Optimization of Virtual Water Trade with Emphasis on Agricultural Sector Support From Two Perspectives: Maximizing Farmers' Welfare and Employment.

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Research Article

Keywords: Virtual Water, Agricultural Sector, Multi – Objective Programming, Welfare, Employment

Posted Date: January 25th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1167478/v1>

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Optimization of Virtual Water Trade with Emphasis on Agricultural Sector Support from Two Perspectives: Maximizing Farmers' Welfare and Employment.

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Abstract

Water scarcity has become a global issue in agriculture. Therefore, sustainable use of water resources is essential. A concept that many planners and experts have recently emphasized in the field of water management that is the water footprint and virtual water trade. The objectives of this study are to maximize farmers' welfare, minimizing water consumption and maximizing employment in agriculture simultaneously. Multi-objective mathematical programming method was used to achieve the research objectives. The results indicated that the area of crops and fruits in Iran is reduced compared to the base year, especially in the irrigated activity, Also, saving water is about 15 billion m³ due to the change of cultivation pattern. Based on the model results, 2 billion m³ of water are imported into Iran by changes in the pattern of trade. The proposed model states water- saving 15 billion m³. The model suggests if the goal of policy -makers is to increase

employment in agriculture or farmer's social welfare, it should cultivate more fruits than crops and If the goal is to protect the environment and save water, it should replace crops with fruits.

Key words: Virtual Water, Agricultural Sector, Multi – Objective Programming, Welfare, Employment.

1. Introduction

Today, water scarcity has caused a lot of problems in providing safe drinking water, adequate production of agricultural crops, and the general process of human life. Hence, providing conditions that ensure the sustainability of water resources requires that the use of water on a national or even global scale be investigated ([Ming and Chen, 2013](#)). The fact is that 70% of the Earth's surface is covered by water. However, only less than one percent of it is available as surface and underground water for human, plant and animal use. Most importantly, even the same amount has not been distributed evenly and equitably between regions and countries ([Hausmann and Patrick, 2013](#)). On the other hand, the scarcity of water resources will create a strong competition between different sectors of the economy to seize it. Given the high share of water use in agriculture, with a share of 70% of the total water resources, the world's largest water consumer ([Molden, 2007](#)). On the other hand, due to the low economic value of water in it than other consumer sectors, the change in cultivated area and pattern of agricultural crops, the change in the pattern of trade in crops, the impact on food security and farmers' welfare is one of the consequences of water scarcity in agriculture ([Lui et al., 2014](#)). In general, two categories of water scarcity can be introduced. 1. The physical shortage of water resources due to population growth

([Avazdahandeh and Khalilian, 2021](#)) and, consequently, surplus of demand for water relative to its supply. 2. The economic shortage of water due to the potential for adaptation to water scarcity, influenced by technological conditions, credit, water resource management and economic policies, optimal allocations and water efficiency ([Tuton and Ohlsson, 1999](#)). But the reality is in many developing countries, including in Iran, the second category of shortages in relation to water resources is more important than the first category, perhaps the poor performance in this regard is the pressure exerted on the deficiencies of the first category is exacerbated. To overcome these constraints, various strategies, especially in the agricultural sector, are among the largest water users worldwide ([Molden, 2007](#)). Increasing water productivity through the development of new technologies, improving water technical efficiency (engineering), and choosing a virtual water market-based business strategy ([Faramarzi, 2010](#); [Garrido et al., 2011](#); [Lui et al, 2014](#)). In the meantime, the concept highlighted by many planners and economic experts and water resources for the sustainable management of water resources is recently the water footprint and, consequently, the issue of water trade in its virtual ([World Bank, 2010](#)). Virtual water is a combination of two concepts of agriculture and economics that emphasize water as a key input for production. From the agricultural point of view, the term refers to the amount of water used for agricultural production. While its economic meaning refers to the cost opportunity of water, the value of other uses of water (the production of alternative outputs in industries and mines or in reproduction activities) ([Mekonen and Hoekstra, 2011](#); [Wichlenz, 2004](#)). The opportunity cost discussion on virtual water, is of paramount importance especially when limited resource efficiency has been investigated. The economic concept of virtual water is closely to the concept of relative advantage based on the abundance of water inputs ([Allen, 2003](#); [Reimer, 2012](#)). Many studies have been done in the field of virtual water, for example: [Gao, L et al \(2014\)](#) used the

model that had been used to assess mine water use strategies in a coal mine in Queensland, Australia. The simulation results indicated that some tested strategies could reduce water use costs by more than 40%, and raw water needed by more than 50%. Further, the optimization revealed more easy-to-handle strategies that could save more than 40% of pipeline water and reduce the risks of penalties associated with discharge and of losing production due to insufficient water.

