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Effect of Virtual Water Trade of Agricultural Crops on the Water Situation in Egypt

Abdul Azim Mohamed Mustafa[1], Enas Al-Sayed Sadiq[1], Waheed Mohamed Al-Bulouni[2] and Nermeen Mohamed Nasr[3]

[1] Professor of Agricultural Economics, Faculty of Agriculture, Fayoum University, Egypt.
[2] Head of Research at the Agricultural Economics Research Institute, ARC, Egypt
[3] Assistant Researcher at the Agricultural Economics Research Institute, ARC, Egypt
elzabalawim@gmail.com

Abstract: The research aimed at analyzing the effect of virtual water trade in agricultural crops on the Egyptian water situation, by calculating the volume of virtual water trade for the most important exported and imported agricultural crops in the Egyptian agricultural trade balance, and studying the apparent and real status quo of water resources and their uses in Egypt, in addition to the average per capita share The apparent and true of water and water density index. As it became clear that the increase in water needs significantly, with the stability of the quantity of the main water resource in Egypt at 55.5 billion m3, which is represented in the Nile River, has led to an increase in the water deficit in 2017 to about 20.75 billion m3, an increase of about 13.70% for a year 2010, amounting to about 18.25 billion m 3. It turns out that the average water footprint resulted from the addition of the net virtual water imported of the various agricultural crops during the period (2010-2017) has reached 77.80 billion m 3, and for the water scarcity index it has reached about 84.19% of the average period, with an annual shortage rate of about 0.7% proven statistically significant At 0.01. The average of the indicators of water dependency and self-sufficiency in water during the average of the same period was about 18.34%, 81.66% for each, respectively. The study dealt with measuring the average per capita share of the virtual and real water, and it was found that for the apparent per capita share of water, it reached about 889.09 m 3 per capita for the average period, with an annual deficiency rate of about 1.8%, its significance proved statistically at 0.01%. It turned out that the real per capita share of water exceeds the virtual per capita share of water by about 19.20% for the average period, reaching about 1058.69 m 3 per capita. The virtual and real water density index was calculated, and the results indicated that the agricultural sector is responsible for 81.51% of the total water use, while its output contributes only 11.69% to the GDP. After adding net virtual water flows as one of the water consuming sectors, the agriculture sector became responsible for 62.94% of the total water use. Therefore, the water intensity index in Egypt for the year 2017 before and after adding the net default water flows becomes 22.36 million m3 / million pounds, 28.96 million m3 / million pounds each, respectively.

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1. Introduction:

The water resources in the Arab region are generally scarce, either in absolute terms, in terms of the low average per capita share, or in relative terms compared to other regions of the world, where the Arab region is considered one of the poorest regions in the world in water resources, and it is also characterized by its Geographically poorly distributed and the difficulty of exploiting the available Among them, moreover, this scarcity worsens at all levels over time, and accordingly water resources are the main determining factor for agricultural production in the Arab world in general and Egypt in particular today and in the future (Al-Anany, 2013).

The water needs have increased significantly, with the stability of the amount of the main water resource in Egypt at 55.5 billion m3, which is represented in the Nile River, where the amount of water needs reached about 76.25 billion m3, with a deficit of about 20.75 billion m3, this deficit is met by other sources such as groundwater, rain, torrents, seawater desalination, and agricultural and sanitation wastewater recycling. Water needs will increase very significantly in the coming years, as a result of rapid population growth and a large concentration of population in urban areas. The most seriously is, climate change and its impact on the low level of water resources. With the increasing demand for water for use in various sectors, increasing the water supply from these sources will become insufficient to solve the problem of the gap between supply and demand for water.

Consequently, the field of water resources management has become the ideal solution for managing water demand and maintaining its use. One of the most important tools used in demand management is the concept of virtual water. Virtual Water is the amount of water that is used to produce a unit of plant, animal or industrial commodity and prepare it for consumption (Zimmer, 2003). (Virtual water trade indicates that imported or exported goods include water, when a country imports a ton of wheat, in this case as if it provided water Necessary to produce this ton of wheat locally.

