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Article

Paradox of Limited Water Resources in Iran and Goals of Self-Sufficiency in Agricultural Sector

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Abstract: Lack of water resources in Iran, especially in recent years, has faced the agricultural sector as the most important consumer of water resources, with serious challenges. In Iran, the agricultural sector accounted for more than 90% of water consumption. However, the focus on domestic production and self-sufficiency policy in staples (wheat, barley, maize and rice) has been emphasized in general agriculture's policy. This study was conducted to estimate the imported virtual water from the imports of basic products in Iran using defined indicators during 1961-2013. Also this study investigated the possibility of achieving self-sufficiency due to the limited water resources in Iran. The results of this study showed with the increase in cereal imports, virtual water imports from 0.28 billion cubic meters in 1961 increased to 17.6 billion cubic meters in 2013 and on average about 60% of virtual water imports in strategic products is related to wheat imports during the past 53 years. Other products in cereal (barley, maize and rice) are also indicative of the general trend of increasing imports of virtual water in development plans. The estimated long-run elasticity of virtual water imports in the cereal group compared with the country's water resources also showed that with a one percent reduction in renewable water resources of the country, the virtual water import in the main cereal group will increase equivalent to 2.89 percent and the determination coefficient more than 90 percent also confirms this negative relationship. According to this result and the emphasis on the fact that renewable water resources per capita in the country is falling increasingly, it cannot be expected that domestic production could compensate for the imports of the cereal group and virtual water imports with current technology, without increasing the water productivity and without additional harm to water resources.

Keywords: Virtual water; Agriculture; Staples; Water resources per capita

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1. Introduction

With shortage of freshwater resources in the world, a topic which has been of concern about the impact of trade different products on the use of water resources in recent years, was water trading that is referred to as virtual water trade (VW) [1, 22]. By definition, virtual water is the amount of water a commodity or a product of agricultural uses in the production process to reach the stage of development and its value is equal to the total water used in the different stages of the production chain from start to finish [1, 6]. In this definition, virtual attribute implies that most of the water consumed in the production process does not have a physical presence in the final product and in fact, at the end, a tiny fraction of the water used will be remained as real water in product texture. The important thing is that the virtual attribute is not meant to be unreal. It should be stated explicitly that virtual water is quite real water [2]. Virtual water trade is an essential tool and standard in calculating national actual water use. During the last 40 years, trade in virtual water has been rising steadily. In fact, 67 percent of world trade in virtual water is associated with global trade in crops and 23 percent of livestock products and related products and only 10 per cent belongs to industrial production [6]. Due to worsening water crisis in many countries, the issue of virtual water trade in

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planning and trade policy-making in agricultural products is of great importance, especially in countries with arid and semi-arid conditions [2, 11]. Paradoxically, Iran's structure in the agricultural sector is that, the country is faced with limited water resources and the agriculture sector is accused mainly for the indiscriminate use of water resources with the current products on the one hand and in the second paragraph of agricultural policies issued in the year 2011, "Food security by relying on internal resources and attaining self-sufficiency in the production of basic products" were emphasized on the other hand. In fact, self-sufficiency does not mean dependence on imports and the goal is supply the country's domestic need by domestic production. However, one must consider that in the current situation, achieving the self-sufficiency would be realistic to what extent. The studies conducted in Iran were mainly regional and large studies such as those that have been investigated in the present study have no much history. On a global scale, the results by Fraiture et al. (2004) showed that in 1995, the sum of all imports included 215 million tons of cereal, which in the case of lack of cereal imports, importing countries were forced to spend 433 cubic kilometers of their effective precipitation (rainfall plus irrigation) and 178 cubic kilometers of irrigation water from local water sources [5]. The study by Chapagain, et al. (2005) showed that the total amount of water required in importing countries was 1605 Gm y^{-1}, if all imported agricultural products were produced inside the country. In the exporting countries, however these products are produced only with 1253 Gm y^{-1} which make saving of 352 Gm y^{-1} of water [3]. Silva et al. (2016) in a study in Brazil, have determined national water footprint of food consumption in Brazil, linking the virtual water trade in goods with the main agricultural, water shortages, water sufficiency and dependence of water in each region of Brazil. Their results showed that the average water footprint of food consumption in Brazil was 1619 M^3 per year per person [9]. In a study by Serrano et al. (2016), it demonstrated that the total per capita water footprint was 2.280 m^3 for EU consisting mainly of green water that has been removed in conventional calculations of water. The use of blue and gray water in the European water policy only includes 32% of the total water footprint. They have also found that Europeans accounted for 585 cubic kilometers of virtual water or about 28 percent of global virtual water trade flow in 2009 [8].