[Lamastra, L et al \(2017\)](#) showed that the composition of virtual water flows was different; Italy imports significant amounts of grey water from China, depending on the different environmental strategies adopted by the two selected countries. This difference could be also related to the fact that traded commodities were very different; the 91% of virtual water imported by Italy was connected to crops products, while the 95% of virtual water imported by China was related to the animal products. Considering national water saving and global water saving, appeared that Italy imports virtual water from China while China exerts pressure on its water resources to supply the exports to Italy. [Fu, Y et al \(2018\)](#) did a study that its objective was supplying the agricultural products virtual water trade evaluation system, determining quantitatively the virtual water flow within the region & regional. Results indicated that the regional differences in virtual water content for each crop were significant, China had a trade surplus in global virtual water trade of agricultural products and China's agricultural products virtual water imports have increased year by year.

[Bazrafshan et al \(2019\)](#) focused on the water footprint components, water footprint accounting and virtual water trading of Saffron Production at the provincial and national level. The average water footprint of the Saffron production in Iran was $4659 \text{ m}^3 \text{ kg}^{-1}$. The share of green, blue, white, and grey water footprints are estimated as 12, 42, 40, and 6 percent, respectively. The total water footprint of Saffron production was around 1541 MCM yr^{-1} that the share of exported virtual water was $1354.6 \text{ MCM yr}^{-1}$. [Liu, X et al \(2019\)](#) used China's multiregional input-output tables

straddling two periods to trace the trade of a given region's three types of goods: local final goods, local intermediate goods, and goods that shipped to other regions and countries. They found that goods traded inter-regionally in China in 2012 embodied 30.4% of all water used nationwide. Nationwide, water use increased substantially over 2007–2012 due to greater shipment volumes of water-intensive products. In fact, as suspected, the rise in value chain-related trade became a major contributing factor. Considering the importance of agriculture in the country's economy. [Qasemipour et al \(2020\)](#), [Su et al \(2014\)](#), [Aldaya et al \(2020\)](#) and [Ye et al \(2017\)](#) also studied about virtual water. The advantage of our study over other studies is that we have comprehensively considered both crops and fruits. No comprehensive study has been conducted in Iran so far also we considered welfare socially and employment virtual.. For example, [Bazrafshan et al \(2019\)](#) focused on the water footprint components, water footprint accounting and virtual water trading of Saffron Production at the provincial and national level. They did their study only Saffron. But we did our study for all crops and fruits. The objective of this research is to minimize virtual water trade, with the consideration of farmers' social welfare and virtual employment.

2. Methodology

2.1. Assumptions and spatial scope of research

In this research, according to the purpose of the study and Buckwell and Hazell (1972)'s suggestion, the climatic-agricultural characteristics of different regions of the country have been the basis of aggregated because it has taken into account the differences between regions in terms of both climate and agricultural factors in the modeling. Therefore, the FAO's Agro-Ecological Zoning System (AEZ) has been used. This zoning system is the main instrument FAO's of assessment of agricultural land potential and its characteristics at the global, regional, national and

local levels. In this zoning system, Iran is divided into 10 broad agro-ecological zones based on climatic similarities (precipitation and temperature), soil type, types of crops.

Fig. 1. , The FAO's Agro-Ecological Zoning System

2.2. Virtual water

Numerous approaches and methodologies have been used in virtual water studies worldwide.

These studies are divided into two general categories in terms of approach and six in terms of methodology. The following picture illustrates the classification based on these two approaches.

As can be seen in the picture above, the computational approaches are generally divided into two groups from bottom to top and top to bottom, each of which is performed in different ways. Life cycle based assessment is one of the standard methods for assessing the needs and environmental impacts of a crop throughout their cultivated period (Yang and et al, 2003). This is basically a bottom-up approach. The most commonly used approach for calculating virtual water content is

the life cycle assessment method and then the model based on the crop growth period. The crop-based model also provides a systematic tool for calculating virtual water content in terms of the share of green and blue water used in crop production. It also enables the analysis of the effects of changes in various factors such as water availability, fertilizer application, and climate change on crop yield and water content.