The Problem of the study:

The problem of the study showed the growing gap between the supply of demand and with the increase in population and the increase in water needs, which led to a decrease in the per capita share of fresh water as it reached about 764.79 m 3 (CAPMAS, 2018. CAPMAS, 2019) per capita in 2017, which is less than the water poverty level estimated at 1000 m 3 per person (Mohamed et al, 2019). The agricultural sector is the largest consumer of water in Egypt, accounting for about 81.5% of total uses in the same year (CAPMAS, 2018). Consequently, water is the main impediment to agricultural development, as the availability of fresh water has become important.

Objectives of the study:

The research aimed to “analyze the effect of virtual water trade in agricultural crops on the Egyptian water situation”, by: calculating the volume of virtual water trade for the most important agricultural crops exported and imported in the Egyptian agricultural trade balance, and studying the virtual and real status quo of water resources and their uses in Egypt, in addition to an average Virtual and real water per capita and water density index.

2. Methodology and Data Sources:

The study relied on descriptive and quantitative methods of secondary data published and unpublished that could be collected, which were obtained from various bodies such as the Central Agency for Public Mobilization and Statistics, and the Economic Affairs Sector of the Ministry of Agriculture and Land Reclamation, in addition to websites such as the FAO site, In addition to references, research and reports related to the field of study.

The virtual water content of the exported and imported crops has been estimated in the Egyptian agricultural trade balance, and the virtual water quantities generated through export and import have been estimated. Some indicators such as the Water Footprint indicators, Water Scarcity, Water Dependency, Water Self-sufficiency, and Water Intensity Indicator were used.

3. Results:

First: Net inflows of virtual water trade in the Egyptian agricultural trade balance:

The water needs per ton of each crop were calculated, and then virtual water trade flows were calculated by multiplying the crop trade flow in its virtual water content. The latter depends on the demand for water from the exporting country that produced it. The virtual water trade is calculated as follows (Hoekstra and Hung. 2002):

$$VWT = CT * SWD$$

Where:

VWT: is the virtual water trade from the exporting country to the importing country resulting from the trade of a particular crop (m3).

CT: Trade the crop from the exporting country to the importing country (tons).

SWD: The crop demand of water in the exporting country (m3 / ton)

The above equation assumes that if a particular crop is exported from a specific country, then this crop is actually cultivated in that country (and not in another country from which the crop was imported for supply).

The balance of a country is calculated from the virtual water trade balance by the difference between the net import of virtual water trade and the net virtual water trade of exports.

In order to calculate what is actually saved from water through import, crops that are not suitable for cultivation in Egypt* are excluded, as their import does not represent providing the water necessary for their cultivation.

Table No. 1 illustrates the development of Egypt's balance of virtual water trade during the period (2010-2017). It is clear from the calculations of net virtual water trade from crops that all results are positive, that is, there is a surplus of virtual water estimated at 14.14 billion m 3 for the average period, and that surplus reached a maximum in 2017 of 22.16 billion m 3, and below in 2012 by 7.7 billion m 3.

Second: The apparent and real water situation in the Arab Republic of Egypt:

The Egyptian lands include the following basins (FAO, 2019): The Northern Interior Basin, which covers 520 881 km2 or 52% of the total area of the country, and a sub-basin of the Northern Interior Basin is the Qattara Depression. The Nile Basin, which covers 326,751 km2 or 33%, is located in the central part of the country in the form of a wide section from north to south. The Mediterranean Coast Basin, which covers 65,568 km 2 or 6%. And finally the Northeast Coast Basin, a narrow strip of 88,250 km2 along the Red Sea coast, or 8%.

Table (2) shows the amount of water resources available in Egypt, according to the source in the years 2010, 2017, as it is clear from the table that Egypt's share of the Nile water remains stable during that period, which is 55.5 billion cubic meters of water, and an increase in both groundwater in the valley and the delta The recycled agricultural wastewater and water from seawater desalination is about 0.4, 2.81, 0.04 billion cubic meters each, respectively, with a rate of about 6.15%, 30.91%, and 66.67% each, respectively.

