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The Analysis of the Imports and the Exports of Food Products based on the Virtual Water Trade to Manage Iran's Water Resources

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ABSTRACT: About 74 percent of the available water resources in the world is consumed in agriculture. This value is 93% in Iran. In addition to issues such as climate and manufacturing technology, people's diet influences the water consumption in a country. The production of many goods requires water. The water used in the various stages of producing a product is called virtual water stored in goods. Dietary changes may increase the available water resources. The discussion of this issue and debate that will be bring forward illustrate that the concept of virtual water, highlights water as a global issue and develops its management at micro and macro levels of society and the business community. World trade of goods creates an international virtual water flow which is known as virtual water trade. With the beginning of international trade of goods virtual water flow happens from region to region.

Keywords: Diet, Virtual Water, International trade, Import and Export

INTRODUCTION

Over the decade the freshwater resources around the world have become scarcer due to increasing population and economic activity and increased water allocation (Postel *et al.,*1996). Iran with a dry and semi dry climate uses more than 94% of its water resources in agriculture. The agriculture has the greatest water consumer in the country (Alizadeh 2013). Virtual water is the water that is consumed in the production process of an agricultural crop or product to reach the final stage. The virtual water can be seen as the amount of water needed to produce a commodity. The term virtual water was introduced by JA Allan in 1993 and before that the term "embedded water" used to refer this concept. In fact virtual here means that the large amount of water used in the production process does not physically exist in the final product and in fact a very insignificant of water remains in the end product (Allen *et al.,* 1998). When the products are presented to the world, virtual water trade is performed. With increasing water scarcity, the concept of virtual water has become an important issue in water resources management. In fact virtual water is the water consumed by an agricultural or industrial product during manufacturing process to reach the final stage and the amount equals to the sum of water used in various stages of supply chain from the beginning to the end. Simply put the virtual water can be defined as the water needed to produce goods. Virtual attribute in this definition means that a large part of the water used during the production process, does not physically exist in the final product and in fact a very insignificant of water remains in the end product (Hoekstra and Chapagain, 2006). The amount of the virtual water varies based on climate and culture, the place of production, management and planning during the production process, internationally, if agricultural products are exported from the areas with more water to the areas with less water, the water is saved. Now if importing countries produce all the imported agricultural products with the use of local resources, they will require about 1,600 cubic kilometers of water per year, while the production of these products needs only1200 cubic kilometers of water and thus 400 billion cubic meters of water is saved within a year (Oki and Kanae, 2004). With the increased focus of the scientists and researchers to the concept of virtual water, all quantitative calculations began in this area. Calculations report of handling the huge flow of water in the form of virtual water through the water consuming products trade. Arid and semiarid countries can import water consuming goods such as food and use their water in other areas of need. Actual water transfer in high volume and at long distances seems almost impossible due to transmission problems and high costs; in this case food trade can transfer large amounts of virtual water as assimilation distribution of water. The agriculture sector consumes 74 percent of the world's fresh water resources as the highest share.

Some water scarce countries ignoring the natural capacity pump groundwater and desalinate the sea water to provide a part of their needs. Research results show that production in this situation is 5 times more expensive. Low-water countries can increase their access to the world's water resources through entering the trade of virtual water in their water policies and reduce the pressure on the limited resources Zimmer and Renault, 2003).

Food imports in order to use virtual water trade affect the economic, social and environmental sectors of a country and it is directly related with food security and culture. Water scarce countries can find the optimal point of food imports based on capacities and local needs as well as considerations of food security. The per capita virtual water use depends on the type of diet and it varies between 1 cubic meter per a day (the amount necessary to survive) to 2.6 cubic meters per day for vegetarians and above 5 cubic meters for a diet with meat (Chapagain and Hoekstra, 2003). The importance of virtual water in the world is increased proportionate to the picture of the increase in global food trade volumes. Thus the transfer of virtual water in the food being traded is an important part of water management at the global and at the regional level especially in arid areas. It must be noted that virtual water trade is not a new topic which dates back to the time when food was traded. The virtual water trade flow starts from the exporters of goods (food and products) to the countries that import these goods. Instead of producing these goods, importing countries can spend the water on other necessary purposes. Water scarce countries can import products that require large amounts of water if they are produced in the country. This saves the actual water supply and pressure on water resources is suppressed. The importers of virtual water are not necessarily dry for example imports bananas and citrus while it is a country with full water supplies. Even the countries that have a severe shortage of water (Jordan) export food (such as fruits and vegetables). Optimizing the use of water is made possible through virtual water trade in the environmental, social and economical categories. On the other hand, countries with abundant water resources can be focused on water consuming production for export advantage. Virtual water trade between nations and even continents can be an ideal tool to improve the worldwide efficiency of water use, achieving water security in arid areas of the world and relieve pressure on the environment by choosing the best place of production (Duarte, 2002) .