Fig. 2. Methods used to calculate virtual water content

Resource: (Yang *et al*, 2003)

2.3. Social value of crops and inputs

2.3.1. Water Valuation

According to internal and external studies and review of Ministry of Energy documents for water pricing, the most common approach in Iran is the residual ratio approach. An important principle in the residual ratio approach is to use social (real) prices rather than market prices. In this method, first data on revenue and costs of a crop are calculated except water cost per unit area. Then, the value of water consumption per unit area is determined with the difference of incomes and costs.

2.3.2. Social value of products and other inputs

The contents of this section are taken from the World Bank's Project Evaluation Guide published in 2012. Accordingly, in order to evaluate the social value of inputs and outputs, it is necessary to first calculate the shadow exchange rate and then calculate the social value of the inputs and outputs.

2.3.2.1. Shadow exchange rate

Exchange rate is an important factor in calculating the shadow social value of products and inputs. The exchange rate in Iran is highly volatile and it is affected by many factors, therefore it should be used the real exchange rate which represents the real purchasing power. There are different ways to calculate the shadow exchange rate. To calculate the shadow exchange rate, the theory of purchasing power equality can be used in both absolute and relative term.

The relative method is used to calculate it in this study. Because the consumer price index is more powerful in Iran and the price of gold in Iran is not sufficiently dynamic due to government interventionist policies. Using the relative purchasing power parity method, the shadow exchange rate (Rial or Toman vs. Dollar) is obtained from:

$$E = E_0 \left(\frac{P_d}{P_f} \right) \quad (1)$$

In above relation, P_d domestic consumer price index, P_f foreign consumer price index, E_0 free exchange rate in the base year and E is shadow exchange rate (Central Bank Balance Sheet of Iran, 2013). Then we evaluate the social value of inputs and outputs. Inputs in agriculture are divided into two groups of tradable and non- tradable inputs. Tradable inputs are a set of inputs

that are traded internationally that in present study including various types of fertilizers, pesticides, seeds and part of machinery. Non-tradable inputs refer to internal inputs which include labor, land, manure and machinery.

2.3.2.2. Social value of tradeable inputs

To calculating of Social value of tradeable inputs, the cost - Insurance – Freight (CIF price) of inputs multiplies shadow exchange rate, then the average cost of shipping the goods plus it. Similarly, with respect to products imported to Iran, their social value is also calculated. In relation to exported goods, their free on board (FOB price) is based on the calculation of their social prices (Vishvanath, 1997).

2.3.2.3. Social value of non - tradeable inputs

To calculate the social value of non-trading inputs that do not have a boundary price, their market value is used to calculate social value. For example, for fertilizer, its market value is used (Vishvanath, 1997).

2.4. Mathematical model

The pattern of regional production and virtual water trade in the agricultural sector of Iran is considered a linear multi-objective model and set of linear constraints. The mathematical framework of this model is as follows:

1) MAX NSB

$$\begin{aligned}
&= \sum_{f=1}^{14} \sum_{g=1}^{10} (\text{yeildzw}_{f,g} \times SPzw_{f,g} - SCzw_{f,g}) \times \text{xcrop}_{f,g} \sum_{v=1}^{12} \sum_{g=1}^{10} (\text{yeildzd}_{f,g} \times SPzd_{v,g} \\
&- SCzd_{v,g}) \\
&\times \text{xcropd}_{v,g} + \sum_{i=1}^{12} \sum_{g=1}^{10} \text{yeildbw}_{i,g} (\text{SPbw}_{i,g} - \\
&\text{SCbw}_{i,g}) \times \text{xfruit}_{i,g} + \sum_{w=1}^8 \sum_{g=1}^{10} \text{yeildbd}_{i,g} (\text{SPbd}_{i,g} - \text{SCbd}_{i,g}) \times \text{xfruitd}_{i,g} - \\
&\sum_{b=1}^{10} \sum_{g=1}^{10} \sum_{gp=1}^9 (\text{dis}_{g,gp} \times \text{tragsportz}_{b,g,gp} \times \text{trcost}_{b,g,gp}) - \\
&\sum_{a=1}^{12} \sum_{g=1}^{10} \sum_{gp=1}^9 (\text{dis}_{g,gp} \times \text{transportb}_{a,g,gp} \times \text{trcost}_{a,g,gp}) + \sum_{b=1}^{10} \sum_{g=1}^{10} (\text{pez}_b \times \text{exportz}_{b,g} - \\
&\text{piz}_b \times \text{importz}_{b,g}) + \sum_{b=1}^{20} \sum_{g=1}^{10} (\text{peb}_a \times \text{exportb}_{a,g} - \\
&\text{pib}_a \times \text{importb}_{a,g}) + \sum_{f=1}^{14} \sum_{g=1}^{10} \text{Pwz}_{f,g} \times \frac{\text{ETz}_f}{\text{yeildz}_f} (\text{importz}_f - \\
&\text{exportz}_f) + \sum_{i=1}^{12} \sum_{g=1}^{10} \text{Pwb}_{i,g} \times \frac{\text{ETb}_i}{\text{yeildb}_i} (\text{importb}_i - \text{exportb}_i)
\end{aligned} \tag{2}$$

