Engineering, 2023, 15, 417-430
https://www.scirp.org/journal/eng
ISSN Online: 1947-394X
ISSN Print: 1947-3931

Virtual Water Trade and Food Security for Iraq

Nasrat Adamo[1], Nadhir Al-Ansari[2*], Varoujan Sissakian[3], Jan Laue[2], Salwan Ali Abed Al Khanfar[4]

[1]Consultant Engineer, Norrköping, Sweden
[2]Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, Lulea, Sweden
[3]Department of Petroleum Engineering, Komar University of Science and Technology, Sulaimaniyah, Iraq
[4]College of Science, University of Al-Qadisiyah, Al-Qadisiyah, Iraq

Email: nasrat.adamo@gmail.com, *nadhir.alansari@ltu.se, varoujan49@yahoo.com, jan.laue@ltu.se, salwan_ali2000@yahoo.com

How to cite this paper: Adamo, N., Al-Ansari, N., Sissakian, V., Laue, J. and Al Khanfar, S.A.A. (2023) Virtual Water Trade and Food Security for Iraq. *Engineering*, **15**, 417-430.
https://doi.org/10.4236/eng.2023.157032

Received: June 16, 2023
Accepted: July 18, 2023
Published: July 21, 2023

Abstract

Iraq depends on its water resources from the water of the Tigris and Euphrates Rivers and their tributaries. Now, the flow of these rivers is decreasing, and Iraq is experiencing a water shortage problem. The situation is expected to be graver in the future if no action is considered. It is expected that the population will be about 70 million in 2050 and about 90 million in 2070. In such a case, thus, the quantities of water available in the future will not be sufficient to produce most of the requirements of food security, whether that be from agricultural or animal products. To overcome this problem, water management planning should be based on scientific background to overcome the present and expected problems. One of the main factors to be considered should be based on scientific studies of the virtual water footprint of different food crops to provide the largest possible amount of virtual water and avoid the acute shortage of its national water from surface and ground irrigation water (blue water) and rainwater (green water), in addition to working hard to provide the largest possible amount of desalinated water and refined sewage (gray water). In addition, any strategic plan for sustainable development in the country must be comprehensive so that it is not satisfied with improving the situation in the field of food security related to water security, but rather among its other elements is community development that directly affects food security, including setting policies to reduce consumption by reducing the steady increase in population where the population rate is 2.97% now. Collective awareness and guidance programs in all the fields of water and food security are very important to be adopted, so that everyone knows that the issue of food security and what derives from it are an existential issue related to the survival of Iraq as a state and people. In this research, facts are stated so that action is to be considered to minimize the water shortage problem. The new strategic water resources management plan is to be adopted that considers existing and future expected problems.

Keywords

Virtual Water, Food Security, Iraq, Blue Water, Green Water, Grey Water

1. Water Scarcity and the Possibilities of Achieving Food Security

The food security of any country is commensurate with its capability to provide the necessary food for its people, whether by producing or importing it from other countries. Therefore, in such cases, sufficient water and financial resources are necessary to achieve this goal. For this reason, poor countries face great problems to realize this to avoid the risk of famine, especially in the case of scarcity of water resources or wasting those resources in the event of inefficient utilization. This means the dependence of such countries on foreign aid, whether from rich countries or international organizations, to secure the sustenance of their people and thus the dependence of their political decisions on what those external powers dictate on them. This matter has been the subject of debate in international conferences to contribute towards the development of sustainable solutions to this dilemma. It was even more highlighted by Professor Tony Allan from the Institute of Oriental and African Studies at the University of London, at the conference of the British Overseas Development Administration which convened in Southampton in July 1992 under the rubric "Priorities for Water Resources Allocation and Management", to shed light in this matter, especially in the countries of the Middle East and North Africa, which the researcher had taken as a subject of his research [1]. In this regard, we can mention some of the countries within this region that are rich in financial resources but poor in their water resources, such as the Kingdom of Saudi Arabia, which produces wheat at a cost that exceeds four to six times its price in the world market yet does not feel embarrassed by that at the present time at least, and as long as it has a surplus of oil revenues and until the non- renewable fossil groundwater resources used in this agriculture are depleted as a result of excessive withdrawal [2]. On the other hand, there are countries that are poor in their financial resources but at the same time are poor in their water resource such as Jordan, which finds itself compelled to seek help from the United States and other countries to adjust its balance of payments [3] [4]. Among the countries that are relatively rich in their water resources but becoming day after day incapable of meeting their food demands is Egypt, since agriculture will not be able to keep up with their needs in the future considering the huge population increase, especially if we know that its population will reach 160 million in 2050 from its level of 107 million at the end of 2022 [5]. Therefore, the best thing for Egypt to do, in addition to optimizing its water resources, is to increase the agricultural area by cultivating more desert land and maximizing its financial resources by strengthening its industrial base, especially in the clean energy sector and the production of green hydrogen which is already doing [6], and in outlook to practice "Virtual Water Trade" for sustainable development. This should be adopted in a new strategic water resources plan. The plan also should include adopting new irrigation techniques that have minimum water losses.

