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Prioritization in Exporting Agricultural Products Using Virtual Water Concept (Case study: Melon and Watermelon)

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ABSTRACT

Aims In the new sight of the world, water is considered a socio-economic good. Hence, commodity exchanges are important matters among nations. In this regard, local and international trade of virtual water as agricultural crops is an important subject in water resources management.
Materials & Methods In this study, the virtual water of two main exported products (watermelon and melon) in Iran were analyzed during 2003-2013. Some indicators, which are used in the water resources management, such as water use intensity and water dependency, were analyzed.
Findings By present assessment, during this period, 218.07 MCM of water in the form of virtual water was transferred from the country to outside. By efficiency calculation, it was obtained that irrigated watermelon production had the highest efficiency.
Conclusion The results showed that producing these products in Iran was completely hinged on the internal water resources. Additionally, water use intensity in watermelon is evaluated 12 times more than melon and these results warn us to have a more precise plan for aranging the allocation of the lands for different kind of agricultural activities.

Keywords Virtual Water Trade; Watermelon Virtual Water; Water Use Efficiency; Water Scarcity

CITATION LINKS

[1] Integrated water management for the 21st century: Problems ... [2] Fortunately there are substitutes for water: Otherwise our ... [3] Globalization of water resources: International virtual water flows ... [4] Global effects of local food-production crises: A virtual ... [5] Strategic importance of green water in ... [6] Water saving through international trade of ... [7] Virtual water trade: An assessment of water use efficiency in ... [8] Are virtual water 'flows' in Spanish grain trade consistent with ... [9] Virtual water trade as a strategy to water ... [10] The story of phosphorus: global food security and food for thought [11] Globalisation of water resources: International virtual water ... [12] The global component of freshwater demand and supply: An assessment of virtual water flows between nations as a result of ... [13] Internal and external green-blue agricultural water footprints of nations, and related water and ... [14] Virtual water trade flows and savings ... [15] Evaluation of the dependency and intensity of the ... [16] Estimation of the international virtual water flow of grain crop ... [17] Analysis of virtual water consumption in China: Using factor decomposition analysis based on a weighted ... [18] Optimal cropping pattern for water resources management in Sistan region of Iran using goal programming method [19] The green, blue and grey water footprint of ... [20] Spatial and temporal trend analysis ... [21] Assessing the stats crops harvested areas ... [22] Evaluation of sugarcane cultivation in the Khuzestan ... [23] Water efficiency determination guidelines ... [24] Virtual water evaluation for grains products ... [25] Statistics of the Islamic Republic of Iran ...

Introduction

The food demand for a growing population is rising and more irrigation water is needed [1]. First of all, the "virtual water" is basically considered as the water needed for agricultural products; subsequently, it is known as the volume of water utilized for goods or service production [2, 3], and also has relevant environmental and socio-economic implications [4]. Building on this concept, virtual water trade (VWT) represents the amount of embedded water in agricultural products for trading purpose [5]. The VWT has often been recognized for its ability to improve well access to food commodities physically and economically in water scarce regions, allowing nations to avoid water losses by importing water-intensive products [6, 7].

In fact, using the virtual water theory in trading agricultural products brings a new viewpoint for water shortage and management of water resources [8]. As an important component of water management at both regional and global levels, the virtual embedded water transferred in various crops is becoming a priority, particularly in regions with lack of water [3]. When the water scarcity becomes serious, the virtual water trade headed to be more important for the codification of water resource management policies. Therefore, taking into account of an appropriate redistribution of water resources, the VWT could play a vital role in decreasing water stress. For instance, watermelon is special products having high virtual water content [9], which is usually planted in Asian countries. According to Diagram 1, the main producer of melon and watermelon is China with 62% of the international market. Seemingly, countries except the arid or semi-arid regions do not have high production, while Iran has a high production rate of this crop (3% of world production).

