assessing water resource use in livestock production: A review of methods. Livestock Science, 187, 68-79

[67] Hoekstra, A. Y. (2015). The water footprint of the industry. In Assessing and measuring environmental impact and sustainability (pp. 221-254). Butterworth-Heinemann.
[68] Postel, S. L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable freshwater. Science, 271(5250), 785-788.
[69] FAO (2019). CropWat 8.0 Model, Food and Agricultural Organization of the United Nations, http://www.fao.org/land-water/databases-and-software/cropwat/en/.
[70] USDA–SCS (1993). Irrigation Water Requirements, Chapter 2, part 623 of the National Engineering Handbook, Soil Conservation Service.
[71] Personal Contact (2019). Personal contact with the engineers of the industrial establishments of the governorate.
[72] Zaid, A. and P. F. de Wet (2002). Botanical and systematic description of the date palm. In A. Zaid and E. J. Arias-Jiménez (eds.), Date Palm Cultivation. FAO Plant Production and Protection Paper 156 Rev. 1. Rome, Italy
[73] Alamoud, A. I., Mohammad, F. S., Al-Hamed, S. A., & Alabdulkader, A. M. (2012). Reference evapotranspiration and date palm water use in the Kingdom of Saudi Arabia. International Research Journal of Agricultural Science and Soil Science, 2(4), 155-169.
[74] Al-Omran, A. O., Eid, S., & Alshammari, F. (2019). Crop water requirements of date palm based on actually applied water and Penman-Monteith calculations in Saudi Arabia. Applied Water Sci., 9(4), 69.
[75] Moioli, B., & Borghese, A. (2005). Buffalo breeds and management systems. Buffalo production and research. Rome: Food and Agriculture Organization of the UN, 51-76.
[76] Dang, Q.; Lin, X.; Konar, M. (2015). Agricultural virtual water flows within the United States. Water Resour. Res. 2015, 51, 973–986.
[77] Mubako, S.T.; Lant, C.L. (2013). Agricultural Virtual Water Trade and Water Footprint of U.S. States. Ann. Assoc. Am. Geogr. 2013, 103, 385-396.
[78] Tigrek, S., & Kibaroglu, A. (2011). The strategic role of water resources for Turkey. In Turkey's Water Policy (pp. 27-42). Springer, Berlin, Heidelberg.
[79] Ercin A.E. (2012) Governance of globalized water resources: The application of water footprint to inform corporate strategy and government policy, PhD Thesis, University of Twente.
[80] Bosire, C. K., Lannerstad, M., de Leeuw, J., Krol, M. S., Ogutu, J. O., Ochungo, P. A., & Hoekstra, A. Y. (2017). Urban consumption of meat and milk and its green and blue water footprints—Patterns in the 1980s and 2000s for Nairobi, Kenya. Science of the total environment, 579, 786-796.
[81] Ibidhi, R., Hoekstra, A. Y., Gerbens-Leenes, P. W., & Chouchane, H. (2017). Water, land, and carbon footprints of sheep and chicken meat produced in Tunisia under different farming systems. Ecological indicators, 77, 304-313.
[82] Hoekstra, A. Y. (2012). The hidden water resource use behind meat and dairy. Animal Frontiers, 2(2), 3-8.
[83] Mekonnen M.M., Hoekstra A.Y. (2011c) The green, blue and grey water footprint of farm animals and animal products. Volume 1: Main Report, UNESCO-IHE Institute for Water Education. UNESCO-IHE Institute for Water Education, The Netherlands.
[84] Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019c). Water Footprint of Wheat in Iraq. Water,

11(3), 535.

[85] Ye, Q., Li, Y., Zhuo, L., Zhang, W., Xiong, W., Wang, C., & Wang, P. (2018). Optimal allocation of physical water resources integrated with virtual water trade in water-scarce regions: A case study for Beijing, China. Water Research, 129, 264-276.

[86] Alwash, A. (2018). Towards Sustainable Water Resources Management in Iraq. The report, 45 p. Iraq Energy Institute. www.iraqenergy.org.

[87] 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

[88] Ewaid, S. H., Abed, S. A., Chabuk, A., & Al-Ansari, N. (2021). Water Footprint of Rice in Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 722, No. 1, p. 012008). IOP Publishing.Zabar, A., & Borowy, A. (2012). Cultivation of date palm in Iraq. Annales Universitatis Mariae Curie-Skłodowska. Sectio EEE, Horticultura, 22(1), 39-54.

[89] El-Juhany, L. I. (2010). Degradation of date palm trees and date production in Arab countries: causes and potential rehabilitation. Australian Journal of Basic and Applied Sciences, 4(8), 3998-4010.

[90] Al-Omran, A. O., Eid, S., & Alshammari, F. (2019). Crop water requirements of date palm based on actually applied water and Penman-Monteith calculations in Saudi Arabia. Applied Water Science, 9(4), 69.

[91] Alamoud, A. I., Mohammad, F. S., Al-Hamed, S. A., & Alabdulkader, A. M. (2012). Reference evapotranspiration and date palm water use in the Kingdom of Saudi Arabia. International Research Journal of Agricultural Science and Soil Science, 2(4), 155-169.

[92] Ali, A. S. A., and Hama, N. N. (2016). Integrated management for major date palm pests in Iraq. Emirates Journal of Food and Agriculture, 24-33.

[93] Xu, M., & Li, C. (2020). Application of the Water Footprint: Water Stress Analysis and Allocation. Springer.