2. Virtual Water, Its Trade, and Other Related Concepts

In dealing with the question of "Virtual Water Trade", one must be familiar with the exact meaning and extent of this concept before trying to apply it to countries like Iraq, which will suffer from chronic scarcity in its water resources and atrophy in its agricultural areas in the future, in addition to its lagging in the field of industry and its increasing population. All these are underscored by the uncertainty of obtaining adequate financial resources from its oil exports in light of the fluctuations in global oil prices and economic depression in cases similar to the COVID-19 pandemic and or wars like the Ukraine War, and most importantly the world's abandonment in the near future of the use of fossil fuel in favor of clean energy sources dictated by the current policies of World governments in minimizing the negative impacts of global climate change. But first, what do we mean by "Virtual Water?"; this concept is a relatively recent one, and although current literature offers different definitions for it, we can summarize this as the "water that is latent or included in agricultural and industrial commodities; meaning that it is the water that is consumed in the chain of processes, which lead to their production" [7] [8] [9]. In other words, it is the water that people deal with indirectly through their daily consumption of various products and commodities without thinking or feeling about its existence. Based on this, the usage of the term "Virtual Water" has become commonplace today in conjunction with the term "Virtual Water Trade". Contrary to this is of course the "direct" water that we see, drink, and feel, whether its source is a stream, a lake, or rainfall, including the water that reaches us through municipal networks. In other words, it is the water needed to satisfy direct human consumption and/or required to perform an activity such as electric power generation and irrigation. From the foregoing, it follows that if a country exports a commodity whose production requires abundant water to another country; it is, in fact, exporting water to that country and by default is helping this other country in satisfying its water needs. Countries that suffer from water scarcity can make this "Virtual Water Trade" attractive to achieve water sufficiency and thus improve food security by importing water-intensive products instead of producing all water-consuming products locally. It follows that the expression "Virtual Water" has an intrinsic value in the "Virtual Water Trading" context as a way of solving the problem of water scarcity.

In seeking food security, it is feasible for countries that suffer from water scarcity to focus on virtual water trade by importing agricultural and animal food products rich in virtual water from countries that have abundant water, provided that their financial resources allow them to do so. Within the framework of "Virtual Water Trade", two questions have to be answered on the "Virtual Water" concept which concern food products. First, how should importing countries reckon their required food imports to ease their water scarcity problem and balance the deficit leading to better food security? And second one is how do exporting countries qualify to be net positive virtual water exporters while other countries remain only importers? To answer these questions the volume of "Virtual Water Trade" involved in this trade must be investigated at the start. For once the total magnitude of virtual water trade in the World as a whole has reached an extremely high value during the year 2021 where exports of virtual water have exceeded by far imports in countries while others remained as net importers. The United States, China, India and Brazil, in addition to Argentina, Canada, Australia, France, Germany, Italy and Indonesia are considered at the forefront of countries that achieved a surplus in virtual water trade even with the fact that the United States, Japan, China, Italy, Mexico, Italy, France, the United Kingdom and the Netherlands at the same time are big importing countries. In specific cases, we recall that Mexico, for example, has succeeded in saving the equivalent of twelve billion m^3 of its water resources annually by importing maize instead of producing it locally. On the other hand, net importing countries find examples in countries in the Middle East which had to import (85%) of their food needs. Specifically, Arab Gulf countries had to import (100%) of their needs of rice, (93%) of their grains, (62%) of the meat, and (56%) of their vegetables due to water shortage [10].

In all transactions of virtual water trading related to food products, quantifying water, and entering the importing and exporting operations is necessary, which refers to the total amount of water required to produce each of those products. This leads to the definition of the "Water Footprint" of those products as another useful concept in the context of the "Virtual Water Trade". In simple terms, the "Water Footprint" is the total amount of water consumed in the production of a crop over the course of its growth period, whether its source is surface water, groundwater, rainwater, or sometimes recycled sewage water, and even desalinated water, or a mixture of these sources. There is an agreement in water resources management literature to name surface and ground irrigation water as (blue water), and rainwater that actually goes for irrigation but not including excess surface runoff as (green water), while (grey water) is the water required for mixing with saline or recycled water to achieve the standard of water quality necessary for environmental uses [11] [12] [13] as stipulated in the ISO specifications (ISO 14046) [14].