Due to the limited water resources in Iran and Iranian macro targeting for self-sufficiency in staples (wheat, barley, maize and rice), this study seeks to answer the question: whether the current domestic production could be considered as a reliable strategy for the replacement of imports and lack of national import dependency in the long run or not?

2. Materials and Methods

This study conducted an economic analysis of virtual imports for cereal group (as the most important country's import basket) during the period 1961 to 2013, an analysis of various development plans and its relation to country's water resources. The average amount of virtual water, a product (in this study crop) could be proportionally calculated from the average water requirement to the average yield of the product [10]:

$$VWC_{c,j} = \frac{\overline{CWR}_{c,j}}{\overline{Y}_{c,j}} \tag{1}$$

Where $VWC_{c,j}$ is the amount of water used to produce one ton of product c in year j in terms of $(m^3 ton^{-1})$ and $\overline{Y}_{c,j}$ is the average yield of product c in cereal group in j year in terms of $(ton \quad ha^{-1})$ and $\overline{CWR}_{c,j}$ is the amount of water used for one hectare of the product in terms of $(m^3 ha^{-1})$. The average cereal yield was calculated using a weighted average for the whole country. Virtual water trade for each product of cereal including import is calculated by multiplying the quantitative amount of import or export of the product in the related virtual water:

$$VWI_{c,j} = VWC_{c,j} \times I_{c,j} \tag{2}$$

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$VWI_{c,j}$ is the virtual water import for product c (of cereal) in year j in terms of (m^3y^{-1}) and $I_{c,j}$ is based on the value of annual imports of the product c in year j (m^3y^{-1}). The total import of virtual water (TVWI) for the country was calculated as follows:

$$TVWI_j = \sum_{c=1}^{M}(VWI_{c,j}) \quad (3)$$

In equation (3), $TVWI_j$ is the total import of virtual water in year j, M is the number of products imported from the cereal group. Thus, the contribution of each product of cereal will be calculated from the following formula:

$$S_W = \frac{VWI_{W,j}}{TVWI_j}\times 100 \quad (4)$$

$$S_B = \frac{VWI_{B,j}}{TVWI_j}\times 100 \quad (5)$$

$$S_M = \frac{VWI_{M,j}}{TVWI_j}\times 100 \quad (6)$$

$$S_R = \frac{VWI_{R,j}}{TVWI_j}\times 100 \quad (7)$$

Where S_W, S_B,represent a share of imported virtual water for wheat, barley, maize S_R and S_M and rice crops from the virtual water of whole cereal, respectively and $VWI_{W,j}$,and $VWI_{M,j}$, $VWI_{B,j}$ $VWI_{R,j}$ are the imported virtual water for wheat, barley, maize and rice, respectively. Next, we consider the amount of imported virtual water in Iran for any of the products in cereal (wheat, barley, maize and rice) during the period 1961-2013 and the total amount of imported virtual water for the cereal group in the same period as well as the share of each product will be estimated. This analysis is separately presented according to different development plans and finally the relationship between water resources restrictions and the imported virtual water is discussed. The information contained in this study have been extracted from Food and Agricultural Organization (FAO) [4] for cereal imports during the period 1961-2013 and report on water resources in the organization.

