SİDAS MEDYA
Akademik Gıda®
ISSN Online: 2148-015X
https://dergipark.org.tr/tr/pub/akademik-gida

Akademik Gıda ***Özel Sayı: Yeşil Dönüşüm / Special Issue: Green Transformation*** (2024) SI26-SI32
DOI: 10.24323/akademik-gida.1554424

Research Paper / Araştırma Makalesi

Assessment of Agricultural Virtual Water Export of Türkiye

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Received (Geliş Tarihi): 02.04.2024, Accepted (Kabul Tarihi): 06.09.2024
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ABSTRACT

As the negative effects of climate change are amplified, the agriculture sector is becoming more fragile. Food security is under risk because agriculture is highly dependent on climatic conditions and availability of water resources all over the world. For this reason, the concepts of virtual water and water footprint have begun to gain importance as decision-support tools for the effective and efficient use of water. However, there is a gap in the literature, where few studies focus on virtual water trade. Given the increasing stress caused by reasons such as the scarcity of water resources and climate change, this concept is likely to gain serious attention in the coming years. Türkiye is a water-stressed country whose water resources are decreasing due to the impact of climate change. More effective water management is needed to meet the increasing demand. In this study, virtual water was determined for Türkiye's agricultural export, and it was observed that crops with high water footprint but low economic returns were also exported in large amounts. It was revealed that the virtual amount of water exported by the evaluated crops was 5.9 billion m^3 annually. This value is high enough to meet the domestic water needs of a metropolitan city like Istanbul for seven years. It is evident that water footprint and virtual water concepts would help decision makers to support optimized water consumption and sustainable water management.

Keywords: Exported crops, Virtual water trade, Water footprint

Türkiye'nin Tarımsal Sanal Su İhracatının Değerlendirilmesi

ÖZ

İklim değişikliğinin olumsuz etkileri arttıkça tarım sektörü daha da kırılgan hale gelmektedir. Tarımın tüm dünyada büyük ölçüde iklim koşullarına ve su kaynaklarına bağımlı olması nedeniyle gıda güvencesi tehlikeye girmektedir. Bu nedenle suyun etkin ve verimli kullanılmasında karar destek araçları olarak sanal su ve su ayak izi kavramları önem kazanmaya başlamıştır. Ancak literatürde bu konuyla ilgili çalışmalar halen yetersizdir; çok az çalışma sanal su ticaretine odaklanmaktadır. Ancak su kaynaklarının kıtlığı ve iklim değişikliği gibi nedenlerin yarattığı stresin giderek arttığı göz önüne alındığında, bu kavramın önümüzdeki yıllarda ciddi anlamda ilgi görmesi muhtemeldir. Türkiye açısından bakıldığında da literatürde çok az sayıda çalışma bulunmaktadır. Türkiye, su stresi yaşayan ve iklim değişikliğinin etkisiyle su kaynakları azalan bir ülkedir. Artan talebi karşılamak için daha etkili bir su yönetimine ihtiyaç vardır. Bu çalışmada Türkiye'nin tarımsal ihracatının sanal su içeriği değerlendirilmiş ve su ayak izi yüksek ancak ekonomik getirisi düşük olan ürünlerin de büyük miktarlarda ihraç edildiği görülmüştür. Değerlendirilen ürünlerle birlikte ihraç edilen sanal su miktarının yıllık 5.9 milyar m^3 olduğu bulunmuştur. Bu değer İstanbul gibi bir metropolün yedi yıllık evsel su ihtiyacını karşılayabilecek düzeydedir. Bu durum, su ayak izi ve sanal su kavramlarının ticari uygulamalarda dikkate alınması durumunda ülkenin su kaynaklarının verimliliği açısından çarpıcı sonuçlar elde edeceğini göstermektedir.

Anahtar Kelimeler: İhraç edilen tarım ürünleri, Sanal su ticareti, Su ayak izi

INTRODUCTION

Food is in greater demand as the global population continues to grow. However, the amount of food production cannot keep up with the increasing demand. Food security is becoming a global concern in recent years. More than 333 million people are already facing acute levels of food insecurity [1]. One of the biggest factors leading to global food insecurity is climate change as agriculture is highly dependent on climate. Global warming is influencing weather patterns, causing heat waves, heavy precipitation, and droughts [2]. A global warming of 1.5-2°C during the 21st century is expected unless serious reductions occur in CO_2 and other greenhouse gas emissions [3]. Millions of people are negatively affected due to increased natural disasters as a result of climate change. Floods are occurring more frequently and more severely due to changing rainfall patterns and melting glaciers. Sea levels are rising rapidly as a result of further melting of the Arctic and Antarctic ice sheets [4].