For these reasons, virtual water trade has been studied in different areas, but mostly for a specific period, in order to obtain saved water quantity through this product [6]. Hoekstra and Hung [11], declared that in case of crop production, 13% of the used water was traded internationally for worldwide during 1995-1999. Chapagain and Hoekstra [12] ascertained that 16% of the global water resource is consumed for the crops production and agricultural/industrial products export. In another investigation, water savings with the effect of virtual water trade was assessed by Fader *et al.* [13]. In addition, Konar *et al.* [14] analyzed the impacts of climate change on the virtual water of crops in global scale and introduced some new ways to saving the water by minimizing virtual water of the crops. Most researches have focused on calculating virtual water and the evaluations related to the water savings methods. Accordingly, the effect of virtual water trade in arid and semi-arid developing countries is significantly considered for analyzing the unequal distribution of virtual water trade. For example, Lee *et al.* [15] conducted a research about virtual water content and measured in agricultural products. The results showed that the crop trading is allocated to the large amount of water consumption in Korea, and the scarcity of water is one of the greatest concerns around the world.

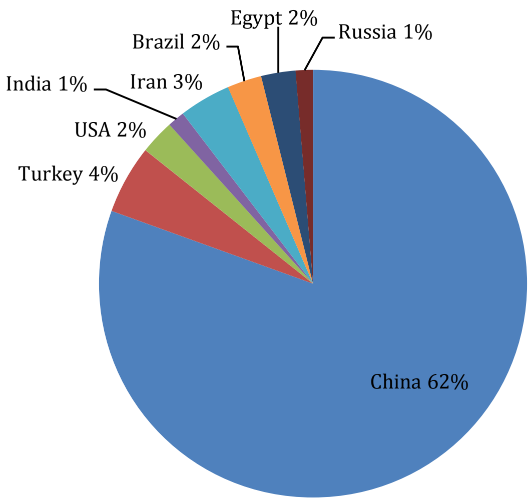

Diagram 1) Main countries contribution (%) in watermelon production [10]

The limitation of water supplies could also lead to broad social disruption due to the conflict over competing uses in the agricultural, domestic, and industrial sectors [16]. Zhi *et al.* [17], analyzed virtual water consumption in China, using decomposition analysis factor based on a weighted average decomposition model. The results revealed that the volume of virtual water consumption in China has decreased 5% during 5 years (from 2002 to 2007), mainly due to technological effect (-548000MCM). The increase in net virtual water exports was largely due to the economic structure changed (616000MCM) and the exports fast growing rate (349000MCM). Virtual water concept would be important in both rainfed and irrigated cultivation, according to the water resources issue, when specific area import or export crops, at the same time virtual water is also exported or imported; so, it is no matter that they are rainfed or irrigated crops.

The main aim of this paper is to quantify the amount of virtual water trade of watermelon and melon in Iran, and to analyze these farm crops trade as well as their efficiency. Low efficiencies in the existing irrigation and water transferring practices are the main causes of huge water waste [18]. Eventually, regarding watermelon and melon products, the evaluations of water dependency and intensity are considered for the Iranian virtual water trade. In fact, the chief reason of choosing these two crops is the large area needed for planting, which may lead to water scarcity. According to the Mekonnen and Hoekstra [19], one of the crops, which has a high content of virtual water, is watermelon (235 m^3 ton^{-1}); therefore, it should be taken as a strategic agricultural product. As the research was done by Feizi *et al.* [20], during summer and autumn for 40 years from 1969 to 2008, the precipitation had a negative trend in the south-eastern parts of Iran; therefore, crop production in these areas will face up to problems.

Instruments and Methods

The study area: The studied area is chosen from the main provinces of the Iran, which have higher watermelon and melon production rate. These provinces are Khouzestan, Kerman, KhorasanRazavi, and Fars in watermelon production and Qazvin, Isfahan, Sistan and Balouchestan, and KhorasanRazavi in melon production. Figure 1 shows the main watermelon and melon production provinces in Iran.