Sarshar and Masoumi (2013) discussed the impact of virtual water on the water resource management. In this investigating the impact of water inside and outside of Iran, the definition of virtual water and its impact on water resource management were discussed and explored.

Keshavarz and Dehghan (2012) analyzed the Productivity Indices in order to the optimal water resource management. In this research the water productivity of various provinces and agricultural crops was studied through virtual water approach.

Mousavi *et al*., (2014) presented the impact of virtual water, the new solution to the water crisis. In this study, the average virtual water index of a product was used as a method of estimating the amount of virtual water.

Poorjafari *et al*. (2012) analyzed Ecological footprint of virtual water and virtual water indices of pistachio and dates in Kerman. In this study in order to investigate the ability of the region to supply water needed for domestic production, the ecological footprint of water in strategic crops of nuts and dates in the province in 2009. In order to perform the calculations the method of Hoekstra and Hang and Hoekstra et al. was used.

MATERIALS AND METHODS

A. The method of calculating virtual water stored in agriculture

In order to determine the net virtual water export and import of the countries the major horticultural crops being exported or imported are evaluated. To calculate the virtual water consumed by each product the following relations are used:

$$SWD_{ij} = \frac{CWR_{ij}}{CY_{ij}} \qquad (1)$$

In equation (1), SWD refers to Specified Water Demand, $(m^3 ton^{-1})$ is the water consumption by product I in the area j. Due to the variation of climate each product in different areas may have different levels of water consumption. Therefore for each product in each area the SWD values are calculated separately and their weighted average is calculated for the country.

CWR_{ij} is the Crop Water Requirement for product i in region j $(m^3 ha^{-1})$. Hokestra and other researchers used ET_C for the calculation of CWR. After deducting the amount of effective watering and applying the irrigation efficiency, they calculated the value of CWR.

$$ET_C = K_C \times ET_0 \qquad (2)$$

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_a - e_d)}{\Delta + \gamma(1 + 0.34U_2)} \quad (3)$$

$ET_0\ [mm\, day^{-1}] =$ Reference evapotranspiration

$R_n\ [MJ\ m^{-2}\ day^{-1}] =$ Net radiation from the plant

$T\ [^0C] =$ Average Temperature

$U_2\ [m\, s^{-1}] =$ Wind speed at a height of 2 meters above the ground

$e_a\ [KPa] =$ Saturated vapor pressure

$e_d\ [KPa] =$ The actual vapor pressure

$e_a - e_d\ [KPa] =$ Vapor pressure difference

$\Delta\ [KPa^0C^{-1}] =$ Vapor pressure curve slope

$\gamma\ [KPa^0C^{-1}] =$ hygrometer constant

In Equation 1 CY_{ij} , is the performance of the product i in the region j.

After SWD was calculated the weighted average of the relation is calculated:

$$SWD_i = \left(\sum_{j=1}^{m} SWD_{ij} . TP_{ij} \right) \Big/ TP_i \quad (4)$$

In the above equation SWD_i is the specific water consumption for each i-th product in the country.

$TP_{ij} =$ Total production of the i-th product in the area j

$TP_i =$ Total production of the i-th product in the country

So SWD_i is calculated for all products. SWD_i is the indicator of water consumption per ton of the i-th product based on cubic meters. In fact it indicates the total water to be consumed to produce 1 ton of the i-th product which is called the unit consumed water of the i-th product. The term consumed water base indicated the total water consumed by a product, agricultural product, a series of activities or generally by a country or even an individual (including real and virtual water).