3. Results

Results of the survey and estimate the amount of virtual water imports products from cereal group over the past 53 years shows that the main contribution has been associated virtual water import wheat imports to the country. So on average about 60% of virtual water imports in strategic goods related to import wheat during the past 53 years. As the results of this table shows, imports of virtual water has been rising in all four major cereal product. In the case of wheat, wheat self-sufficiency by the year 2004 and the beginning of the celebration, the virtual water imports were reduced and the process went on for years, But the lack of real self-sufficiency in wheat production and lack of attention to efficiency in the production of this product, Imports of wheat and consequently the virtual water import continued again. In the case of barley, imported the greatest volatility and consequently the maximum swing virtual water import happened during the past 53 years. Finally in 2013, the import of virtual water import wheat, rice, corn and barley were respectively 8.02, 3.65, 4.89 and 1.09 billion cubic meters.

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Table 1. Virtual water imports for cereal group and share of them during 1961-2013

Year	Wheat		Rice		Maize		Barley	
	Cubic meter	Percent	Cubic meter	Percent	Cubic meter	Percent	Cubic meter	Percent
1961	25267410	89.1	18873113	6.7	12097800	4.3	0	0
1962	72166500	60.8	32133311	27.1	7332000	6.2	7115000	6
1963	11290860	81.5	11217465	8.1	7332000	5.3	7115000	5.1
1964	25121250	95.9	5064171	1.9	4399200	1.7	1283546	0.5
1965	92315752	92.1	68766992	6.9	2901028	0.3	7618742	0.8
1966	28241400	85	47742401	14.4	58656	0	2047697	0.6
1967	11291773	80.2	17042851	12.1	10910016	7.7	0	0
1968	97688776	88.5	40730858	3.7	86260980	7.8	0	0
1969	913500	22.3	3056571	74.7	122200	3	0	0
1970	41361453	63.6	9412298	14.5	14142206	21.7	140877	0.2
1971	18149253	80.1	101199770	4.5	76304124	3.4	273019626	12.1
1972	14092052	83.8	153701856	9.1	86102120	5.1	32935335	2
1973	14338460	81.2	19559043	1.1	159847376	9.1	153006652	8.7
1974	26197389	75.6	320307561	9.2	272424126	7.9	253981309	7.3
1975	26301930	75.3	478727277	13.7	95212130	2.7	290098472	8.3
1976	74124130	42.4	435043574	24.9	260933660	14.9	312752632	17.9
1977	21179735	52.9	986909392	24.7	420393662	10.5	475005938	11.9
1978	13343074	48.7	454087333	16.6	471770208	17.2	480078933	17.5
1979	73128598	31.5	561452108	24.2	853189402	36.8	174815550	7.5
1980	24299100	55.4	610245153	13.9	790665772	18	552102655	12.6
1981	29213857	52.6	900522364	16.2	106243735	19.1	671653154	12.1
1982	32326499	61.5	650520955	12.4	796544814	15.2	573301086	10.9
1983	43479073	60.8	936135515	13.1	119680358	16.7	669838829	9.4
1984	47574002	63.3	900828523	12	874361774	11.6	979190491	13
1985	39171939	58.8	823967557	12.4	116280143	17.5	757881262	11.4
1986	34863234	62.7	719140723	12.9	114104738	20.5	211840587	3.8
1987	58374623	69.7	122297471	14.6	109012664	13	227852183	2.7
1988	42263095	80.7	315638218	6	568503728	10.9	126759417	2.4
1989	94621371	72	132859789	10.1	130054893	9.9	105788381	8
1990	61785723	68	933534000	10.3	114357448	12.6	835522988	9.2
1991	66440006	71	960777132	10.3	148822247	15.9	259158183	2.8
1992	44821224	60	142113486	19	141382833	18.9	157119122	2.1
1993	44752712	58.9	174436850	23	937948544	12.4	435082250	5.7
1994	42451806	61.6	725071508	10.5	938884596	13.6	987078180	14.3
1995	56637000	55.3	245880810	24	140530000	13.7	711500000	6.9

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Table 1. Cont.