Data: In this study, information about average, minimum, and maximum of cultivated lands, the amount of production, and also the performance of crops (melon and watermelon) in both rainfed and irrigated fields were collected from 2003 to 2013 [21]. Then, virtual water content, the efficiency of used water, and other indicators, which are essential in water management scope, have been analyzed.

Average water requirement of the crop was calculated in the country based on equation 1, using the weighted average method.

$$CWR_{C,j} = \frac{\sum_{i=1}^{n}(CWR_{C,i,j} \times A_{c,i,j})}{TA_{c,j}} \quad (1)$$

Where c, i, and j relate to product, province, and year, respectively. $CWR_{c,j}$ represents the water requirement for product c in year j (m^3 ha^{-1}), which was obtained from CropWat family software, $CWR_{c,i,j}$ is the water requirement for product c in province i in year j (m^3 ha^{-1}), $A_{c,i,j}$ is the cultivated area for product c in province i in year j (ha), and $TA_{c,j}$ stands the total area of cultivated product c in year j (ha).

Virtual water content was calculated based on equation 2. Diagram 2 shows the study procedure step by step. Thereupon, the statistical amount of exports related to the mentioned two crops is analyzed and economic values are discussed as well.

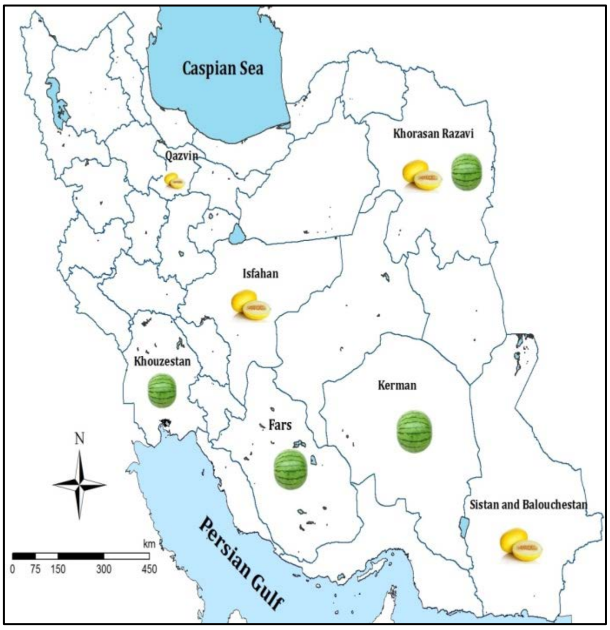

Figure 1) Studied areas and main provinces in farm production

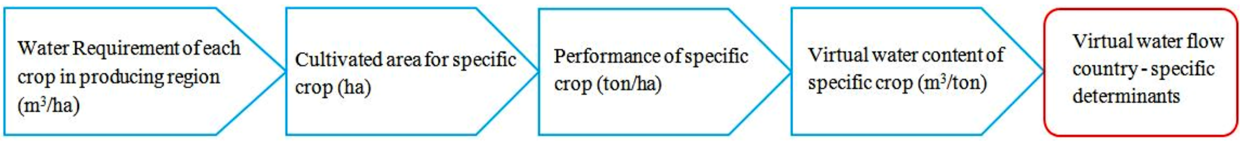

Diagram 2) Workflow of methodology

The virtual water is determined by the proportion of the crop water requirement to an average yield of the specific crop (m³ton⁻¹) [22]:

$$\mathrm{VWC}_{c,j} = \frac{\mathrm{CWR}_{c,j}}{\overline{\mathrm{Y}}_{c,j}} \tag{2}$$

Where $\mathrm{VWC}_{c,\ j}$ is virtual water content for product C in year j (m^3 ton^{-1}), $\mathrm{CWR}_{c,\ j}$ is average water requirement for product C in year j (m^3 ha^{-1}), and $\mathrm{Y}_{c,\ j}$ is average yield for product C in year j (ton ha^{-1}).