B. Virtual water flow rate calculation method

To determine the total virtual water to export a product, , the following equation is used:

$$TSWD_{i\,\exp} = SWD_i . TP_{i\,\exp} \quad (5)$$

In the above equation $TP_{i\,\exp}$ is the total exports of the product i. Similarly, the total virtual water entering the country through the i-th product is calculated as follows:

$$TSWD_{i\,imp} = SWD_i . TP_{i\,imp} \quad (6)$$

In the above equation, $TP_{i\,imp}$ is the total imports of the product i. It should be noted that these figures are based on cubic meters.

The total exchange value of $TP_{i\,\exp}$ and $TP_{i\,imp}$ for the i-th product is available in FAO website. It is assumed that the total dollar value of exported and imported product is referred to as the virtual water content. Of course any product or commodity virtually contains other factors of production, however, according to research about the importance of water in our country the assumptions are based on water.

To determine the total virtual water export, $TVWT_{\exp}$.

The following equation was used:

$$TVWT_{\exp} = \sum_{i=1}^{n} TP_{i\exp} \quad (7)$$

For total virtual water entering the country, the same method is used:

$$TVWT_{imp} = \sum_{i=1}^{n} TP_{i\,imp} \quad (8)$$

The total value of the total exported and imported selected product is the value of virtual water.

To calculate the dollar value per cubic meter of virtual water export, $VWV_{\exp}$. The following formula is used:

$$VWV_{\exp} = \frac{TVTP_{\exp}}{TVWT_{\exp}} \quad (9)$$

In the above equation $TVTP_{\exp}$ is the total export value of the exported products. In this method, the virtual water import value per cubic meter is calculated. Now it is possible to evaluate the role of virtual water trade in dealing with the water crisis and reduce the pressure on the resources from an economic perspective by comparing the imported and exported virtual water.

RESULTS AND DISCUSSION

According to the FAO, the average amount of various foods groups in Iran is expressed in the following tables:

Table 1: Different groups of food products in Iran.

Production of food				
Products ($kg / person / year$ **)**				
country	Food Group	92-1990	97-1995	05-2003
Iran	Cereals	240	246	301
Iran	Potato	45	50	65
Iran	Sugar	14	13	21
Iran	Edible seeds (peas, beans, split peas, ...)	9	10	10
Iran	Vegetables	161	157	207
Iran	Fruit	133	170	190
Iran	Meat	18	22	29
Iran	Milk	69	75	102

Table 2: Different groups of food products in Iran.

Production of food				
Products				
The country	Food Group	1990-1392	1995-1997	2003-2005
Iran	Wheat	155	165	205
Iran	Barley	56	43	42
Iran	Corn	3	11	27
Iran	Potato	45	50	65
Iran	Sugar cane	28	30	81
Iran	Sugar beet	84	74	75
Iran	Rice	26	26	27

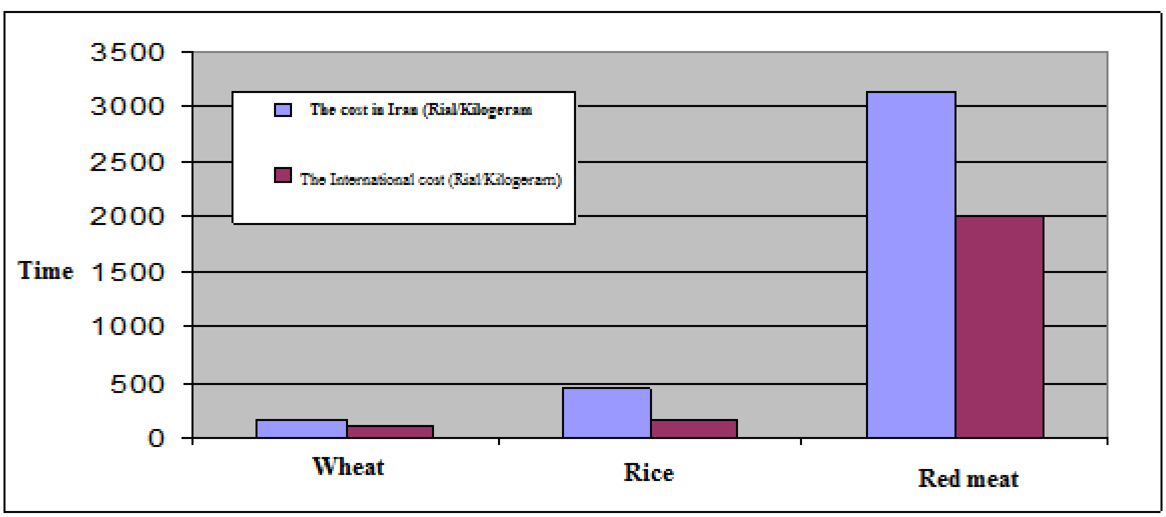

Fig. 1. Comparing the cost of food products in international markets (2003).