Year	Wheat		Rice		Maize		Barley	
	Cubic meter	Percent	Cubic meter	Percent	Cubic meter	Percent	Cubic meter	Percent
1996	70777980	71.3	173155500	17.4	108635800	10.9	3667950	0.4
1997	10855938	79.1	959880404	7	184525421	13.5	5469750	0.4
1998	64588579	73.3	950536699	10.8	984946664	11.2	4129125	4.7
1999	11246895	77	128285640	8.8	123082528	8.4	8450978	5.8
2000	12017781	73	170064130	10.3	144280562	8.8	1291193	7.8
2001	11763961	72	117198836	7.2	207170914	12.7	1336692	8.2
2002	75308629	69.1	145380521	13.3	161994674	14.9	2903788	2.7
2003	21081296	28.2	158220461	21.2	377565128	50.5	9070202	0.1
2004	40620969	7.2	164698150	29.2	215559700	38.2	1440905	25.5
2005	21294233	3.3	194550660	30.1	273869018	42.4	1557890	24.1
2006	20096342	26.3	209036832	27.4	314994451	41.3	3846824	5
2007	45749176	7.6	168874125	28.1	345235651	57.5	4056773	6.8
2008	68201964	48.9	200615285	14.4	365496778	26.2	1472574	10.6
2009	99758182	56.7	134316637	7.6	456417611	26	1703109	9.7
2010	25691219	20.9	189420238	15.4	707539710	57.5	7661816	6.2
2011	12972613	1.7	188312210	24.7	445377940	58.4	1154987	15.2
2012	99487658	50.7	171669374	8.8	571435183	29.1	2233954	11.4
2013	80176817	45.4	364735247	20.7	489469900	27.7	1094432	6.2

If the performance of five-year development plans in Iran to be investigated, it is known that on the average, the highest virtual water imports belonged to wheat equivalent to 26.8 billion cubic meters during the second development plan and it is clear that due to a temporary increase in wheat production, the amount of virtual water imports declined during this period in the fourth development plan and reached about 3.9 billion cubic meters. However, with the lack of continuity of wheat self-sufficiency, virtual water imports have again increased significantly and increased to more than 6 billion cubic meters during the first three years of the fifth development plan. As can be seen, the highest virtual water import fluctuations occurred in the fourth development plan and is indicative of the lack of stability in production and imported strategy of wheat and then, the process is also continued during the three years of the fifth development plan and virtual water import fluctuations are remarkable in it.

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Table 2. The virtual water imports due to wheat imports during the different Development Plans

plans	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
First development plan	4475271213	9462137139	6248420753	2046533909	0.328
Second development plan	5663700000	11246895072	8260637994	2600140742	0.315
Third development plan	406209699	12017781279	6765389039	5368624820	0.794
Fourth development plan	212942331	9975818286	3895216618	4314560838	1.108
Fifth development plan[1]	129726135	9948765897	6032057913	5201962308	0.862

[1]Fifth development plan is available from 2011 to 2013 (3 years)

As it is shown in Table 3, the highest imported virtual water from barley import has been realized during the during the three years of the fifth development plan amounted to about 1.5 billion cubic meters, whereas the lowest virtual water import fluctuation from barely occurred during this period. The highest imported virtual water fluctuation regarding the import of this crop was also occurred during the second development plan and also in the same year, with lower imports of barley, the lowest virtual water import from the barley also occurred.