Environmental analyses carried out in various industrial areas have shown that although waste materials have different characteristics in terms of volume and composition, they are usually discharged with little or no treatment [5]. The sustainability of water resources depends on the fact that water resources are not polluted. Agriculture contributes to climate change due to environmental and water pollution and is affected by climate change as one of the most vulnerable and water-dependent sectors. Both as a result of the negative effects of climate change and due to water pollution, limited water resources are becoming increasingly scarce, which leads to a direct impact on agricultural production. The fact that 69% of the water on Earth is withdrawn for agricultural use is evidence of the dependency of the sector on water [6].

Located in the Mediterranean Basin, Türkiye is one of the countries expected to be most affected by climate change. A significant warming on Türkiye is expected during the 2015-2100 period according to the ClimaHydro Project performed by the Ministry of Agriculture and Forestry [7]. The project also predicted that the temperature increases will reach 3.4°C according to the RCP4.5 scenario and 5.9°C according to the RCP8.5 scenario for the 2090-2100 projection period.

Along with the effects of climate change on temperature in Türkiye, its effects on water resources are also inevitable. Türkiye is one of the countries with limited water resources. Turkey's annual water potential is 112 billion m^3 and the average precipitation is 574 mm/year. Additionally, the annual per capita water availability was reported as 1346 m^3 in 2020 [8]. According to the Falkenmark indicator [9], Türkiye is considered a water-stressed country. When the impacts of climate change on the water resources of Türkiye are investigated on a basin level, projections show that the Euphrates-Tigris Basin will have the most significant water deficit according to all scenarios and projection periods. Additionally, a substantial water deficit is expected for the Eastern Mediterranean and Konya Closed Basins [7].

As the importance of food security continues to grow, the concepts of water footprint and virtual water trade have emerged as important tools for assessing and measuring water use in food production and trade, particularly in the context of climate change and adaptation strategies. There is a strong decoupling between the food trade and virtual water. When countries trade food, they also exchange virtual water along with goods. However, the concept of virtual water trade is not considered yet in international trade practices. Virtual water trading can be a valuable tool for water-scarce countries to optimize their water use. In a world where water resources are decreasing, this aspect of trade may emerge as a very important research area in the future.

Water footprint was first introduced by Arjen Hoekstra in 2002 [10]. Water footprint is a measure of water utilized in relation to consumer goods [11]. It quantifies the freshwater volume required to produce a particular product by considering the different stages of the production process. There are three components of water footprint as Water Footprint Network [12] defines; green water footprint, blue water footprint and grey water footprint. Green water footprint (WFgreen) refers to the precipitation water stored in the root zone of the soil and evaporated, transcribed by plants, or absorbed by them. It is crucial for agriculture, forestry, and horticulture products. Blue water footprint (WFblue) is the water which has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can have a blue water footprint. On the other hand, grey water footprint (WFgrey) is related to pollution; it is the amount of freshwater required to dilute the pollution to acceptable levels required by the legislation.

Virtual water was introduced by Tony Allan at the beginning of 1990. It is the water embodied in a product in a virtual sense. It refers to the water needed to produce the product, and it has also been called “embedded water” [13]. Each product contains virtual water in different proportions depending on the processing methods of the products and the conditions of the production areas. If a country exports goods to another country the water used in its production is also exported which refers to virtual water trade. There is a strong relationship between the trade of virtual water and food. It becomes beneficial, especially for water-scarce countries when they import water-intensive products instead of producing them with their limited water resources. Virtual water trade plays a vital role for water-scarce countries to optimize their water usage.

There are very few studies evaluating the virtual water trade of Türkiye. The study of Hoekstra and Hung [14] stated that Türkiye is a virtual water importer country.

The study conducted by World Wide Fund for Nature (WWF) [15] indicated that the water budget is balanced in exports and imports. However, in these studies, only a general comprehensive evaluation was made for Türkiye's virtual water exports. There are only a few studies conducted to calculate the water footprint of certain products or areas in Türkiye. The study conducted by WWF Türkiye [15] is the most comprehensive and timely study conducted in the field.