According to the table of water resources in order to attain self-sufficiency Iran has allocated above 0.42% of the water resources to this area while at the present time this value is about 32% of the total water resources of the country.

Table 3: The amount of water resources in Iran.

Total renewable water resources (Billion Cubic Meters)	Agricultural water needs (Billion Meter Cubic)	Percent of water required
137.5	21	32%

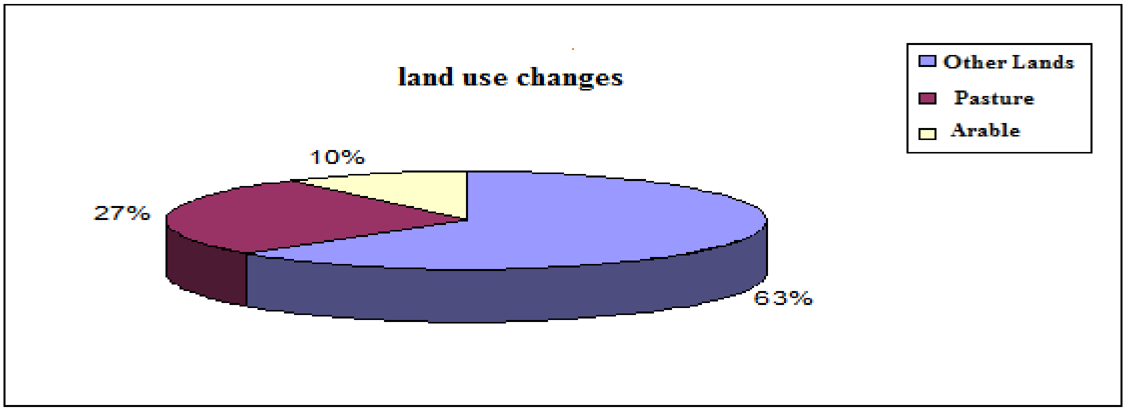

Fig. 2. The distribution of resources in the agricultural industry –land use – 2004.

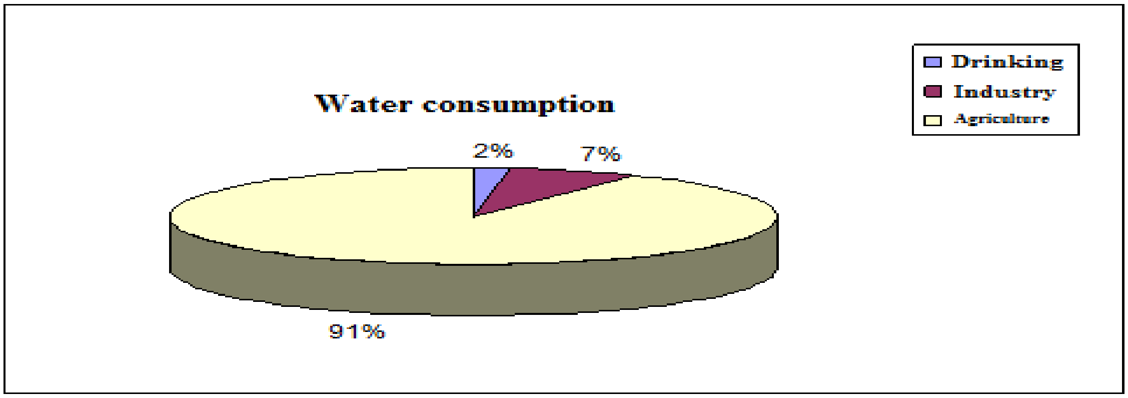

Fig. 3. Distribution of water use in the agricultural industry in Iran – 2004.