Table 3. The virtual water imports due to barley imports during the different Development Plans

Plans	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
First development plan	157119122	1057883814	548953271	384582339	0.701
Second development plan	36679500	845097825	412177465	369393153	0.896
Third development plan	9070202	1440905609	873648059	670491066	0.767
Fourth development plan	384682436	1703109012	1104786748	653043725	0.591
Fifth development plan[1]	1094432146	2233954893	1494458317	641138160	0.429

[1]Fifth development plan is available from 2011 to 2013 (3 years)

Regarding the maize, as shown in table 4, the virtual water import of maize imports in the country has been quite rising during different development plans, so that in the first development plan, on average 1.26 billion cubic meters of virtual water import was due to maize import and, this figure has been increased by more than 5 billion cubic meters during the fifth development plan. Meanwhile, the lowest fluctuation in the virtual water imports of maize imports has also been achieved in the same year and the highest fluctuation in the virtual water imports of maize imports also occurred during the third development plan.

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Table 4. The virtual water imports due to maize imports during the different Development Plans

Plans	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
First development plan	937948544	1488222476	1256824556	220575665	0.176
Second development plan	984946664	1845254216	1310536833	338201780	0.258
Third development plan	1442805624	3775651282	2213141960	923315856	0.417
Fourth development plan	2738690188	4564176110	3512027022	681939135	0.194
Fifth development plan[1]	4453779408	5714351838	5020943417	639698329	0.127

[1]Fifth development plan is available from 2011 to 2013 (3 years)

The results in table 5 show that regarding the rice, on average, the highest virtual water imports have been realized during the three years of the fifth development plan more than 4.2 billion cubic meters and generally, on average, the ascending trend in the rice virtual water import is completely obvious in various development plans. Additionally, the highest virtual water import fluctuation occurred in the fifth development plan.

Table 5. The virtual water imports due to rice imports during the different development plans

Plans	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
First development plan	933534000	1744368507	1277682480	339055301.9	0.265
Second development plan	950536699	2458808100	1476727321	634628443	0.43
Third development plan	1171988363	1700641306	1511124201	210787184.4	0.139
Fourth development plan	1343166377	2090368329	1814787085	303301465.5	0.167
Fifth development plan[1]	1716693741	3647352471	2415722773	1069863722	0.443

[1]Fifth development plan is available from 2011 to 2013 (3 years)

As indicated in Table 6, the total imports of virtual water has been rising in the main cereal during the years 1961 to 2013. As in 1961, the total import of virtual water in imported wheat, barley, maize and rice was equivalent to 0.28% billion cubic meters, but the amount of virtual water imports was reached to 17.65 billion cubic meters in 2013. This figure was the highest amount of virtual water import from the main cereal group import over the past 53 years.

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Table 6. The total amount of virtual water imports due to cereal group imports in Iran during 1961-2013

Year	Cubic meter	Year	Cubic meter
1961	283645013	1988	5237210940
1962	118746811	1989	13149167784
1963	138573065	1990	9091203823
1964	261959417	1991	9352158392
1965	1002444284	1992	7474204792
1966	332262760	1993	7592670514
1967	140870602	1994	6896214944
1968	1103879603	1995	10239308100
1969	4092271	1996	9932390500
1970	65056834	1997	13715771116
1971	2265448877	1998	8807253765
1972	1681944605	1999	14605674581
1973	1766259114	2000	16452421684
1974	3466451950	2001	16344351363
1975	3494230927	2002	10894993701
1976	1749971171	2003	7475055726
1977	4000282493	2004	5649693814
1978	2740243903	2005	6455029563
1979	2320743042	2006	7634629505
1980	4382923580	2007	6004266915
1981	5555998657	2008	13953891594
1982	5253016807	2009	17586269785
1983	7150685315	2010	12304903035
1984	7511780995	2011	7621615562
1985	6661844217	2012	19613766369
1986	5558352119	2013	17654165328
1987	8378415858		

Now the main question is whether cereal group imports with the current situation can be controlled and domestic production can be replaced with it? To better answer this question, it is necessary to examine the country's renewable sources per capita over the past years. In Table 7, the renewable water resources per capita was extracted with cubic meters during the period of 5 years from 1963 after FAO report (2016) [4]. As Table 7 shows, renewable water resources per capita is equivalent to 5026 cubic meters in the period 1963 to 1967, that this figure was reduced to 1779 cubic meters in the period 2008 to 2012. The estimate of long-run elasticity for the relationship between renewable water resources per capita and the virtual water import for cereal also showed that with a one percent reduction in the country’s renewable water resources, the import of virtual water in the main group cereal will be increased equivalent to 2.89 percent.