$$\begin{aligned}
2) \text{ MAX LAM} &= \sum_{g=1}^{10} \sum_{b=1}^{26} l_{b,g} \times \text{xcrop}_{b,g} + \sum_{g=1}^{10} \sum_{a=1}^{20} l_{a,g} \times \text{xfruit}_{a,g} - \sum_{b=1}^{26} \frac{l_b}{\text{yeildz}_b} \times (\text{importz}_b - \\
&\text{exportz}_b) - \sum_{a=1}^{20} \frac{l_a}{\text{yeildb}_a} \times (\text{importb}_a - \text{exportb}_a)
\end{aligned} \tag{3}$$

$$3) \text{ Min WAT} = \sum_{f=1}^{14} \frac{ET_{f,g}^a}{efirre_g} \times (1 - \text{definx}z_{f,g}) \times \text{xcrop}_{f,g} + \sum_{i=1}^{12} \frac{ET_{i,g}^a}{efirre_g} \times \text{defin}b_{i,g} \times \text{xfruit}_{i,g} - \quad (4)$$

$$\sum_{g=1}^{10} (Swat_g + Gwat_g) \leq 0$$

$$4) - \sum_{b=1}^{26} yeildz_{b,b,g} (1 - \%seed) \times \text{xcrop}_{b,g} + t_{b,g} \leq 0 \quad \forall b,g \quad (5)$$

$$- \sum_{b=1}^{26} \text{convert}z_{b,g} \times t_{b,g} + \sum_{b=1}^{26} \text{natcog}z_{b,g} - \sum_{b=1}^{26} \sum_{gp=1}^9 \text{transport}z_{b,g,gp} + \sum_{b=1}^{26} \sum_{gp=1}^9 \text{transport}z_{b,g,gp} - \quad (6)$$

$$\sum_{b=1}^{26} \text{import}z_b + \sum_{b=1}^{26} \text{export}z_b \leq 0 \quad \forall g$$

$$- \sum_{i=1}^{12} yeildbw_{i,g} \times \text{xfruit}_{i,g} - \sum_{w=1}^8 yeildbd_{w,g} \times \text{xfruit}d_{w,g} + \sum_{a=1}^{12} \text{xw}_{a,g} \leq 0 \quad \forall a,g \quad (7)$$

$$- \sum_{a=1}^{20} \text{convert}b_{a,g} \times t_{a,g} + \sum_{a=1}^{20} \text{natcog}b_{a,g} - \sum_{a=1}^{20} \sum_{gp=1}^9 \text{transport}b_{a,g,gp} + \sum_{a=1}^{20} \sum_{gp=1}^9 \text{transport}b_{a,g,gp} - \quad (8)$$

$$\sum_{a=1}^{20} \text{import}b_a + \sum_{a=1}^{20} \text{export}b_a \leq 0 \quad \forall g$$

$$\sum_{f=1}^{14} \text{xcrop}_{f,g} - \text{irrland}z_g + \sum_{v=1}^{12} \text{xcrop}d_{v,g} - \text{dryland}z_g \leq 0 \quad f \in b, v \in b \quad \forall g \quad (9)$$

$$\sum_{i=1}^{12} \text{xfruit}_{i,g} - \text{irrland}b_g + \sum_{w=1}^8 \text{xfruit}d_{w,g} - \text{dryland}b_g \leq 0 \quad i \in a, w \in a \quad \forall g \quad (10)$$

$$\left(\sum_{f=2,7,14} \text{xcrop}_{f,g} \times yeildzw_{f,g} + \sum_{v=2,7,12} \text{xcrop}d_{v,g} \times yeildzd_{v,g} \right) \times \sum_{n=1,2,3} \text{tdn}_n + \left(\sum_{f=1,2} \text{xcro} \right) \quad (11)$$