The same table shows a decrease in both recycled wastewater, rain water and torrents by approximately 0.10 and 0.65 billion cubic meters each, with a decrease of about 7.69% and 50% each, respectively.

An increase in the total amount of available water resources in Egypt in general was shown to increase by about 3.39% during the same period, by 2.5 billion cubic meters of water.

The same table shows the relative distribution of water resources available in Egypt according to the source in 2017, and Egypt's share of Nile water represents about 72.74% of the total available water resources, followed by each of the recycled agricultural wastewater and groundwater in the valley and the delta with 15.6%, 9.04% each Respectively, followed by recycled wastewater, rain and torrential water, and seawater desalination by 1.57%, 0.85%, and 0.13% each, respectively.

Table No. (1): Egypt's balance of virtual water trade during the period (2010-2017) Million m^3

Years	virtual water trade for exports	virtual water trade for imports (1)	virtual water trade for imports (2)	virtual water trade balance (1)	virtual water trade balance (2)	rate of change%
2010	2517	14627	14375	12110	11858	-2.08
2011	1614	20059	19906	18445	18292	-0.83
2012	1296	9281	8992	7985	7696	-3.62
2013	3126	15680	15107	12554	11981	-4.56
2014	1684	12755	12299	11071	10615	-4.12
2015	1983	14716	14436	12733	12453	-2.20
2016	2313	20662	20398	18349	18085	-1.44
2017	2876	25363	25036	22487	22160	-1.45
Average	2176	16643	16319	14467	14143	-3
growth rate %	4 (0.702)-	602 (1.798)-	602 (1.798)-	6.6 (1.858)-	6.7 (1.763)-	

(1) Imports include all imported crops.
(2) Imports are excluded from crops that are not cultivated in Egypt.
Where: The numbers in parentheses below the value of the growth rate in the table indicate the calculated value (F).
**significant 0.01 level. * significant at the level of 0.05. Not significant
Source: collected and calculated from:
- Central Agency for Public Mobilization and Statistics, annual bulletin of production and foreign trade movement available for consumption of agricultural commodities, Cairo, various issues.
- Annual Bulletin of Irrigation and Water Resources Statistics, Central Agency for Public Mobilization and Statistics, various issues.

Table No. (2): The quantity of water resources available in Egypt according to the source for the years 2010, 2017 Billion m 3 / year

Source	2010	%	2017	%	Change Rate
Share of Nile River water	55.50	75.20	55.50	72.74	-
Groundwater in the valley and the delta	6.50	8.81	6.90	9.04	6.15
Recycling agricultural wastewater	9.09	13.32	11.90	15.60	30.91
Waste water recycling	1.30	1.76	1.20	1.57	-7.69
Rain and Flood	1.30	1.76	0.65	0.85	-50.00
Seawater Desalination	0.06	0.08	0.10	0.13	66.67
Total	73.80	100	76.30	100	3.39

Source: Collected and calculated from data: Central Agency for Public Mobilization and Statistics, Egypt Bulletin in Figures, Cairo, March 2017 Issues, March 2019.

Table No. (3) shows the distribution of the amount of available water resources among the different water uses in Egypt in 2010 and 2017, and it is clear from the table that the amount of water destined for industry during this period is stable, at about 1.2 billion cubic meters. And an increase in the amount of water directed to the rest of the uses by 2.05% for agriculture, 8.9% for drinking, and an increase in the amount of waste evaporation from the Nile and canals by 19.05%.

Table No. (3): Water uses in Egypt in 2010 and 2017Billion m 3 / year

Source	2010	%	2017	%	Change Rate
Agriculture	60.90	82.52	62.15	81.45	-2.05
Evaporation from the Nile and canals evaporation	2.10	2.85	2.5	3.28	-19.05
drinking water	9.55	12.94	10.4	13.63	-8.90
Industry	1.20	1.63	1.2	1.57	-
Total	73.80	100	76.3	100	-3.39

Source: Collected and calculated from data: Central Agency for Public Mobilization and Statistics, Egypt Bulletin in Figures, Cairo, March 2017 Issues, March 2019.