Water Use Efficiency: Water use efficiency in the simplest form can be defined as the ratio of output to input, which is shown in equation3 (here input is water and output is the weight of crop or yield). It is simply understandable for everyone and requires no expertise [23].

$$\mathrm{WUE} = \frac{\mathrm{Y}}{\mathrm{W}} \tag{3}$$

Where WUE is water use efficiency (kgm^{-3}), Y is yield (kg ha^{-3}), and W is water usage (m^3). It is necessary to say that water requirement is different in each product and region. Therefore, this index indicates crop production per unit volume of water. The index can be used to compare the efficiency of a specific product in different areas or for a certain region but in different time period. In other words, this index can be used for external or inter-regional and internal comparisons [24].

Water usage intensity: Water usage intensity indicates the ratio of total harvested water from domestic water resources for agricultural use to total water resources of the country (Equation4):

$$WI = \frac{WU}{WA} \times 100 \tag{4}$$

Where WI is water usage intensity, WU is total harvest from domestic water resources for agricultural use (m^3y^{-1}), and WA is total water resources of the country (m^3y^{-1}). Moreover, the renewable water resources have been characterized in this study for a year.

Water dependency: This index indicates country dependency to external water resources by importing the virtual water. This index is the ratio of total virtual water imports to the total internal harvest of water resources for the purpose of producing products (Equation5):

$$WD = \frac{TNVWI}{WU + TNVWI} \times 100 \tag{5}$$

Where WD is water dependency, TNVWI is assumed the total net virtual water import (m^3y^{-1}), and WU is domestic water use in the agricultural sector (m^3y^{-1}).

Water self-sufficiency: In contrary to water dependency index, water self-sufficiency shows the national ability to supply water for all national products. If water self-sufficiency gets close to zero, the country extremely depends on virtual water import. Equation 6 shows this relation:

$$W\mathrm{WSS} = 100 - \mathrm{WD} \tag{6}$$

We investigate the determinants of bilateral (import and export) virtual water flows related to the international trade in agricultural goods across the country scope, following a sequential approach (Diagram 2) that includes 4 main components, which will be explained in the following.

Watermelon: Diagram 3 determines the harvest area and amount of watermelon production in rainfed and irrigated land in Iran separately [21].

Obviously, in Diagram 3, cultivated area of watermelon during 11 years, is varied, but since 2008 to 2013 increased and also rainfed cultivation had the same process. But, there is a bit difference because this process was reversing (falling) flow. In addition, the highest and lowest irrigated area was in 2013 and 2004, respectively. In addition, the highest and lowest rainfed area was in 2007 and 2013. Thence in most cases production extend directly depends on cultivation area, this situation is also true for rainfed and irrigated watermelon production (Diagram 4). Table 1 shows the yields of watermelon during the study period. Table 1 also shows the yield of watermelon during the study period.