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Table 7. Long-run relationship between limited renewable water resources per capita and the virtual water import

Period	Renewable water resources per capita - Cubic meter	Virtual water import of cereals-Billion cubic meter
1963-1967	5206	0.375
1968-1972	4555	1.024
1973-1977	3935	2.895
1978-1982	3273	4.051
1983-1987	2678	7.052
1988-1992	2357	9.861
1993-1997	2195	9.675
1996-2002	2024	13.421
2003-2007	1910	6.644
2008-2012	1799	14.216
Estimation of long run elasticity		-2.89

But there is a very noticeable point in Figure 1. The relationship between renewable water resources per capita and the virtual water import for cereal group was negative and the determination coefficient of 90 percent confirms the negative correlation identified. Due to this negative relationship and also given that the renewable water resources per capita in the country is increasingly falling, it cannot be expected that domestic production could compensate for the imports of the cereal group and virtual water imports with current technology and without additional harm to water resources.

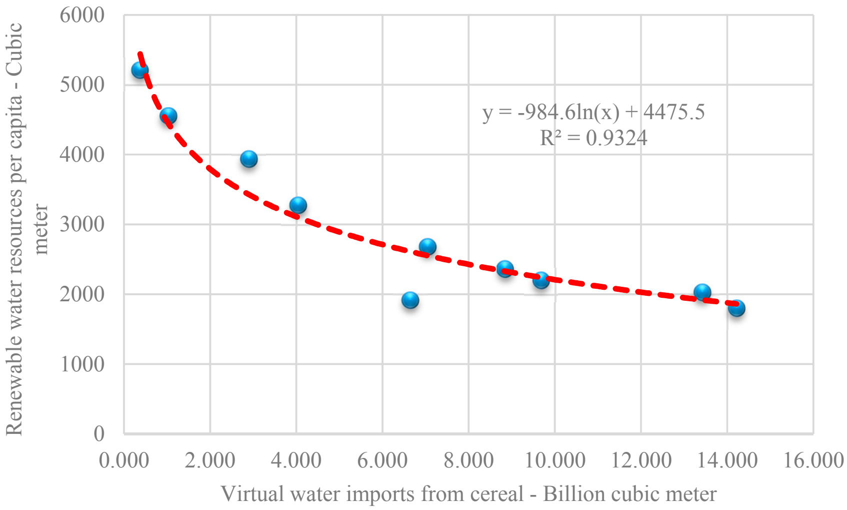

Figure 1. The relationship between renewable water per capita and the amount of virtual water imports

In fact, according to the results of this study, the major cereal group imports is equivalent to more than 17.65 billion cubic meters of virtual water imports in 2013. Given that the current state of the agricultural sector has always been faced with serious challenges and it is demonstrated that this sector consumes about 80 billion cubic meters of water resources, so how can we hope to replace

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surplus of 17.65 billion cubic meters with the use of the country's current irrigation technology, only in the group cereal import?

Replacement of imports with domestic production is not practically feasible without achieving production efficiency and productivity, especially without access to water and improving irrigation efficiency in various sectors of agriculture. If we insist on doing it, it will lead to loss of water resources and creates a critical situation in the future of country's water resources. With the loss of the country's water resources, not also all economic sectors will be practically affected, but also the agricultural sector will face a considerable drop in production and the need to import. So if we follow import purposes according to the plan, it could be helpful in the transition period in which the country seeks to build infrastructure to improve efficiency in domestic production, and after the improvement of productivity in the transition period, we can hope for targeted replacement of imports with domestic production.