In above equations, equation (2) is first objective function that shows net social benefit. Equation (3) is second objective function that implies employment in agriculture. Equation (4) is third objective function that shows water consumption in agriculture. Equation (5) and (6) indicates crop production and consumption ballance. Also, equation (7) and (8) shows fruits production and

consumption balance. In this model, the resource constraints include land and water resources. Equations (9) and (10) are land constraints for crops and fruits. Finally, equation (11) is livestock feed restriction. Model's subscripts are: crops: $b=1,2,3,\dots,26$, f, v : irrigated and dry crops fruits: $a=1,2,3,\dots,20$, i, w : irrigated and dry fruits and regions: $g=1,2,3,\dots,10$.

3. Result

3.1. Results of virtual water calculation

In the first step, model ran through the application of multi objective mathematical programming method. Table 1 shows the amount of virtual water for irrigated crops and consumption value of one m^3 of water in crop production in (2012-2013). Also Table 2 indicates the amount of virtual water for irrigated fruits and consumption value of one m^3 of water in the same period. One thing to note about this Table: crops like rice, sugar beet and vegetables, there is little difference between the virtual water content in terms of quantity and value.

Table. 1. Virtual water for irrigated crops and consumption value of 1 m^3 of water (2012-2013).

Virtual water	Wheat	Barely	Corn	Beans	Cotton	Potato	Alfalfa	Oilseed	Onion	Tomato	Sugar beet	Vegetables	Rice	Fodder corn
Amount														
t														
(m^3 /ton														
)	2046	1693	1997	2403	4757	471	1772	3907	368	321	247	433	2005	233

Value														
(Toman														
/m³)	236	314	703	373	235.7	2095	121	413	1248	1794	337	544.2	1846	444

Source: Researcher's calculations.

Table. 2. Virtual water for irrigated fruits and consumption value of 1 m³ of water (2012-2013).

Virtual water	Tea	Apricot	Pomegranate	Pistachio	Grapes	Olive	Apple	Oranges	Barberry	Date	Saffron	Cherry
Amou												
nt		201	136	836		201	106		637	613	13951	216
(m³/to	1086	3	1	5	896	9	3	910	5	2	39	9
n)												
Value												
(Toma	3193.	243	297	396	362	401	210	399	361	913	3588	389
n/ m³)	6	1	0	1	9		9	7	6			2

Source: Researcher's calculations.

The highest amount of virtual water is related to cotton, 4757 (m³/ton) and the lowest belongs to fodder corn. And the highest value was for the potato and the lowest value was for alfalfa. The highest amount of virtual water in fruits is related to saffron, with an average of 1395139 (m³/ton). The exception of saffron, pistachio has the highest amount of virtual water about 8365 (m³/ton). The lowest belongs to oranges with 910 (m³/ton). Comparing the quantitative and valuable content of virtual water in fruits, we see that apricot has the same amount and value. The more important

point is that value virtual water for pistachio, oranges and cherry is almost equal while the amount of virtual water is very different from each other.

The virtual water balance of crops has been showed in [Table 3](#). As the calculations indicate, the net amount imports of water is about 35.5 billion m³. It means that Iran can save water in crops about 35.5 billion m³.

Table. 3. The virtual water balance of crops per billion m³

crops	Net export (ton)	Water balance (billion m3)
Wheat	-3906800	-7.99
Barely	-653213	-1.1
Corn	-1955266	-3.9
Beans	-182104	-0.43
Cotton	178403.9	0.08
Potato	260026.5	0.09
Alfalfa	765791.4	0.24
Oilseed	601476.4	0.26
Onion	-11278561.6	-2.8
Tomato	-54732.3	-0.26
Sugar beet	-4264580	-16.7
Vegetables	-37398.3	-0.07
Rice	-4003222	-0.93
Fodder corn	12427.77	0.02

Source: Researcher's calculations.