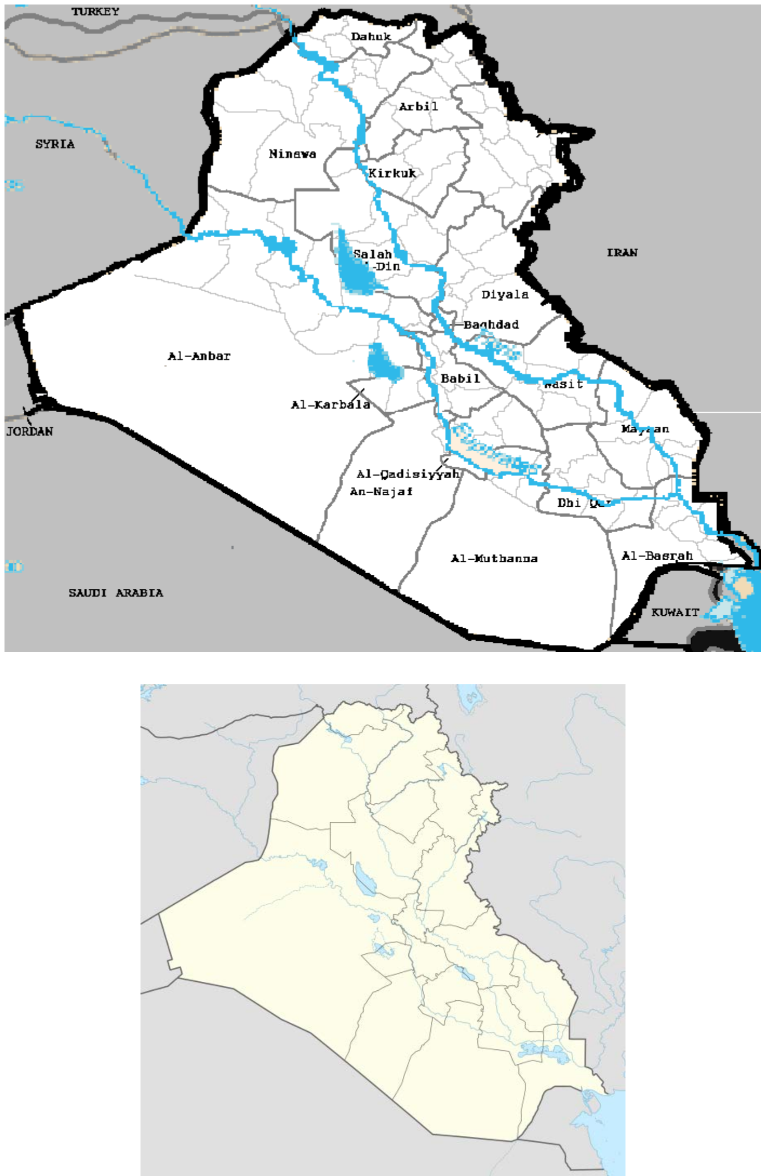
Naturally, the water footprint differs from one crop to another, as well as according to the country that produces that crop and its prevailing climate. If we take wheat that Turkey consumes annually as an example; according to 2020 statistics, we find that the total water footprint of this crop was equal to 47.9 billion m^3/year; from this water 38.9 billion m^3/year was water from inside Turkey, while the rest was virtual water imported from abroad, and therefore, 81% of the water used that had been consumed came from resources within Turkey, while the remaining 19%, amounting to 9.0 billion m^3/year was imported virtual water provided to Turkey by exporting wheat to it; 93% of which comes from Russia, Kazakhstan, Ukraine, the United States, Lithuania, Mexico and Canada. Noting that 98% of this water is green water (*i.e.*, from rainfall) [15]. On this basis, Turkey has profited from the point of view of virtual water trade since it has saved part of its national waters, which could be used for other purposes.

3. Iraq and Virtual Water Trade in the Perspective of Food Security

Let us now study a case like Iraq. Iraq is in the Middle East (**Figure 1**). The population is about 40 million and it relies in its water on the flow of the Tigris and Euphrates rivers and their tributaries. The irrigated area reaches 35,250 square kilometers Wikipedia:
https://en.wikipedia.org/wiki/List_of_countries_by_irrigated_land_area (**Figure 2**).