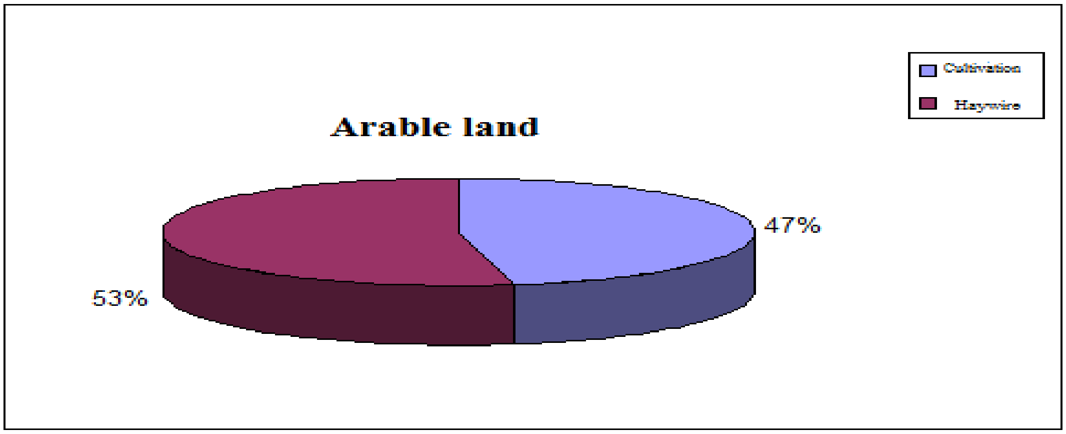

Fig. 4. Distribution of arable land in the agricultural industry in Iran – 2004.

Table 4: The amount of consumption and imported food and virtual water to Iran 2001-2003.

Food Group	Consumption (1,000)	Water Requirements (Billion Cubic Meters)	Import (1,000)	Virtual water imports Iran (Billion Cubic Meters)
Cereals	14174	17	7193	8.63
Vegetable oil	576	0.4	1042	0.73
Sugar	1808	2.71	724	1.09
Potato	335	0.05	34	0.005
Meat	1638	26.21	35	0.56
Lion	3924	3.53	71	.064
Rice	2900	7.83	1200	3.24
Total		57.73		14:32

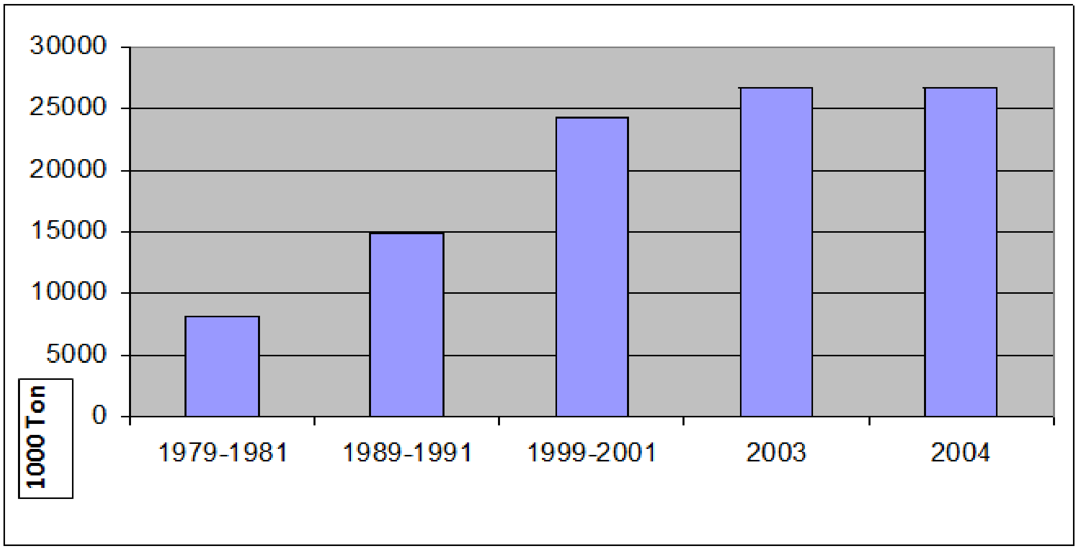

Fig. 5. Production of fruit and vegetables in Iran.