4. Conclusions

As the results of this study in different parts showed, import of basic goods in Iran has always been increased with the virtual water import in periods of limited water resources. In fact, the agricultural sector in Iran has been accused of excessive water consumption and 90 percent of water resources are used in this section. However, according to general agricultural policies issued in 2012, achieving self-sufficiency and focus on domestic products have been considered as an important goal. Iranian MPs have also required the government to provide food security as well as attain self-sufficiency in basic agricultural products, livestock and aquatic to 95 percent by the end of 2021. But the fact is that with the current trend of water use in agriculture, there is no possibility of increasing the annual consumption more than 17 billion cubic meters of water in excess of current expenditure in the agricultural sector (according to the estimates of virtual water in 2013). Therefore, before the adoption of any policy aimed at achieving self-sufficiency in basic products, it is necessary to provide the necessary infrastructure in order to increase productivity and water resources efficiency. Without improving the productivity and efficiency of water resources in the current situation, achieving the goals of self-sufficiency not only will lead to further crisis of water resources, but also self-sufficiency goals will not be achieved. As a result, with the increased water resource crisis, agricultural production will be confronted with serious harm and in the long term, the country will need to import even more than before and self-sufficiency coefficients will also be reduced. The policy recommendation is that before any hasty adoption of the goals of self-sufficiency programs in agriculture, critical infrastructure should be developed by a group of specialists and experts and the necessary requirements should be provided in order to prevent conflict in the country's policy objectives.

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Author Contributions: Hamed Rafiee was the leader of the project but the manuscript was written jointly by Hamed Rafiee and Fereshteh balovi. All the results have been conducted with the cooperation of both the authors such as virtual water calculation and investigation of relationship self-sufficiency and limitation of water resources.

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References

1. Allan, J.A. Virtual water: a long term solution for water short Middle Eastern economies. Occasional paper, Water Issues Group, School of Orient and Affair Student, King's College, London, U.K, 1997.
2. Allan, J.A. Virtual water – the water, food, and trade nexus useful concept of misleading metaphor. *J.Water International*. 2003, 28, 106-113.
3. Chapagain, A. K.; Hoekstra, A. Y.; Savenije, H. G. Water saving through international trade of agricultural products. *J. Hydrol. Earth Syst. Sci*.2005, 2, 2219-2251.
4. FAO, http://www.fao.org/faostat/en/. 2016.
5. Fraiture, C.; Cai, X.; Amarasinghe, U.; Rosegrant, M.; Molden, D. Does international cereal trade save water? The impact of virtual water trade on global water use. Comprehensive Assessment Research Report 4. International Water Management Institute. Colombo, Sri Lanka. 2004.
6. Hoekstra, A.Y.; Hung, P.Q. Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of Water Research. Report Series No. 11. Delft, the Netherlands, IHE. London. 2002.
7. Safi, R.; Mirlotfi, S. M. Evaluation of sugarcane in Khuzestan province from the perspective of virtual water. *J. Water Resources Engineering*. 2015, 8, 87-95.
8. Serrano, A.; Guan, D.; Duarte, R.; Paavola, J. Virtual Water Flows in the EU27: A Consumption-Based Approach. *J. Industrial Ecology*. 2016, 20, 547-558.
9. Silva, V. P. R.; Oliveira, S. D.; Hoekstra, A. Y.; Neto, J. D.; Campos, J. H. B. C.; Braga, C. C.; Araujo, L. E.; Aleixo, D. O.; Brito, J. I. B.; Souza, M. D.; Holanda, R. M. Water Footprint and Virtual Water Trade of Brazil. *J. Water*. 2016, 8, 1-12.
10. Temea, S.; Allamano, P.; Carr, J. A.; Claps, P.; Laio, F.; Ridolf, F. Local and global perspectives on the virtual water trade. *Hydrol. Earth Syst. Sci*. 2013, 17, 1205–1215.
11. Yang, H.; Zehnder, A. Virtual water: an unfolding concept in integrated water resources management. *J. Water Resources Research*. 2007, 43, 1-10.