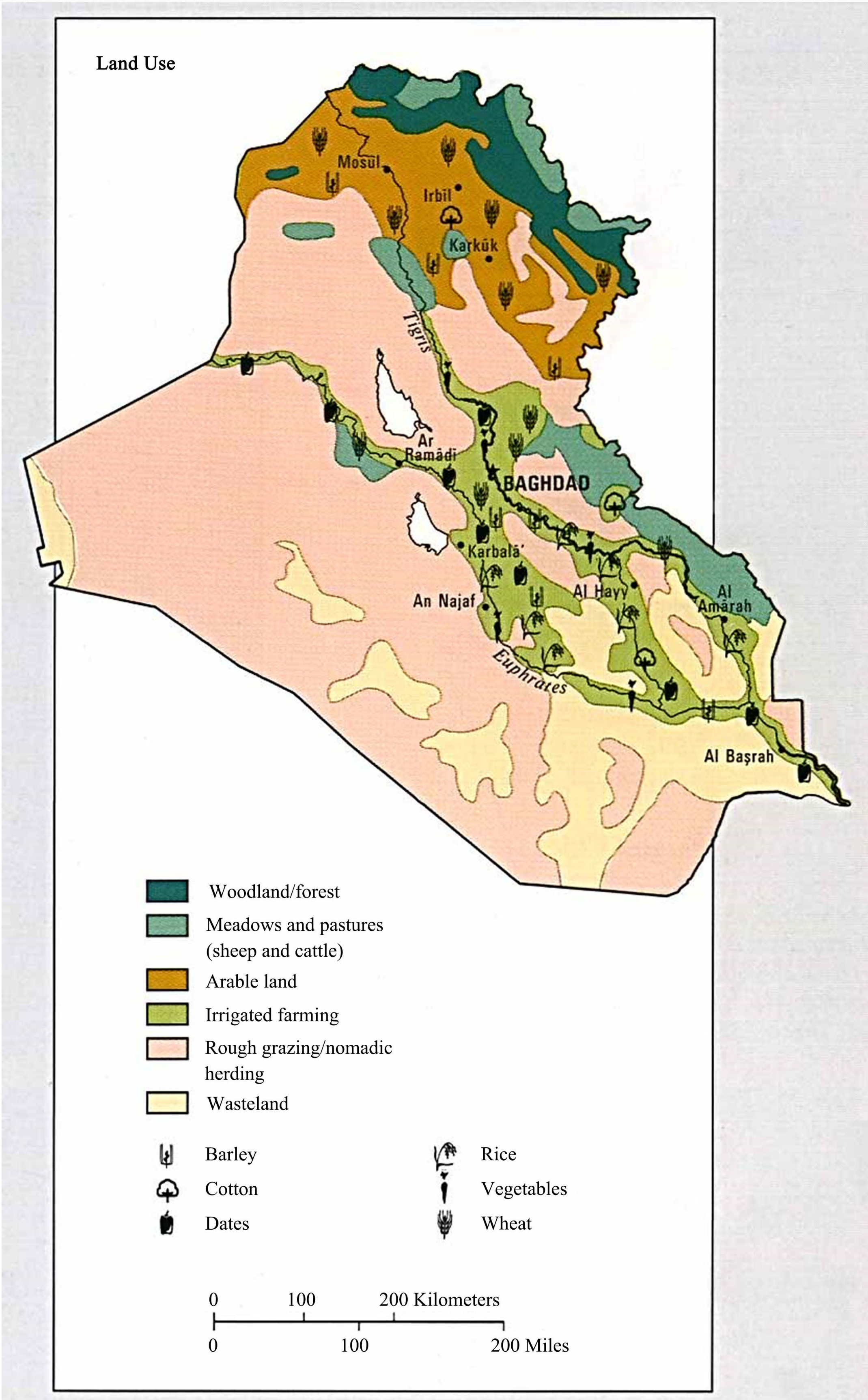
The important question here is what virtual water trade can provide to Iraq's food security, and if this trade offers a complete solution to the issues of expected water scarcity and food security in the future. Or should this matter be considered as just one element of a set of actions that must be part of a comprehensive plan for the management of water resources? In answer to this, we consider that the adoption and application of "Virtual Water Trade", and the concepts of "Water Footprint" are necessary to produce some of the strategic crops such as wheat, barley, and corn and this is becoming an urgent matter for Iraq to secure food security for the Iraqi population in the future. This is due to two important facts; first, the water crisis that the country is witnessing now which will worsen in the future as a result of shortage of water inflows of the Tigris and Euphrates rivers due to the policies of neighboring countries, coupled with the effects of global climate change of which Iraq's share has been severe droughts, second; the expected increase in population in the future. As the current number of people (2022) amounting to 42.6 million people will become 70.94 million in the year (2050) to reach 89.54 million people in the year (2070) [16], and thus the quantities of water available in the future will not be sufficient to produce most of the food security requirements, whether it is agricultural or animal products. On this basis, it is necessary that future water resource management plans in Iraq must be based on scientific studies of the "Virtual Water Footprint" of the various food crops to provide the largest possible amount of "Virtual Water" and avoid the acute shortage of its national water from all blue, and green resources, and doing the utmost to provide the largest possible amount of desalinated water and recycled sewage (gray water). Moreover, agricultural planners are required to exclude all crops with high water footprints from future agricultural plans in Iraq and encourage the import of these crops from water-rich countries, thus saving large amounts of virtual water and preventing waste of such quantities of national water resources that can be exploited in other basic sectors and having as a goal ensuring the minimum level of food security required. Perhaps the cultivation of rice in Iraq is the clearest example that can

(a)



(b)

Figure 1. Location of Iraq. (a) Location of Iraq within Middle East; (b) Maps of Iraq showing the main two rivers.


Land Use
Mosul
Irbil
Karkūk
Tigris
Ar Ramādī
BAGHDAD
Karbalā'
An Najaf
Al Hayy
Al Amārah
Euphrates
Al Başrah
Woodland/forest
Meadows and pastures (sheep and cattle)
Arable land
Irrigated farming
Rough grazing/nomadic herding
Wasteland
Barley
Cotton
Dates
Rice
Vegetables
Wheat
0 100 200 Kilometers
0 100 200 Miles

