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Quantity and quality evaluation of virtual water trade in Iran (Case study of Khuzestan province)

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Abstract: ***The virtual water term first time was expressed by Allen(1997) to note the amount of available water in universal system by Exchanging of agricultural goods.Water is needed to produce most goods. the water used in different steps of production of a good is called virtual water and is saved in good.Many countries located in arid and semi-arid with food imports, saves the part of water can be used to produce Domestic production for using in other uses which is called Virtual water imports.in this research, in 11 hydrologic unit in case study of khuzestan province, the virtual water in production goods was assessed.First Weighted Average of 11 goods of crop production and 2 production of Horticultural products with collecting distributed data about agriculture was calculated.then amount of needed water and virtual water for every production was calculated. then benefit and percent of water supply for hydrologic unit was assessed. finally imports or exports of every production according to Per capitation consumption and production was calculated. results show the percent of water supply over 90 in most plains and being negative export rather than import in production. although few benefit in Lentil and maximum in Tomatoes and saving the maximum virtual water in Lentil and the minimum in Sugar beet. so it can be said that assessing virtual water can be so beneficial in optimum Cropping patterns and although in managing of cropping and horticulture productions and water resources and to increase water Benefit.***

Keywords: virtual water exports; Virtual water imports; Virtual Water Trade.

1. Introduction

Agricultural sector plays a basic and vital role in the national economy and food production in Iran. Meanwhile, irrigated agriculture is the main axis of food production due to the special climatic status of the country and improper spatial and temporal distribution of precipitation. Despite almost similar extent of dry and irrigated cultivation in the country, most of the production comes from irrigated sector. So that almost invariably near 90 percent of the total agricultural production during the past five years in Iran is obtained from irrigated agriculture. Approximately74% of the available water resources in the world are consumed in agricultural sector. This number is about 93% for Iran. In addition to the issues such as climate and manufacturing technology, people's dietary habits also have a large impact on water consumption in a country. The concept of virtual water highlights the water as a key global issue and expands its management at micro and macro levels of society and business scope.
Production of many commodities needs water. The water used in various stages of production of a commodity is called virtual water stored in the commodity. Many countries located in arid and semi-arid regions maintain some part of the water required for domestic production of goods for use in other applications by importing food which is called virtual water import. If the production requires less water in the exporting countries than the importing countries, global water saving will take place. Thus, virtual water trade reduces global water consumption by better utilization of capacities and resources.

1.1 Definition of terms and specialized terms

- **Virtual Water:** Production of many commodities needs water. The water that is used in various stages of production of a commodity is called virtual water stored in the commodity.
- **Virtual Water Import:** Many countries located in arid and semi-arid regions maintain part of the water required for domestic production of goods for use in other applications by importing food.
- **Virtual Water Trade:** If the production requires less water in the exporting countries compared to the importing countries, then global water saving takes place. Thus, virtual water trade reduces global water consumption by better utilization of capacities and resources.

2. Study scope

Khuzestan Province with more than 64 thousand square kilometers, with a population of about four million and three hundred thousand is located in the southwest of Iran. Khuzestan Province is very rich in terms of soil and water resources and produces about 11.3 million tons agricultural crops where this amount can be increased to more than 24 million tons. This province ranks first as the hub of agriculture in Iran. Presence of surface water resources, five rivers of Karkhe, Dez, Karoon, Zohre and Maroon, with a discharge capacity of 33 billion cubic meters provides such conditions. Enjoying soil and water resources and favorable climatic conditions results in the possibility of four seasons of cultivation and harvesting of agricultural products three times in a year in Khuzestan Province. Sixty five types of products amounting to 11.3 million tons are produced of which 2.5 million tons are vegetables and cucurbits. Enjoying extensive and valuable palm groves, date exports amounts to 50 thousand tons per year which has led to earning the first rank in date export in the country.

3. Hydrological areas studied in the research

In this research, to achieve the desired goals, agricultural situation, net and gross amount of water needed and agricultural and horticultural crops have been investigated in eleven hydrological areas for virtual water calculations.

- hydrologic units Chegarman-Andika-Lali
- hydrologic units Hamidieh-Ghouds
- hydrologic units Ahou Dasht
- hydrologic units Barangard-Izeh-Piyon-Dahsheikh
- hydrologic units Dezfoul,Andimeshk
- hydrologic units Gomar
- hydrologic units Gotvand
- hydrologic units Jafarabad-Ghaleh raeesi
- hydrologic units Masjed soleiman
- hydrologic units Shoushtar
- hydrologic units North ahwaz

4. The parameters used in the study

In this research, the amount of virtual water, water use intensity index and the index of dependency and independency to virtual water import are calculated and estimated. In order to perform these calculations the data on crop type, area under cultivation and their production levels are saved in a database. The average water requirement of crops in the province is calculated in all plains of the province using a weighted average.