The same table shows the relative distribution of water uses in Egypt in 2017, as it turns out that agriculture alone represents 81.45% of the total water uses, followed by drinking water by 13.63%, followed by each of the lost water by evaporation from the Nile and canals and water destined for industry by 3.28%, 1.57% For each of them respectively.

It is clear from the previous offer that the increase in water needs significantly, with the stability of the amount of the main water resource in Egypt at 55.5 billion m3, which is represented in the Nile River, has led to an increase in the water deficit in 2017 to about 20.75 billion m3, an increase of about 13.70% For the year 2010, amounting to about 18.25 billion m 3. This deficit is met by other sources such as groundwater, rain, torrents, seawater desalination and recycling of agricultural and sanitation wastewater.

The total use of water in a country is not an accurate measure of the actual water resources it contains. The net imported virtual water should be added to the volume of the country's water resources in order to get a true picture of the water resources implicit in it. Likewise, if there is a net export of virtual water, it should be subtracted from the volume of the country's water resources in order to reach the accurate picture. This can be seen as a country's Water Footprint.

- The country's water footprint is calculated as follows (Hoekstra and Hung. 2002):

WF = WU + NVWT

Where:

WU: Total domestic water use (Total domestic water use refers to the use of Blue Water, which refers to ground surface water, and Green Water, which refers to the use of rain water.) (m3) / year.

NVWT: Net Virtual Water Trade (Exports or Imports) (m 3) / year.

Water Scarcity, Water Dependency and Water Self-sufficiency were also calculated, as it is logical for any country suffering from water scarcity to seek to take advantage of its net imports of virtual water. Likewise, countries with abundant water can achieve Profit by exporting water in its virtual form.

The water reliability index reflects a country's level of dependence on foreign water resources (through net imported virtual water). The water self-sufficiency index is a counterpart to the water reliability index.

Water scarcity can be calculated as follows, (Water scarcity generally ranges from zero to a hundred, but in exceptional cases such as groundwater extraction exceeding a hundred, and to measure water availability, annual internal renewable water resources are taken, and water use refers to the sum of both blue and green water.):

WS = WU / WA * 100

Where:

WU: Water uses for a country (m3). WA: water availability (m3).

- The water reliability is calculated as follows:

WD = NVWI / WU + NVWI * 100 if NVWI $\geq$ 0

= 0 if NVWI $\leq$ 0

- The water self-sufficiency index is considered to be a counterpart to the water reliability index, and it is calculated as follows:

WSS = WU / WU + NVWI * 100 if NVWI $\geq$ 0

= 0 if NVWI $\leq$ 0

That is, the self-sufficiency index of water is related to the water reliability index as follows:

WSS = 1 – WD

The level of self-sufficiency indicates the state's ability to provide the water needed for domestic demand for goods and services. It is equal to 100% if all the water needs are covered from within the state's lands, and approaches zero as it depends on imports of virtual water.

Table No. (4) shows the evolution of the indicators of water fingerprint, water scarcity, water dependency and self-sufficiency in water during the period (2010-2017), and it turns out that the average water footprint resulting from the addition of virtual net water imported from different agricultural crops during that period has It reached 77.80 billion m3, and the index reached its maximum in 2017 by 85.54 billion m3, and the lowest in 2012 by 71.62 billion m3. As for the water scarcity index, it reached about 84.19% for the average period, and it reached a maximum in 2010 and 2011 by 85.83%, and the lowest year in 2016, and 2017 by 82.69%, the annual rate of deficiency is about 0.7%, and its significance has been proven statistically At 0.01.