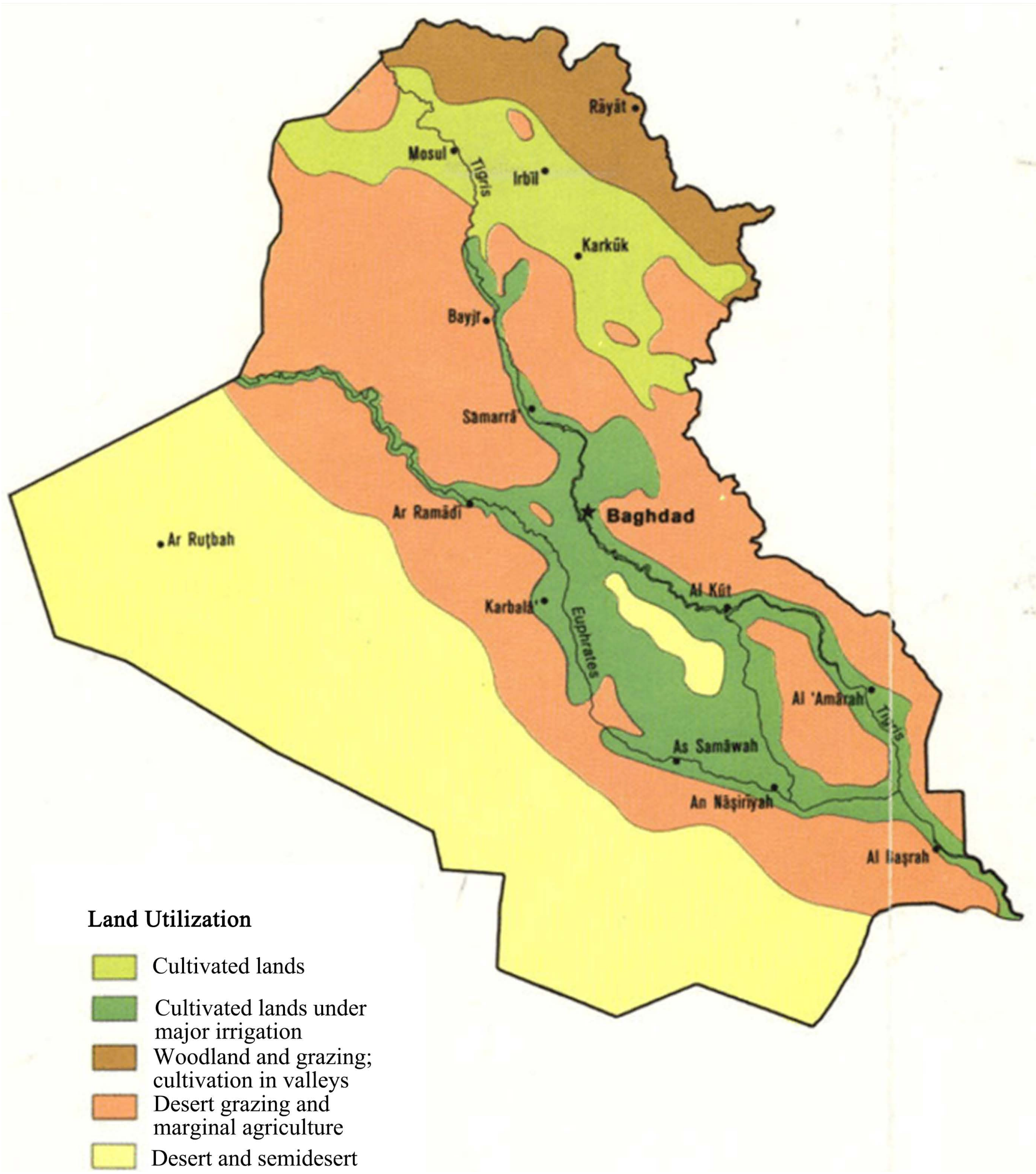


Figure 2. Land utilization in Iraq.

be taken as an example of this. In one scientific study, results have shown that rice water footprint in seven Iraqi governorates in 2017 averaged (3072) cubic meters of water/ton, compared to the global average of (1325) cubic meters of water/ton in order to produce (265,852) tons, which are equivalent to 820 million cubic meters of (blue) water in absolute absence of (green) water since rice is one of Iraq's summer crops, and its cultivation is done at complete absence of rainfall [17]. By simple calculation, this means, in view of the population growth and the continuation of the same current pattern of rice consumption, there will be needed for 1.72 billion cubic meters of (blue) water to produce the required quantity of this crop in 2070 when this volume of water will not be available for cultivation of this crop considering the dwindling water resources in the future

[18]. Scientific research indicates that water stress in Iraq will increase from 3.48 points (high stress) in the year of measurement (2013) to 4.66 points (excessive stress) in the year (2040) [19]. Therefore, it is necessary and logical to reduce or completely prevent rice cultivation in Iraq and import it from other countries, or even to buy farms specialized in cultivating Iraqi varieties in other countries. Iraq had rice and tea plantations in Vietnam and Sri Lanka at the end of the last century [20]. Another study on the average water footprint calculated for the years 2007-2016 for five main agricultural crops in fifteen Iraqi governorates supports the necessity of this approach: a summary of the results is given in **Table 1**. This table indicates that the average water footprint of rice was 3694 cubic meters/ton, which confirms what is already being mentioned above, especially since all this water is (blue) except for 10 cubic meters/ton which is (green) which constitutes severe pressure on irrigation water in summer. The study also reached similar results for another summer crop, which was maize. It shows that the irrigation water needed by this crop (blue) is 9096 cubic meters/ton, and its consumption of rainwater (green) is only 288 cubic meters/ton. These figures support treating this crop in the same way as rice and importing it from other countries and thus saving the country's own virtual water [21].

In differentiating between different crops, it may be appropriate to focus on strategic crops judged by their relatively moderate or low water footprint that achieve food security at a minimum level to fill part of the need for food security and avoid the risk of famine in cases of war and political unrest and at the same time do not exhaust the scarce national water resources (note **Table 1**), while at the same time adopting virtual water trade as a cornerstone of the country's water resources management and trade exchanges policies. On this basis, it is necessary to encourage the cultivation of wheat and barley, provided that this is done using modern irrigation techniques, *i.e.*, supplementary irrigation using sprinklers; whether north of the 200 mm isohyet or even in the central and southern regions below this line, while the remaining needed quantities can be

Table 1. Average values for years (2007-2016) of five major crops in Iraq showing the cultivated areas and the amount of yield in addition to the amounts of irrigation water used for each of these crops with the water footprint of the annual total production and the water footprint of each crop [21].