Water consumption of each product is calculated based on the area under cultivation, irrigation efficiency and the total amount of water used in the province agricultural sector. The virtual water content of each product is obtained as a proportion of average water requirement to average crop yield using Equation 1 (cubic meters of water per ton of product):

$$VWC_C = \frac{CWR_C}{T_{PC}} \qquad (1)$$

In which $\boldsymbol{VWC_c}$ is the virtual water content of the plant $_c$ and $\boldsymbol{CWR_c}$ is the water requirement of the plant $_c$ and $\boldsymbol{T_{pc}}$ is the average crop yield (tons per kilogram per year) (ton kg^{-1}). According to the definition, agricultural water productivity is inversely related to the amount of virtual water and can be calculated using Equation (2).

$$wp_c = \frac{T_{PC}}{CWR_C} \qquad (2)$$

Virtual water exchange of the Khuzestan Province per export and import of each product is calculated as the product of the quantitative amount of import or export of that product and its virtual water content. The province water deficiency index is calculated from the proportion of total water use of the province to total water resources of the province.

$$WS = WU/TWU \qquad (3)$$

In which WS is the province water deficiency index (in terms of %), WU is the total water use in the province agricultural sector (in terms of cubic meters per year) and TWU is the total water resources in the province (in terms of cubic meters per year). WS can range from 0 to 100. The more WS approaches to 100 it means that the intensity of water use in study scope is higher in the agricultural sector.

5. Calculation and analysis of the products' virtual water

considering the presented relations as well as to achieve the research purposes, the virtual water content of agricultural and horticultural crops in the area were calculated. This was performed by calculating the weighted average of the crop yield with respect to the area under cultivation. Agricultural and horticultural crops used are as follows:

Table 1: The agricultural crops used in the

Row	*Product name*
1	wheat
2	Barley
3	Rice
4	Lentil
5	Cucumber
6	Sugar beet
7	Tomato
8	Potato
9	Onion
10	Watermelon
11	Other vegetables

Table 2: horticultural crops used in the research

Row	*Product name*
1	Citrus fruits
2	Pomegranate

Table 3: The virtual water content of agricultural crops

Virtual water (kg/m^3)	*Virtual water* $(m3/ton)$	(m^3) *Average yield*	*Average water requirement* (m^3/ha)*(cwr)*	*Total area under cultivation (ha)*	*Product name*
2.63551	2635.51	3.3801	8908.56	156380	**wheat**
3.6561	3656.16	1.9189	7015.96	13450	**Barley**
8.058	8058.19	3.7457	30183.80	32120	**Rice**
16.38	16389.95	0.81	13275.86	75	**Lentil**
0.701	701.13	17.80	12483.61	4620	**Cucumber**
0.26	262.23	50.04	13123.4	4155	**Sugar beet**
0.24	240.66	31.36	7547.14	8085	**Tomato**
0.52	526.33	19.71	10374.71	5230	**Potato**
0.64	645.33	21.49	13873.02	2690	**Onion**
0.51	513.45	27.73	14241.22	9545	**Watermelon**
0.437	437.0003	21.82	65.9537	6785	**Other vegetables**

Table 4: The virtual water content of horticultural crops

Virtual water (kg/m^3)	*Virtual water* $(m3/ton)$	*(m^3) Average yield*	*Average water requirement* (m^3/ha)*(cwr)*	*Total area under cultivation (ha)*	*Product name*
4.26	4268.51	6.85	29271.61	4480	**Citrus fruits**
3.61	3619.31	8.62	31215.63	980	**Pomegranate**

a) Virtual water values for different products are shown in descending order.

Table 5: Virtual water values of products in descending order

Virtual water (kg/m^3)	*Product name*	*Row*	*Virtual water* (kg/m^3)	*Product name*	*Row*
0.64	**Onion**	**8**	16.38	**Lentil**	**1**
0.52	**Potato**	**9**	8.058	**Rice**	**2**
0.51	**Watermelon**	**10**	4.26	**Citrus fruits**	**3**
0.437	**Other vegetables**	**11**	3.61	**Pomegranate**	**4**
0.24	**Tomato**	**12**	3.656	**Barley**	**5**
0.26	**Sugar beet**	**13**	2.635	**wheat**	**6**
			0.701	**Cucumber**	**7**

According to Table 5, lentil has the maximum amount of virtual water and sugar beet has the minimum amount. In addition, citrus fruits and pomegranate are in the third and fourth orders.