Table No. (4): Evolution of indicators of water fingerprint, water scarcity, water reliability and self-sufficiency in water during the period (2010-2017)

Years	Water footprint Billion m 3	water scarcity %	Water reliability%	Self-sufficiency in water%
2010	75.41	85.83	16.06	83.94
2011	8175	85.83	22.56	77.44
2012	71.62	85.80	11.15	88.85
2013	76.49	84.80	16.41	83.59
2014	74.17	83.03	14.93	85.07
2015	76.03	82.85	16.75	83.25
2016	81.40	82.69	22.54	77.46
2017	85.54	82.69	26.29	73.71
Average	77.80	84.19	18.34	81.66
growth rate %	1.2(1.954)$^{-}$	-0.7(39.772)**	5.4(1.820)$^{-}$	-1.3(2.159)$^{-}$

Where: The numbers in parentheses below the value of the growth rate in the table indicate the calculated value (F).
**significant at 0.01 level. * Morale at the level of 0.05. Not significant

Source: collected and calculated from:

- Central Agency for Public Mobilization and Statistics, Egypt Bulletin in Figures, Cairo, various issues.
- Table No. (1)

The average of the indicators of water dependency and self-sufficiency in water during the average of the same period was about 18.34%, 81.66% for each respectively, and the water dependency index reached the maximum in 2017 by 26.29%, and the lowest in 2012 by 11.15%, and the self-sufficiency index of Water reached the highest in 2012 by 88.85%, and the lowest in 2017 by 73.71%.

To measure the density of water use in different sectors, the water density index is used, and the following formula is used in calculating the density of water in an economy (Valeria and Maria, 2012):

$$\frac{W_c}{Y_c} = \sum_{j=1}^{2} \frac{W_{j,c}}{Y_{j,c}} \frac{Y_{j,c}}{Y_c} + \frac{W_{r,c}}{Y_c} \qquad (1)$$

It is measured for sectors above average for the density of water in a country relative to other sectors r. The left side of the equation indicates the density of water in state c, where Wc indicates Water consumption, Yc denotes GDP, as a function of water density in the sector $\frac{W_{j,c}}{Y_{j,c}}$, and j indicates economic sectors consuming water. It measures the extent to which the sector j contributes to the country's GDP. Thus the indicator allows the analysis of the water density to a water density and a production density.

In this section, net virtual water flows of agricultural crops were added to water uses and considered as one of the sectors consuming water, in order to measure the real water density index. Table (5) shows the apparent and real relative importance of the sectors consuming water in Egypt for the year 2017.

Table No. (5): Water consuming sectors in Egypt for the year 2017Billion m 3 / year

Source	Virtual		Real	
	2017	%	2017	%
Agriculture	62.15	81.51	62.15	62.94
Evaporation from the Nile and canals evaporation	2.5	3.28	2.5	2.53
drinking water	10.40	13.64	10.4	10.53
Industry	1.20	1.57	1.2	1.22
Net virtual water flows	-	-	22.49	22.78
Total	76.25	100	98.74	100
Average	19.06	25	19.75	20

Source: collected and calculated from:
- Central Agency for Public Mobilization and Statistics, Egypt Bulletin in Figures, Cairo, March 2018.
- Table No. (1)

It turns out that the agriculture sector is the largest consumer of water, with its apparent consumption reaching about 81.51%, and the actual consumption of 62.94% of the total water consumed in all sectors. Ostensibly followed by drinking water, then evaporation loss, then industry, with rates of 13.64%, 3.28%, and 1.57%, respectively. Next, after adding the net virtual water flows, each of the net virtual water flows is drinking water, then evaporation loss, then industry, with rates of 22.78%, 10.53%, 2.53%, 1.22% for each of them, respectively.

The value of agricultural income is 398.5 billion pounds in 2017, which represents 11.69% of the gross domestic product, which amounts to 3409.5 billion pounds for the same year (CAPMAS, 2019). Table No. (6) shows the indicators of water intensity and productivity of the most important sectors consuming water in 2017.

Table No. (6): indicators of the water and production intensity of the agricultural sector as the most important sectors consuming water in Egypt for the year 2017

Sector	Source	Water density%	Production intensity%
Agriculture	Virtual	81.51	11.69
	Real	62.94	
Industry	Virtual	1.57	16.74
	Real	1.22	
Water density index Million m 3 / million pounds	Virtual	22.36	
	Real	28.96	

Source: collected and calculated from:
- Central Agency for Public Mobilization and Statistics, annual bulletin of income estimates from the agricultural sector in 2.16 / 2.17, Cairo, May 2019.
- Central Agency for Public Mobilization and Statistics, Egypt in numbers, Cairo, March 2019.
- Table No. (1)

It indicates that the agricultural sector is responsible for 81.51% of the total water use, while its output contributes only 11.69% to the GDP. This reflects the fact that many agricultural production outputs are used as inputs in other sectors. While the agricultural sector uses more water than other sectors, much of this is to meet sector demand The other has inputs to their production processes. Like the industry sector, which contributes 16.74% of the GDP, although it is responsible for only 1.57% of the total water use.