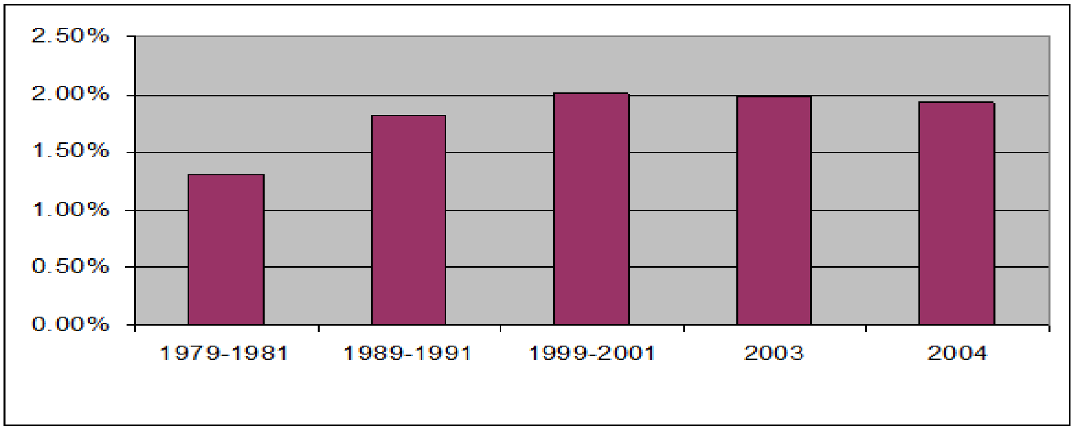

Fig. 6. Share of Iran in world production of fruit and vegetables.

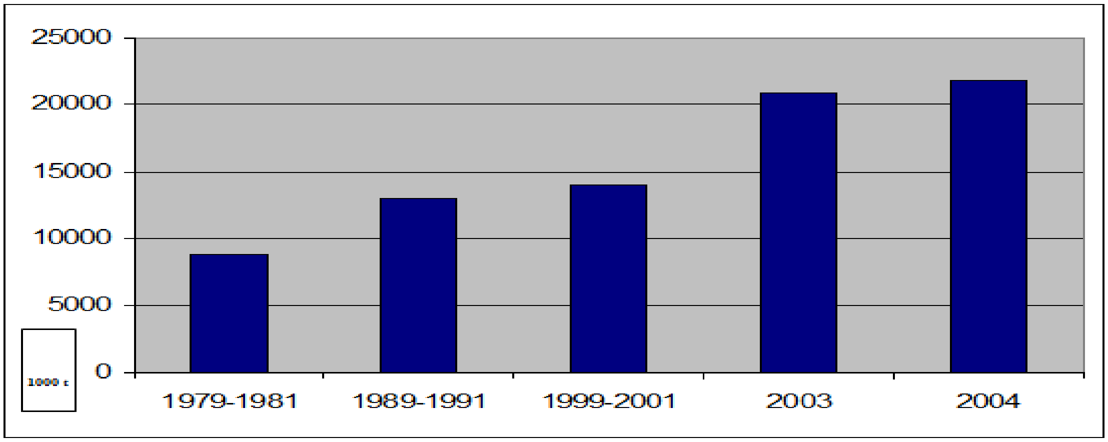

Fig. 7. Cereal production in Iran.