Crop	Planted Area	Production		Crop Water Use (m^3/ha)			WF of Production (Mm^3/yr)			Water Footprint (m^3/ton)		
	ha	ton/yr	ton/ha	Green	Blue	Total	Green	Blue	Total	Green	Blue	Total
Wheat	1,786,235	3,036,882	1.700	1257	1181	2438	2,707,073,151	2,563,931,419	5,271,004,570	891	844	1736
Barley	623,666	833,815	1.336	1203	1119	2322	953,170,654	522,128,613	1,475,299,267	1143	626	1769
Rice	68,897	269,970	3.918	717	13.127	13,199	2,692,008	994,531,633	997,223,641	10	3684	3694
Maize	123,678	366,523	2.963	288	9.096	9384	25,292,837	794,944,139	820,236,976	69	2169	2238
Total	2,602,476			3465	2322	27,343	3,688,228,650	4,875,535,804	8,563,764,454			

imported from such countries with wheat of a high green water footprints such as Canada, the United States and the Ukraine. In the same sense, it would be better to encourage the cultivation of summer crops with low water footprints such as beans (543 m^3 water/ton), tomatoes (171 m^3 water/ton), potatoes (314 m^3 water/ton), as well as cauliflower, eggplant, and onions whose water footprints do not exceed (100 m^3 water/ ton). These principles should be applied also to animal food products. It is noted that livestock meat and dairy products have very high-water footprints, which are five to twenty times greater than the water footprint of agricultural crops since the water footprint of fodder is relatively high. As a fact, the average world beef water print is almost (13,000 m^3 water/ton), and the water footprint of cheese is (5000 m^3 water/ton) [22]. Statistics from the United States of America indicate the water footprint of beef of about (15,000 m^3 water/ton) and pork (10,000 m^3 water/ton), while for poultry it is around (4000 m^3 water/ton) [23]. On the other end of the scale, all types of marine, river and lake fish have water footprints equal to zero since they do not consume any amount of water. Fish farming, on the other hand, can contribute to very high-water losses through evaporation, especially in dry and hot climates such as that of Iraq. On these bases, Iraq has to improve the ways and means of meat production by limiting large scale breeding and fattening of calf farms, as well as encouraging lamb meat production by extension of natural pastoral and grazing areas and stop overgrazing. Any deficits in the available biomass may be rectified by adopting "Virtual Water Trading" principals by importing from countries such as Brazil, Argentina, India and New Zealand; at the same time, to focus on the production of poultry meat and on marine and river fishing industries eliminating all unlicensed random fish ponds and preventing the establishment of new one in the future since they drain huge quantities of valuable water through evaporation and encroach on the water quotas of important agricultural projects.

From the foregoing, it is necessary to stress that "Virtual Water Trade" cannot be the sole solution to the various issues of food security in Iraq. It should be emphasized that proper planning in this trade should be observed to strike a balance between Iraq's imports of food and what it can produce to relieve its political decisions from any external pressures. Moreover, in view of the strong connection between food security and water availability, rational water strategies must be adopted in which Iraq controls and maximizes all of its water resources by curbing any negligence or wasteful practices, adopting rational and optimal uses, and at the same time developing non-traditional water resources through desalination of drainage water, recycling of wastewater and rainwater harvesting as well as working to obtain fair shares of the Tigris and Euphrates river waters which have been unjustly overtaken by the riparian countries.

4. Conclusion

Iraq is suffering from water resources shortage problem due to the decrease in flow of the main rivers and their tributaries. To overcome this problem, the new water resources long-term water management strategy is to be adopted that considers existing and future expected problems. In such a strategy, scientific agricultural planning is to be put into practice so that some high-water consuming plants are to be restricted and others to be forbidden from plating. Existing irrigation systems are to be completely abandoned because water losses are very high and new irrigation techniques with low water losses are to be used. Non-conventional water resources are to be used like rainwater harvesting, wastewater treatment and reuse for agriculture and desalinization of salty water. The public awareness program is to be put into practice so that individuals know how to act to save water.

5. Recommendations

1) Food security of Iraq is closely linked to its water security. This must be taken into consideration in any strategy for sustainable development in the country, whether for the near or long-term. It is possible to adopt "Virtual Water Trade" as an important element in these strategies since it contributes to reducing the deficit between available water and actual needs to produce the necessary food products; therefore, eliminating the possibility of famine or relying on external aid to this end. This requires first classifying food products according to their water footprints then adopting crops and products with moderate and low water footprints and excluding those with high water footprints from agricultural planning. At the same time, concentrate on saving as much "Virtual Water" as possible by importing products with high water footprints and adopting this policy as a routine approach in this context.