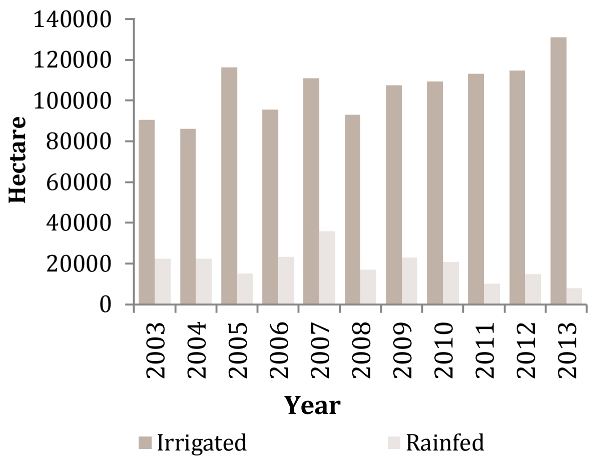

Diagram 3) Comparison of irrigated and rain fed area of watermelon

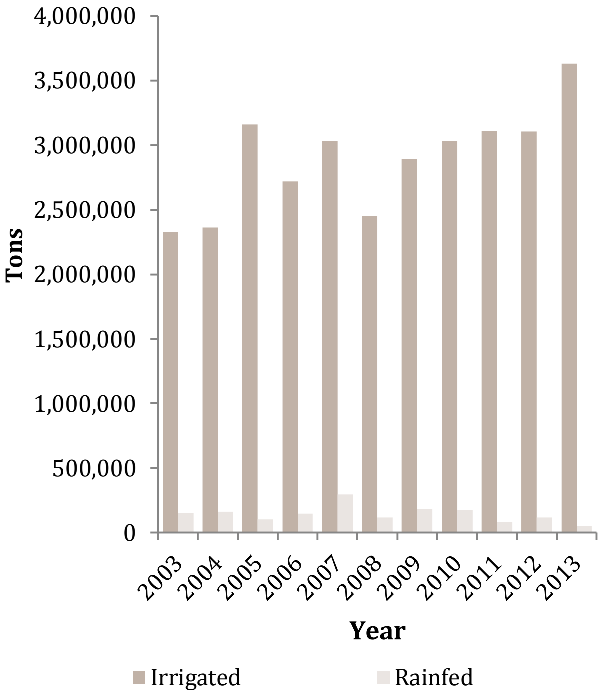

Diagram 4) Comparison of irrigated and rain fed production of watermelon

Table 1) Yield of watermelon crop [21]

Crop year	Yield ($kgha^{-1}$) Irrigated	Rain fed
2003	25723.9	6798.7
2004	27441.4	7416.5
2005	27137.5	6766.2
2006	28409.8	6287.9
2007	27336.6	8351.7
2008	26303.1	6967.8
2009	26848.4	7992.4
2010	27709.3	8610.1
2011	27506.8	8138.6
2012	27031.9	7832.5
2013	27685	6910.9
Sum	299134.3	82073.7
Average	27194	7461.2
Total yield (ton)	27.1	7.4

Melon: The next analyzed crop was Melon. As it is clear, cultivation area and consequently production amount (Diagram 5) have the same process as the watermelon has. From 2007 to 2009, cultivation area and irrigated lands decreased (Diagram 6); however, the harvesting in rainfed cultivation increased since this year (2006). The maximum irrigated area is in 2005 and the minimum occurs to 2009 and also the maximum and minimum rainfed area is in 2006 and 2002, respectively. Table 2 illustrates the yields of melon crop during study period.