Table 4 presents the virtual water balance of fruits per billion m³. Accordingly, Iran has imported about 401 mm³ water through the export of tea and olives in 2013 and has exported about 2961 mm³ water with the export of other fruits. The largest amount import water has been through tea and the largest amount export water has been through pistachio. In contrast, the lowest amount of water import has been through olive and the lowest amount export has been with barberry. Therefore, in horticulture sector unlike crop sector, 2560 mm³ water exits from Iran. By comparing the results of Tables 3 and Table 4, we conclude that if policy – makers want to save water and achieve environmental goals. They should seek to replace crops with horticulture crops.

Table. 4. The virtual water balance of fruits per billion m³

Fruits	Net export (ton)	Water balance (billion m³)
Tea	-35880.4	-0.04
Apricot	6480.097	0.01
Pomegranate	12181.77	0.02
Pistachio	124837	1.04
Grapes	545629	0.48
Olive	-453.809	-0.0009
Apple	183319.2	0.19
Oranges	98309.59	0.09
Barberry	278.553	0.001
Date	143750.2	0.9
Saffron	136.605	0.2
Cherry	15969.61	0.03

Source: Researcher's calculations.

3.2. Model of proposed cropping pattern

Table 5 compares the status of the virtual water trade balance in agriculture between the base year and the proposed model. As it can be seen, if the proposed model is implemented, about 2 billion m³ water will be imported into the country, which could be a reduction of pressure on water resources.

Table 5. Comparison of the virtual water trade balance between the base and proposed model (crops).

	proposal model	Base model	Rate
Export of virtual water (mm ³)	2176.6	835.5	1.6
Import of virtual water (mm ³)	37525.6	33054.2	0.13
Net export of virtual water (mm ³)	-35349	-32218.6	0.1

Source: Researcher's calculations.

Table 6 compares the state of virtual water balance in the garden sector between the base year and the proposed model. As shown in the Table, if the proposed pattern is implemented that it will result in 0.24% increase at virtual water exports relation to base year.

Table. 6. Comparison of the virtual water trade balance between the base and proposed model (fruits).

	Proposal model	Base model	Rate
Export of virtual water (mm ³)	4048.6	3018.4	0.34

Import of virtual water	407.9	102.7	3
(mm ³)			
Net export of virtual water	3640.7	2915.7	0.24
(mm ³)			

Source: Researcher's calculations.

3.3. Result of virtual labor trade

As shown in [Table 7](#), because Iran is a net importer of crops based on the proposed model, so it is an importer of labor in the agriculture trade sector. Iran in production of wheat was the largest importer of labor among other crops. On the other hand, alfalfa in Iran was the largest exporter of labor. So if politicians want to increase employment in the agricultural sector, they must cultivate crops that export labor.

Table. 7. Labor balance for crops.

Crops	Net export (ton)	Labor balance (Person - days /ton)
Wheat	-7409303	-68165587.6
Barely	-1318301	-10941898.3
Corn	-2061878	-19794028.8
Beans	-445096	-12996803.2
Cotton	547432.7	985378.86
Potato	780079.5	1716174.9
Alfalfa	2297536	5054579.2

Crops	Net export (ton)	Labor balance (Person - days /ton)
Oilseed	1804429	4150186.7
Onion	-15175855	-18211026
Tomato	0	0
Sugar beet	-2833202	-25215497.8
Vegetables	0	0
Rice	0	0
Fodder corn	0	0

Source: Researcher's calculations.

Comparison of the crop export and import situation of virtual labor in the proposed model compared to the base year shows that the amount of labor export or employment creation is higher in the proposed model than the base year.

[Table 8](#) examines the virtual commerce of labor in the fruit sector based on the proposed model. As can be seen, Iran's proposed model can be a net exporter of the virtual labor and create employment opportunities. According to the proposed model, Iran will have a 26% net export in the fruits sector as compared to the base year. Among fruits, pistachio and grapes exported the largest virtual labor. By comparing the virtual labor of horticultural and agricultural crops, if Iran is looking to maximize employment, it should cultivate more horticultural than agricultural crops because other than tea and apricot, other fruits are exporters of virtual labor. The total export of virtual labor of horticultural crops is much higher than that of agricultural crops. According to the results of [Tables 7](#) and [8](#), in the specified period, Iran is a net importer of labor in the production of agricultural crops and a net exporter of labor in the field of horticultural crops.