2) The policy can never be considered, however, as the sole solution for the water scarcity problem in the country. The government and all its agencies are called upon to make every effort possible to maintain and develop the national water resources within the country. Among other things, the present unfair exploitation of the Euphrates River by the other riparian countries must be ended, and Iraq's fair share must be secured. In this respect, we would like to suggest the adoption of diplomacy of (water versus cooperation) since Iraq has much to offer in advancing mutual security issues and trade; having in view that Iraq's imports from these countries amount to tens of billions of dollars every year. Internally, strong government actions are necessary to stop all sorts of wasteful use of water through much better water management that consists of modernizing the present old and inefficient irrigation methods and systems to up-to-date international standards and stopping the irresponsible use of water by some users; being farmers or government or other private concerns, which cause rivers pollution and degrading water quality. The force of law shall be utilized relentlessly by enacting deterrent laws and applying them strictly to all abusers. Moreover, Water must be considered also an essential economic commodity, the same as any other production element, which has a remunerative price, therefore, consumption must be metered and charged in an escalation fashion according to the

volume used, the same as electrical power. At the same time, developing available non-traditional resources to the maximum extent possible through desalination of brackish water and recycling wastewater using solar energy, in addition to expanding the extent of rainwater harvesting to develop groundwater reserves while at the same time preventing their overuse.

3) Any strategic plan for sustainable development throughout the country will have to be comprehensive and not be restricted to improving food security aspects related to the water sector alone, but it must have other elements, which are concerned with community development that affect food security either directly or indirectly including policies of reducing consumption. One such element is addressing the very high population growth rate in the country which ranks among the highest in the world. The steady population growth rate of Iraq in the period (2012-2021) has reached an average of (2.97%) annually, compared with other countries such as China (0.49%) and India (1.09%). These countries have resorted to imposing birth control policies to prevent starvation and provide enough food for their populations [24], which, in the writers' opinion may be considered for Iraq". In the same context, efforts must be made for radical changes in the dietary habits of individuals and groups to reduce the extravagance and waste observed in some wealthy classes of society compared to others that are less fortunate. It also requires the use of alternative products in daily meals; one example is encouraging the consumption of potatoes as an alternative to rice, thus maintaining the same level of required calories.

4) Finally, it may be said that perhaps one of the most important goals that any social development plan shall pursue, with or without "Virtual Water Trade", is to guide and heighten collective awareness of all the matters to convince everyone that food security and other related issues are existential concerns pertaining to the survival of Iraq as a state and a nation. This work is a responsibility to future generations that falls upon the shoulders of the government, the media, and NGOs in addition to all enlightened citizens.

Acknowledgements

Lulea University of technology gratefully supported this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Allen, T. (1992) Fortunately There Are Substitutes for Water: Otherwise, Our Hydro-Political Futures Would Be Impossible. *Proceedings of the Conference on Priorities for Water Resources Allocation and Management*, Southampton, July 1992, 13-26. https://www.ircwash.org/sites/default/files/210-93PR-11967.pdf

[2] USGS (2016) Earth View-Saudi Wheat Experiment Relied on Fossil Water. https://www.usgs.gov/news/science-snippet/earthview-saudi-wheat-experiment-reli

ed-fossil-water

[3] Arabic CNN (2018, December 4) America Increases Economic Aid to Jordan in 2018 by 57%.
https://arabic.cnn.com/business/article/2018/12/05/jordan-usa-economic-economic-development-projects-education-healt-budget-deficit

[4] Al Daraawi, U. (2023, January 18) American Aid to Jordan. Al Ghad News Paper.
https://alghad.com/%D8%A7%D9%84%D9%85%D8%B3%D8%A7%D8%B9%D8%AF%D8%A7%D8%AA-%D8%A7%D9%84%D8%A3%D9%85%D9%8A%D8%B1%D9%83%D9%8A%D8%A9-%D9%84%D9%84%D8%A3%D8%B1%D8%AF%D9%86

[5] The World Counts. The Population of Egypt Is Expected to Increase from 102 Million People in 2020 to 121 Million in 2030, 160 Million in 2050, and 225 Million in 2100. https://www.theworldcounts.com/populations/countries/egypt

[6] The Seventh Day (Arabic) (2022, November 11) Egypt Leads the World in the Production of Green Hydrogen to Preserve the Environment.
https://www.youm7.com/story/2022/11/11/%D9%85%D8%B5%D8%B1-%D8%AA%D8%AA%D8%B5%D8%AF%D8%B1-%D8%A7%D9%84%D8%B9%D8%A7%D9%84%D9%85-%D9%81%D9%89-%D8%A5%D9%86%D8%AA%D8%A7%D8%AC-%D8%A7%D9%84%D9%87%D9%8A%D8%AF%D8%B1%D9%88%D8%AC%D9%8A%D9%86-%D8%A7%D9%84%D8%A3%D8%AE%D8%B6%D8%B1-%D9%84%D9%84%D8%AD%D9%81%D8%A7%D8%B8-%D8%B9%D9%84%D9%89-%D8%A7%D9%84%D8%A8%D9%8A%D8%A6%D8%A9/5972688

[7] Frontier Economics (2008, January) The Concept of "Virtual Water"—A Critical Review. A Report Prepared for the Victorian Department of Primary Industries.
https://www.frontier-economics.com.au/documents/2014/06/concept-virtual-water-critical-review.pdf