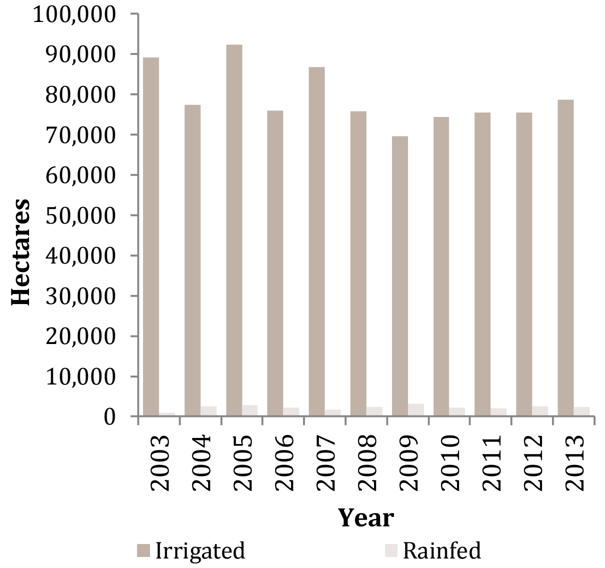

Diagram 5) Comparison of irrigated and rain fed area of melon

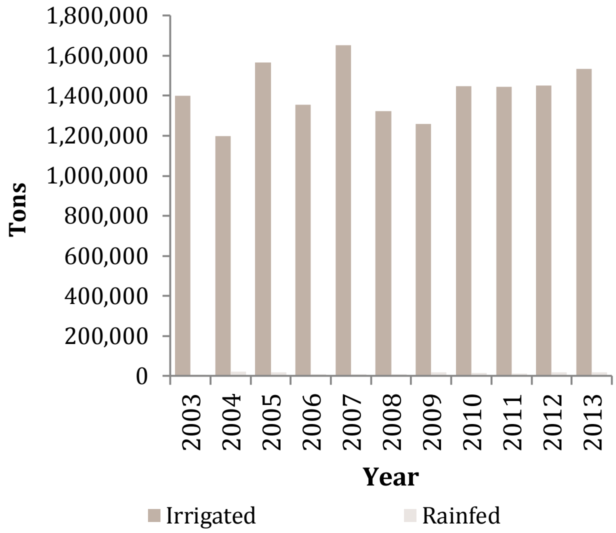

Diagram 6) Comparison of irrigated and rain fed production of melon

Table 2) Yield of melon crop [21]

Crop year	Yield($kgha^{-1}$) Irrigated	Rain fed
2003	15709	4648
2004	15485.7	8870.4
2005	16958.3	6390
2006	17871.9	4740.1
2007	19036.7	5014.2
2008	17428.9	4202.6
2009	18081.8	6345.2
2010	19524.9	7264.4
2011	19115.75	6939.5
2012	19263	7050.2
2013	19484.9	7180
Sum	197961.3	68645.1
Average	17996.4	6240.4
Total yield (ton)	17.9	6.2

Findings

Top watermelon producing provinces are mentioned in Table 3. The virtual water content of watermelon is calculated, dividing the provincial water requirement by average crop yield.

$$VW\ of\ watermelon\ (Irrigated) = \frac{5520.5}{27.194} = 203\ m^3 ton^{-1}$$

$$VW\ of\ watermelon\ (Rainfed) = \frac{5520.5}{7.4612} = 739.8 m^3 ton^{-1}$$

Top provinces of melon production are mentioned in Table 4

$$VW\ of\ melon\ (Irrigated) = \frac{5329}{17.9964} = 266.49\ m^3 ton^{-1}$$

$$VW\ of\ melon\ (Rainfed) = \frac{5329}{6.2404} = 853.95\ m^3 ton^{-1}$$

Water use efficiency is the reverse of virtual water. Table 5 shows water use efficiency for each product separately.

Results indicated that the irrigated watermelon product and rainfed melon product have the highest and the lowest water efficiency, respectively.

Table 3) Top watermelon producing provinces [21]

Province	Water requirement (m^3ha^{-1})
Khouzestan	4120
Kerman	4472
Khorasanrazavi	7525
Fars	5965
Average	5520.5

Table 4) Top melon producing provinces [21]

Province	Water requirement (m^3ha^{-1})
Khorasanrazavi	5127
Sistan and Balouchestan	5683
Isfahan	5713
Qazvin	4795
Average	5329

Table 5) Water use efficiency for each product (kg m³)

Product	Water use efficiency
Watermelon (Irrigated)	4.9
Watermelon (Rain fed)	1.3
Melon (Irrigated)	3.7
Melon (Rain fed)	1.1

In this section, by using the data from National Customs Administration, the value of exported melon and watermelon were analyzed in Rials during 11 years (Table 6). The largest melon and watermelon importers from Iran, according to Statistics of The Islamic Republic of Iran Customs Administration, are Iraq, UAE, Turkey, Germany, and England (Diagram 7).

For exported watermelon and melon, the water use intensity, water dependency, and water self-sufficiency were analyzed and shown in Table 7.

Table 6) The value of export tax for melon and watermelon crop in Rial [25]

Year	Value of export tax
2003	147245819894
2004	219473714715
2005	429339864319
2006	297705621405
2007	426362735263
2008	583747935400
2009	23962558085
2010	17479854798
2011	17863055849
2012	70433953759
2013	71461313188
2014*	115726347587
Total	2420802774262

*We have considered 2014 here because crop year for 2013 included 2014.