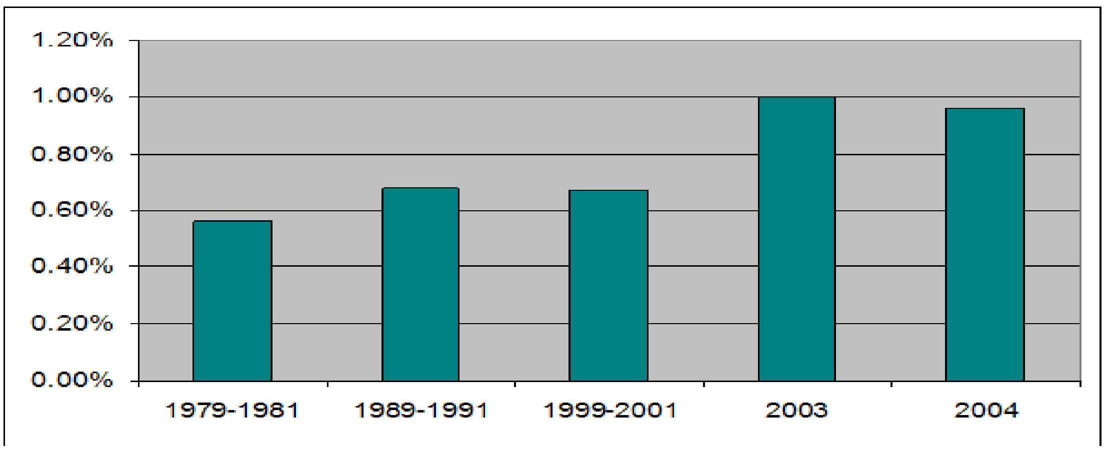

Fig. 8. Percent share of the global cereal production.

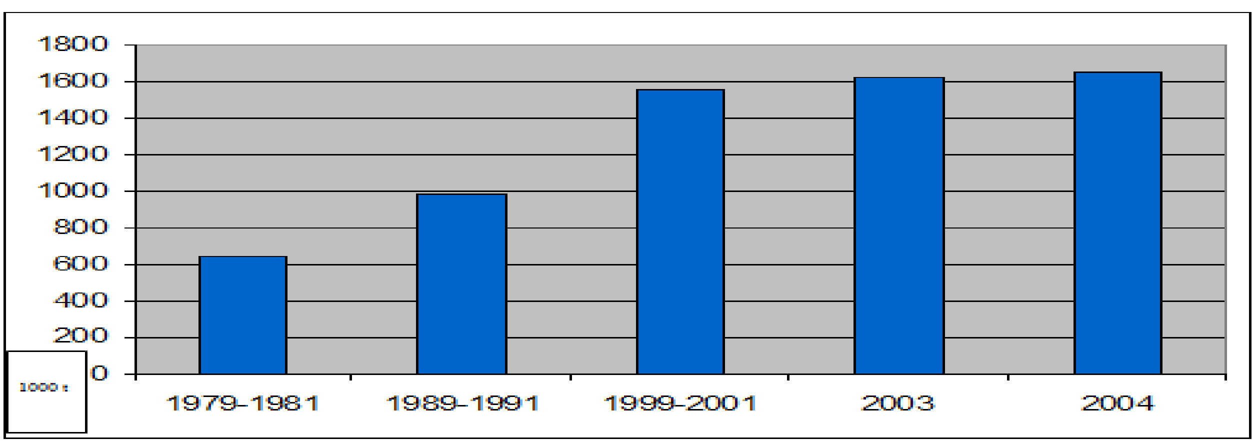

Fig. 9. Meat production in Iran.

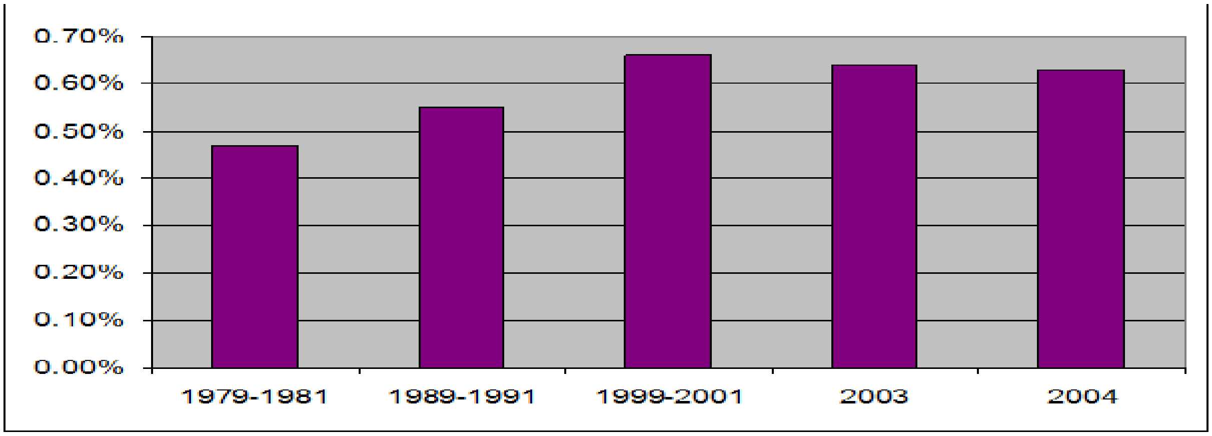

Fig. 10. Share in world production of meat.