Table. 8. Labor balance for fruits.

fruits	Net export (ton)	Labor balance (Person - days /ton)
Tea	-62953.1	-1864914
Apricot	-22374.9	-148490.6
Pomegranate	31568.69	155839.6
Pistachio	181289	4323329.4
Grapes	742004.2	4323329.4
Olive	1645.55	1590602.6
Apple	316675.7	1745356.1
Oranges	301426	1150657.4
Barberry	5330.5	226382.21
Date	94334.45	1140096.4
Saffron	151.82	3355259.7
Cherry	42125.48	253932.58

Source: Researcher's calculations.

3.4. Objective function values

Table 9 gives the values of the target functions. As it can be seen, the social profit of crops has decreased in the proposed model compared to the base year, which is reasonable given the reduced cultivated area. It is important to note that this reduction is offse by the positive trade balance and storage of \$ 6 million due to increased exports. The opportunity created by 15 billion m³ reduction

consumption of water resources against social profit reduction could also have a very high potential for welfare. In fact, in order to save water of one mm^3 , Iran should be waived from 0.0005 million Tomans of social benefits and 0.0002 day - person of employment of the labor.

Table 9. The values of the target functions

Objective function	Proposal model	Base model	Rate
Welfare (m Toman)	114228930	131620360	-0.13
Water (mm^3)	61702.73	76996.551	-0.25
Employment (day-person)	314863800	332472800	-0.05

Source: Researcher's calculations.

4. Discussion and conclusion

In this study, according to the method used in the studies of Fritcher et al (2004), Hoekstra and Hung (2005) and a number of other researchers, the CWR index of actual evapotranspiration (ET_c) was used to calculate virtual water. The results of this calculation show that evapotranspiration and water requirement in virtual water content are uncontrolled components and irrigation efficiency and yield are controllable components. The results indicated that the highest virtual water of crops was for cotton 4757 m^3 /ton and the lowest virtual water was for fodder corn 233 m^3 /ton. These results are similar to [Su et al \(2014\)](#)'s study. In their paper, at the same time, the planting ratio of food crops, such as corn, reduces, while the planting ratio of cash crops, such as cotton, vegetables, and fruits, increases. Through regional virtual water strategy in the basin, with the crops of different districts having comparative advantages, the proportion of green water

utilization and the blue water use efficiency are improved. Similar results were obtained in [Ye et al \(2017\)](#)'s research. They concluded that when considered the virtual water trade of eight agricultural products in water allocation procedure, the proportion of agricultural consumption decreased to 45% in total water demand, while the groundwater consumption decreased to 24% in total water supply. Virtual water trade overturned the traditional components of water supplied from different sources for agricultural consumption, and became the largest water source in Beijing.

The highest of net import water in the crop sector was about 17 billion m^3 for oil seeds and the lowest was for maize 0.07 billion m^3 . On the other hand, the highest net export water was related to vegetables 0.26 billion m^3 and the lowest was related to alfalfa about 0.02 billion m^3 . In total in crop sector and base year, Iran was net importer water 33.47 billion m^3 . In the proposed model of crop, the highest net import of virtual water was through wheat import 15.15 billion m^3 and the lowest net import was through beans imports about 1.4 billion m^3 . Accordingly, the highest net export of virtual water was related to vegetables with 0.78 billion m^3 and the lowest was for sugar beet exports with 0.000007 billion m^3 . Overall, in the field of crops, Iran will be a net importer of water at 35.7 billion m^3 , which increased by about 3 billion m^3 compared to the base year.