Table7) Indicators condition of water resources management (%)

Crop	Water Use Intensity	Water dependency	Water self-sufficiency
Watermelon	12.1	0	100
Melon	6.8	0	100

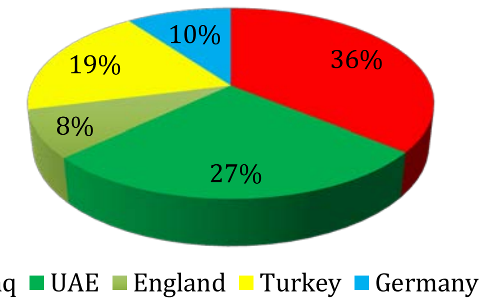

Diagram 7) Watermelon and melon exporting countries (Source: IRICA)

According to the Table 7, the water use intensity of watermelon is twice greater than melon.

It is remarkable that in both products, water dependency is zero and water self-sufficiency is hundred. It means that all the water consumed for watermelon and melon production is indeed referred to the internal water resources. So, it cannot promote national water conservation in a water-stressed country such as Iran.
The virtual water amount was also analyzed and the results are obviously shown in Table 8.
Irrigated melon is the most water consumption among others. The total virtual water of objective products is shown in Table 8. The total weight of exported farm crops during the study period was 122.786 tons [25]. Therefore, domestic consumption of these crops is 4.877.4130 tons. It is important to pay attention that in exporting segment, production (melon and watermelon) and cultivation types were not separated. Hence, for computing the volume of virtual water exports, the virtual water content is taken 515.8 m^3ton^{-1} as an average. By considering the exported crops, virtual water export will be 218 MCM. Also, we can distinguish during 11 years in average, for each cubic meter of water, just 11000 Rials (0.3$) was earned by the country. It is found that for per kilogram of exported watermelon and melon, only 5720 Rials (0.14$) was gained, which is not equal to the value of transferred virtual water.

Table 8) Total virtual water content of crops during study period

Crop	Total Virtual water(11years)(MCM)
Watermelon(Irrigated)	6456.69
Watermelon(Rain fed)	1184.17
Melon(Irrigated)	4164.87
Melon(Rain fed)	137.67
Sum	11819.42

Discussion
Regarding the information that was printed by the journal of "International Trade Center", announced purchase value per kilogram of watermelon from china is 78 cent, while we suppose each watermelon is about 5 kg and 1 dollar considered to be 40000 Rials. Thus, for importing each watermelon, we have to pay 160000 Rials (4$). To clarify the amount of water consumption in both products, following issue is presented:
According to the information of Iranian Water and wastewater Company, the average per capita consumption of water is about 250 l per day in summer; however, it is about 190 l per day in the other seasons, the average is 220 l per day. If we consider the population of Iran as 80 million, during a year, Iranian use 642 MCM cubic meter (6424 MCM m^2) of water; so, the volume of water, which is used in these products, is equal to almost 2 years of water usage by Iranian during 2003-2013.

Conclusion
Due to the data from exported crops, first, economic value is remarkable but in fact, income which from 5 kg watermelon is 28600 Rials. As it is clear, Iran is located in an arid and semi-arid region, where water supply is an important issue. It is needless to say that all the world is facing the climate change, drought, and the population rise. In Iran, considering the high water usage (as virtual water) of watermelon and melon, it is better to import them or at least diminish the cultivated area instead of production. By calculations, for the exported water (m^2) in form of virtual water, just 1100 Rials is gained as the profit and it is unfortunately quite a low amount. In addition, for producing per kg of watermelon, 572 Rials is earned, while the costs of supplied water, cultivation, fertilizer, and something like that are much more than it. As the results showed, Iran is dependent on internal water resources on producing these crops. Totally, it is better to import this product as a substitute of production.

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