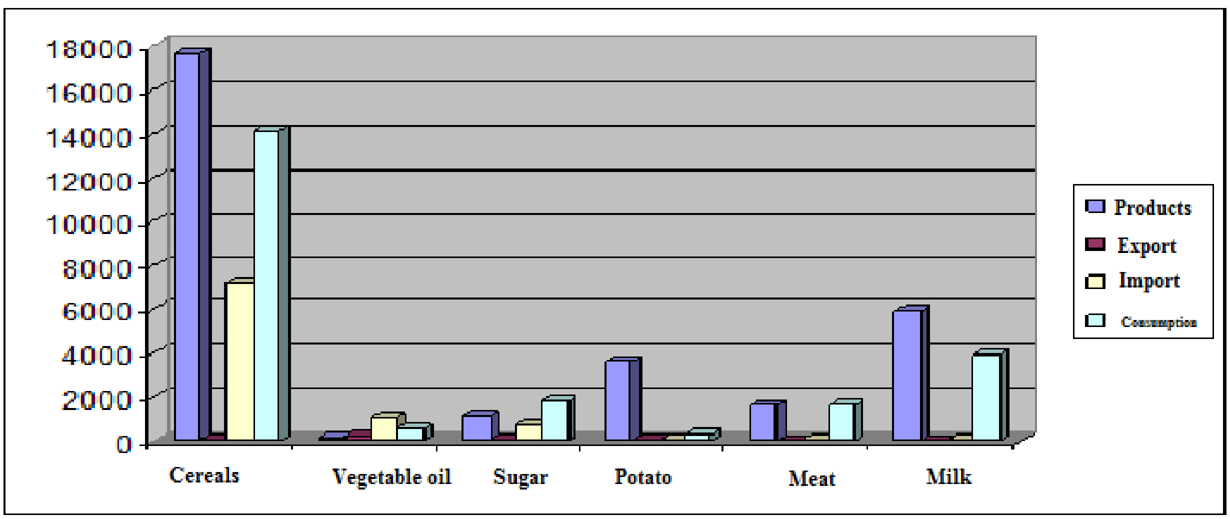

Fig. 11. Production, import, export and consumption of food products in Iran, 2001-2003.

Table 5: Production, import, export and consumption of food products in Iran, 2001-2003.

Food Group	Products (1,000)	Export (1,000)	Import (1,000)	Consumption (1,000)
Cereals	17712	61	7193	14174
Vegetable oil	167	241	1042	576
Sugar	1164	37	724	1808
Potato	3631	81	34	335
Meat	1615	13	35	1638
Milk	5912	27	71	3924

Table 6: Export of Food and virtual water from the country of Iran, 2001-2003.

Food Group	Export (1,000)	The virtual water export (Billion Cubic Meters)
Cereals	61	0.073
Vegetable oil	241	0.17
Sugar	37	0.056
Potato	81	0.012
Meat	13	0.21
Milk	27	0.024
Total		0.545

CONCLUSION

Factors affecting the volume of virtual water trade can be divided into two general categories, controllable and uncontrolled factors. Uncontrolled factors include factors affecting plant water requirement (average minimum temperature, average maximum temperature, wind speed, sunshine hours, rainfall, potential crop evapotranspiration, crop coefficients and evapotranspiration). However, controlled factors include plant performance and performance of agricultural trade. This study has shown that variables such as income, population, and value added agriculture, irrigation and exports of goods and services have a significant effect on the variance of virtual water. Calculations of crop water requirements that products indicated that some plants have high water requirements, but due to high production yield, will have less special water appeal. Thus it is suggested that through increasing the performance of the products, while improving the production performance, the efficiency of water use would improve and demand for water by products, especially exported products decrease so that the export of virtual water decreases. The calculated results show that the water demand of exported products was higher than imported products. In other words the agricultural export pattern was based on the water-based products.

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