In relation to fruits, the highest amount of virtual water (excluding saffron) was 8365 m^3 /ton for pistachio, and the lowest was 910 m^3 /ton for oranges. Also, the highest net import of water through tea was 0.04 billion m^3 and the lowest was for olive 0.0009 billion m^3 . According to the results, the highest net export of fruits was related to export of pistachio 1.04 billion m^3 and the lowest was through barberry export 0.001 billion m^3 . In total, Iran exported about 2.9 billion m^3 of water through fruits in the base year. The proposed model states that the highest net export of virtual water in fruits sector was related to pistachio (1.5 billion m^3) and the lowest was through

olive exports (0.003 billion m³). In contrast, the highest net import water is through tea that it imports 0.06 billion m³ and the lowest is through apricot with 0.04 billion m³. Overall, in the proposed model, net export of water by fruits is about 3.5 billion m³. These results are similar to [Qasemipour et al \(2020\)](#)'s study. They showed that The results show that the northern part of the country, with no water scarcity, imported virtual water through the trade of goods and services, while severely water-scarce regions were net virtual water exporters. Iran had a net export of 1811Mm³ per annum. While blue water resources (surface and groundwater) accounted for 92.2% of the national water footprint, 89.1% of total exports were related to the agriculture sector. [Aldaya et al \(2020\)](#) also indicated that Spanish agricultural trade grew both in import and exports, overcoming water scarcity limitations with the virtual water trade, with net water imports being predominant and even widening the gap during the 1996–2006 period of study. The agricultural economy showed a clear dependence on virtual water imports in the form of cereals and animal feed, which has continued to grow in the last 25 years. [The results of Oki et al \(2017\)](#)'s study indicated same findings: water has an extremely low unit price, and a tremendous volume of water is consumed per person each day and the rich but water-scarce countries tend to reduce local water consumption by importing virtual water. Also they demonstrate that nations characterized by net virtual water exports have higher water resources and income per capita and that no countries fall below a certain threshold with respect to both GDP and water resources.

The results of calculating the economic value of water showed that the highest value of consumption of 1m³ water was 2095 Tomans for potato and the lowest was 121 Tomans for alfalfa. Regarding the fruits, the highest value of 1 m³ was obtained 3997 Tomans from oranges and the lowest value 401 Tomans from olives. Our findings about economic value is similar to [Lowe et al \(2020\)](#). They showed that the total value of the virtual water used to produce one tonne of durum

wheat pasta (\$212). More importantly, the case study also highlights how variations in economic value between multiple locations where durum wheat is cultivated (Saskatchewan \$0.10 m³ , Arizona \$0.08 m³ and Baja California \$0.24 m³) indicate relative water scarcity and thus impact, as well as the potential for a more efficient allocation of virtual water. [Pouran et al \(2017\)](#) also concluded that The economic value of blue water of West Azerbaijan, Bushehr, Isfahan, Semnan, Ilam provinces according to maximizing water productivity are 1461, 4060, 7240, 467 and 3927 Toman per cubic meter of blue water, respectively. In relation to gray water for West Azerbaijan 722 and for Isfahan is 833 Toman per cubic meter of gray water. In general, the provinces have more bad water situation, the economic value of water content of their products is higher.

In this study, a multi-objective planning model was used that its aims were to maximize social welfare, maximizing the value of virtual water trade as well as minimizing pressure on water resources and maintaining optimal employment. Using the proposed model, the welfare will be 11625790 million Tomans, the reduction of pressure on water resources will be about 15 billion m³ and the optimal employment level will be about 3148.63800 person-day. Regarding the virtual labor balance, the results of the proposed model show that although it imports crops and fruits then it will lead to import labor into the country (this represents an increase of about 18% compared to the base model), but instead, there will be a 79% growth in the export of labor through the export of crops.

5. Recommendation

According to the results of the research, by applying the proposed model, water consumption, profit and employment will decrease. On this basis and in view of the Iranian water crisis, therefore, in the country, if the goal of policy -makers is to increase employment in agriculture or

farmer's social welfare, it should cultivate more fruits than crops and If the goal is to protect the environment and save water, it should replace crops with fruits.

Declarations:

Ethical Approval: All authors kept to the Ethical Responsibilities of Authors.

Consent to Participate: Not applicable.

Consent to Publish: The authors declare that they consent to publish this manuscript.

Competing of Interest: The authors declare that they have no conflict of interest.

Authors Contributions: Conceptualization: Fahimeh Bahrami; Methodology; Somayeh Avazdahandeh: Formal analysis, Writing – review; Mohammad Reza Nazari: Investigation; Seyed Fazlollah Ranjbaran: editing.

Funding: No funding was received for conducting this study.

Availability of data and materials: The authors announce that there is no problem for sharing the used model and codes by make request to corresponding author.

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