6. Water productivity

Another objective of this study was to determine the productivity of products in the two sections of agricultural and horticultural crops. The corresponding equation was reviously provided and in fact it is the opposite of virtual water determination equation.

$$wp_c = \frac{T_{PC}}{CWR_C} \quad \text{(crop water productivity)} \qquad (4)$$

Table 6: Productivity value for agricultural crops

Productivity kg/m³	*Productivity ton/m³*	*Product name*
0.37	0.00037	**wheat**
0.27	0.00027	**Barley**
0.12	0.00012	**Rice**
0.06	0.00006	**Lentil**
1.42	0.0014	**Cucumber**
3.81	0.0038	**Sugar beet**
4.1	0.0041	**Tomato**
1.9	0.0019	**Potato**
1.5	0.0015	**Onion**
1.9	0.0019	**Watermelon**
2.2	0.0022	**Other vegetables**

Table 7: Productivity value for horticultural crops

Productivity kg/m³	*Productivity ton/m³*	*Product name*
0.23	0.00023	**Citrus fruits**
0.27	0.00027	**Pomegranate**

a) As Tables 6 and 7 indicate, in agricultural crops lentil has the lowest productivity and tomato has the highest productivity amounting to 0.06 and 4.1 kilograms per cubic meter, respectively and in horticultural crops, pomegranate has a higher productivity than citrus fruits.

The productivity of agricultural and horticultural crops is shown in Table in descending order.

Table 8: Productivity values of products in descending order

Productivity kg/m³	*Product name*	*Row*
4.1	**Tomato**	**1**
3.81	**Sugar beet**	**2**
2.2	**Other vegetables**	**3**
1.9	**Watermelon**	**4**
1.9	**Potato**	**5**
1.5	**Onion**	**6**
1.42	**Cucumber**	**7**
0.37	**wheat**	**8**
0.27	**Barley**	**9**
0.27	**Pomegranate**	**10**
0.23	**Citrus fruits**	**11**
0.12	**Rice**	**12**
0.06	**Lentil**	**13**

b) Therefore, in the studied scope tomato and lentil (4.1 and 0.06 kilograms per cubic meter, respectively) have the maximum and minimum value of productivity across all products.

7. Import and export of virtual water

Regarding the population of the studied scope and per capita consumption of each product the total amount of virtual water stored in the product can be specified. As a result, the amount of import or export of products into or out of the studied scope can be obtained. Export or import values of virtual water of each product are shown in Table with respect to the production as well as population and per capita consumption.

Table 9: Exports and imports of virtual water of agricultural and horticultural crops

Virtual water exports $(^{kg}/_{m^3})$*(vwE)*	*Virtual water imports* *(m^3)(vwi)*	*Virtual water of the product* $(^{kg}/_{m^3})$	*Total consumption* *(Kg)*	*Total production* *(kg)*	*Product*
375071289.2	0	2.6355	386281145.1	5285955250	**wheat**
90254101.95	0	3.6561	123904.66	25809800	**Barley**
128809359.44	0	8.058	104327671.7	120312750	**Rice**
0	49431096.51	16.38	3078521.46	60750	**Lentil**
57487195271.45	0	0.701	52530326.5	82177095000	**Cucumber**
7271461.106	0	0.26	79971341.9	207938500	**Sugar beet**
31443830.23	0	0.24	122530040.7	253546000	**Tomato**
0	8940298.27	0.52	120282231.3	103089350	**Potato**
1608060.54	0	0.64	553155655.4	57828250	**Onion**
78184672	0	0.51	78184672	264740500	**Watermelon**
40846655.11	0	0.43	53092278.83	148084500	**Other vegetables**
0	406194685.326	4.26	1260727836	307219185	**Citrus fruits**
0	55925418.93	3.61	23944055.8	8452250	**Pomegranate**
58233413239.92	520491499.03				**Total**

a) Therefore, virtual water trade is 57712921740.89 billion cubic meters a year toward exports.

8. Final conclusions

Considering the research objectives, the following items can be stated as the conclusion:

Lentil has the maximum amount of virtual water while sugar beet has the minimum amount. In addition, citrus fruits and pomegranate are in the third and fourth orders.

In agricultural crops, lentil has the lowest productivity and tomato has the highest productivity (0.06 and 4.1 kilograms per cubic meter, respectively) and in horticultural crops, pomegranate has a higher productivity than citrus fruits.

In the majority of the studied hydrological units the percentages of water supply is over 90 % considering the available water resources and only in a few units it is approximately 80 %.

The balance of exports and imports of virtual water in the studied scopes are toward exports and this means that the studied scope loses much of its water resources. The positive balance is 57712921740.89 billion cubic meters.

The concept of virtual water and its export and import can help preserving the water resources and that depends on the changes in the cropping pattern of the region.

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