After adding net virtual water flows as one of the water consuming sectors, the agriculture sector became responsible for 62.94% of the total water use. Thus, the water intensity index in Egypt for the year 2017 before and after adding the net default water flows becomes 22.36 million m3 / million pounds, 28.96 million m3 / million pounds each, respectively.

Third: Average per capita (virtual and real) water:

Table No. (7) shows the annual development of the population and each of the average real and apparent per capita share of water during the period (2010-2017), and it turns out that the average population during that period has reached 84.83 million people, and it has reached about 92.12 million people in 2017, An increase of 18.35% over the year 2010, and with an annual growth rate of about 2.4%, its statistically significant figure was 0.01%.

As for the per capita water share, it reached about 889.09 m 3 per capita for the average period, and it reached about 827.72 m 3 per capita in 2017, with a decrease of about 12.64% over the year 2010, and with an annual rate of deficiency of about 1.8%, its significance proved statistically at 0.01%.

The table shows the results of calculating the real per capita share of water during the same period, and it turns out that the real per capita share of water exceeds the apparent per capita share of water by about 19.20% for the average period, the increase reached its maximum in 2017, when it reached about 29.49%, and the lowest in 2012 when it reached Only about 10.77%.

The average real per capita share of water was about 1058.69 m3 per capita for the average period, and it reached about 1071.83 m3 per capita in 2017, a decrease of about 2.83% from 2010, and at an annual rate of deficiency of about 0.8%, its significance has not been statistically proven.

Table No. (7): the annual development of the population and the average apparent and real per capita share of water during the period (2010-2017) m 3 per capita

Years	Population in million	Virtual Per capita water share	Real Per capita water share	% Change rate
2010	77.84	947.46	1103.03	16.42
2011	79.62	926.27	1157.94	25.01
2012	81.57	909.16	1007.05	10.77
2013	83.67	901.16	1051.05	16.65
2014	85.78	885.99	1015.05	14.57
2015	87.96	868.58	1012.34	16.67
2016	90.09	846.38	1050.05	24.06
2017	92.12	827.72	1071.83	29.49
Average	84.83	889.09	1058.69	19.20
growth rate %	2.4(22058.112)*	-1.8(484.054)*	-0.8(1.350)-	-

Where: The numbers in parentheses below the value of the growth rate in the table indicate the calculated value (F). significant at 0.01 level. * significant at the level of 0.05 - Not significant

Source: collected and calculated from data:
- Central Agency for Public Mobilization and Statistics, Annual Statistical Book - Population, Cairo, Various Issues.
- Central Agency for Public Mobilization and Statistics, Egypt Bulletin in Figures, Cairo, various issues.
- Table No. (1)

Recommendations:

The study reached results and indicators, through which it can suggest some recommendations that would help in facing the possibilities of water shortage, as follows:

1- Encouraging technically and economically integrated research and studies in the field of water and the sustainability of natural resources, linking the economic dimension to the technical dimension in studies of practical branches of agricultural colleges and research centers, and economic evaluation of relevant technical studies, such as water treatment methods, modern irrigation methods and the desalination of sea water, and trying Reach her at the lowest cost.

2- Paying attention to the role of water guidance and spreading awareness regarding water scarcity and potential hazards, and encouraging the use of modern irrigation methods.

3- Using non-traditional alternatives and methods to increase the water supply. So that it maximizes the opportunities to increase exports by increasing production, whether locally by providing water and increasing cultivated areas or externally by integration through joint agriculture, for the optimal direction of scarce agricultural resources which is water, or through substitution of imports, which can have positive reversal effects On the commodity agricultural trade balance of virtual water.

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