[8] Horlemann, L. and Neubert, S. (2008, December) Virtual Water Trade—A Realistic Concept for Resolving the Water Crisis. German Development Institute, Bonn.
https://www.gwp.org/globalassets/global/toolbox/references/virtual-water-trade.-a-realistic-concept-for-resolving-the-water-crisis--neubert--s.-2007.pdf

[9] Yang, H. and Zehnder, A. (2007) Virtual Water: An Unfolding Concept in Integrated Water Resources Management. *Water Resources*, **43**, W12301.
https://www.eqb.state.mn.us/sites/default/files/documents/VirtualWater2007WR006048.pdf
https://doi.org/10.1029/2007WR006048

[10] Shanker, M. (2022) Virtual Water Trade. Maithri Aquatech.
https://www.maithriaqua.com/post/virtual-water-trade

[11] Zhuo, L. Water Footprint. Scholarly Community Encyclopaedia.
https://encyclopedia.pub/item/revision/0ef372829524af16427676a0a0875baa

[12] Hoekstra, A.Y., Mekonnen, M.M., Chapagain, A.K., Mathews, R.E. and Richter, B.D. (2012, February 29) Global Monthly Water Scarcity: Blue Water Footprints versus Blue Water Availability. *PLOS ONE*, **7**, e32688.
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0032688
https://doi.org/10.1371/journal.pone.0032688

[13] Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) The Water Footprint Assessment Manual—Setting the Global Standard. Earthscan, London, 2.
https://waterfootprint.org/media/downloads/TheWaterFootprintAssessmentManual_2.pdf

[14] ISO Online Browsing Platform (IOB). ISO 14046: 2014.

https://www.iso.org/obp/ui/#iso:std:iso:14046:ed-1:v1:en

[15] Muratoglu, A. (2020) Assessment of Wheat's Water Footprint and Virtual Water Trade: A Case Study for Turkey. *Ecologic Processes*, **9**, Article No. 13. https://ecologicalprocesses.springeropen.com/articles/10.1186/s13717-020-0217-1 https://doi.org/10.1186/s13717-020-0217-1

[16] Statistics Times (2021, August 23) Population of Iraq. https://statisticstimes.com/demographics/country/iraq-population.php

[17] Ewaid, S.H., Abed, S.A., Chabuk, A. and al-Ansari, N. (2021) Water Footprint of Rice in Iraq. *IOP Conference Series: Earth and Environmental Science*, **722**, Article ID: 012008. https://iopscience.iop.org/article/10.1088/1755-1315/722/1/012008/pdf https://doi.org/10.1088/1755-1315/722/1/012008

[18] Al-Ansari, N., Ali, A. and Knutsson, S. (2014) Present Conditions and Future Challenges of Water Resources Problems in Iraq. *Journal of Water Resource and Protection*, **6**, 1066-1098. https://doi.org/10.4236/jwarp.2014.612102 https://www.diva-portal.org/smash/get/diva2:977582/FULLTEXT01.pdf

[19] Martens, M. (2017) Food and Water Security in the Middle East and North Africa. NATO Special Parliamentary Assembly Special Report, Table 4. https://www.nato-pa.int/download-file?filename=/sites/default/files/2017-11/2017%20-%20176%20STC%2017%20E%20bis-%20FOOD%20AND%20WATER%20SECURITY%20MENA%20-%20MARTENS%20REPORT.pdf

[20] al-Baynna al-Jadeda (2020, November 25) Ministry of Trade Reveals the Secretes of Its Tea Plantations in Vietnam and Its Factories Abroad. No. 26616. (In Arabic) https://www.facebook.com/people/%D8%AC%D8%B1%D9%8A%D8%AF%D8%A9-%D8%A7%D9%84%D8%A8%D9%8A%D8%A7%D9%86-%D8%A7%D9%84%D8%AC%D8%AF%D9%8A%D8%AF/100063833003586/?paipv=0&eav=AfY4lz9u4dbam2UzQRn7pfu9BOojVr1nCc8vi_qKt1p0VTbZ3orjDxhsvUJSzFSloDk&_rdr

[21] Ewaid, S.H., Abed, S.A. and al-Ansari, N. (2020, January 9) Assessment of Main Cereal Crop Trade Impacts on Water and Land Security in Iraq. *MDPI, Agronomy Journal*, **10**, Article No. 98. https://www.mdpi.com/2073-4395/10/1/98 https://doi.org/10.3390/agronomy10010098

[22] Al-Babily, D. (2020, August 10) Virtual Water between Food Security and World Trade. https://www.agri2day.com/2020/08/10/%D8%AF-%D8%B9%D9%84%D8%A7%D8%A1-%D8%A7%D9%84%D8%A8%D8%A7%D8%A8%D9%84%D9%8A-%D9%8A%D9%83%D8%AA%D8%A8%D8%A7%D9%84%D9%85%D9%8A%D8%A7%D9%87-%D8%A7%D9%84%D8%A7%D9%81%D8%AA%D8%B1%D8%A7%D8%B6%D9%8A%D8%A9

[23] Smil, V. (2008, September-October) Water News: Bad, Good and Virtual. *American Scientist*, **96**, Article No. 399. https://doi.org/10.1511/2008.74.399 https://www.americanscientist.org/article/water-news-bad-good-and-virtual

[24] Population Development in Iraq since 1960. https://www.worlddata.info/asia/iraq/populationgrowth.php