Studies focusing on virtual water trade are quite new in the literature and there is a knowledge gap on this subject. Considering the increasing stress caused by scarcity of water resources and climate change, this concept is likely to gain serious attention in the coming years. Türkiye is a country suffering from water shortage, with its water resources decreasing due to the impact of climate change. More effective water management is needed to meet increasing demand. In this regard, this study has promising results to raise awareness and lead to new studies on virtual water trade concept in Türkiye and beyond.

To this end, the aim of this study is to determine the virtual water content of Türkiye's most exported crops by identifying the key exported crops in terms of quantity, economic value and water footprint. It is also aimed to suggest solutions for reducing the exported virtual water of Türkiye by identifying crops with high water footprints, especially blue water which shows the dependency on irrigation.

METHODOLOGY

A literature review was made to determine the impacts of climate change on Türkiye’s agricultural production. Next, the most exported crops were determined to examine Türkiye's virtual water trade. Detailed information on the provided data and assessment of the virtual water export of Türkiye is given below.

The data of the exported crops in terms of quantities and economic values were obtained from UN Comtrade to determine Türkiye's agricultural virtual water exports [16]. The data for the 2013-2020 period was used. Then, the obtained data were averaged over the years 2013-2020 on Excel and put in two ranks in terms of quantity (ton) and economic value ($). The top ten products according to the ranking were included in the study.

The global green and blue water footprints (m^3/ton) of these crops presented in Water Footprint Statistics (WaterStat) which provides data on blue, green and gray footprints broken down by product type and country were evaluated to determine how much water is used on average to grow those crops [17]. Global average water footprint data was provided from the study conducted by Mekonnen and Hoekstra [18]. Next, as seen in Equation 1, the data was multiplied by the amounts (ton/year) exported by Türkiye to reveal how much water was averagely exported in total. According to the result, a ranking was made from the highest water footprint to the lowest and the result was evaluated.

$$\text{Virtual Water Export (m}^3\text{/year)} = \text{Export Amount (ton/year)} \times \text{Water Footprint (m}^3\text{/ton)}\ [19] \qquad \text{(Equation 1)}$$

RESULTS and DISCUSSION

Türkiye’s average agricultural export is 32,907,488 tons/year, and the income from this export is 32.3 billion USD/year (2013-2020). Table 1 and Table 2 show the top 10 crops exported by net weight and value for the 2013-2020 average. It can be seen from the tables that the most exported crops in terms of value bring almost twice as much income as the most exported crops in quantity. Hazelnuts, tobacco, apricots, figs, and cotton are not among the most exported products in terms of quantity. However, these crops are important in terms of their economic value [20].

The study calculating Türkiye's water footprint carried out by WWF revealed that while the share of agricultural products (including both processed and unprocessed) in the total water footprint of exports was 53%, the total economic export value was only 10% [15]. Considering that Türkiye is not a water-rich country, it is obvious that it is not a good practice to export products that do not add value to the country but have a high share in water consumption.

In Figure 1, the global water footprints of the crops determined in terms of quantity and value are given. It is seen that crops such as lentils, hazelnuts and cottons have high global water footprints when considering the total water footprint. On the contrary, crops such as grapes, oranges and tomatoes have the lowest water footprint. On the other hand, hazelnuts, cotton, and figs have the highest blue water footprint which means they require more irrigation water to produce those crops.

Table 1. Top 10 crops exported (net weight) (average between 2013 and 2020) [16]

Crops	Net Weight (tons/year)	Trade Value (USD/year)
Mandarins	1.227.508	620.124.313
Tomatoes	525.608	327.269.452
Maize	477.391	119.632.681
Lemons	473.263	290.426.975
Grapes	459.567	650.971.088
Oranges	340.133	158.024.727
Bananas	323.224	167.130.616
Lentils	315.554	270.853.933
Rice	246.186	137.044.055
Apples	179.262	67.450.169
Total	4.567.696	2.808.928.009

Table 2. Top 10 crops exported (value) (average between 2013 and 2020) [16]

Crops	Trade Value (USD/year)	Net Weight (ton/year)
Hazelnuts*	1.194.617.963	158.064
Grapes	650.971.088	459.567
Mandarin	620.124.313	1.227.508
Tobacco*	367.933.749	50.181
Tomatoes	327.269.452	525.608
Apricots*	323.159.795	140.823
Lemons	290.426.975	473.263
Figs*	274.080.185	76.923
Lentils	270.853.933	315.554
Cotton*	194.330.278	106.522
Total	4.513.767.731	3.534.013

*Crops different from the list in terms of net weight

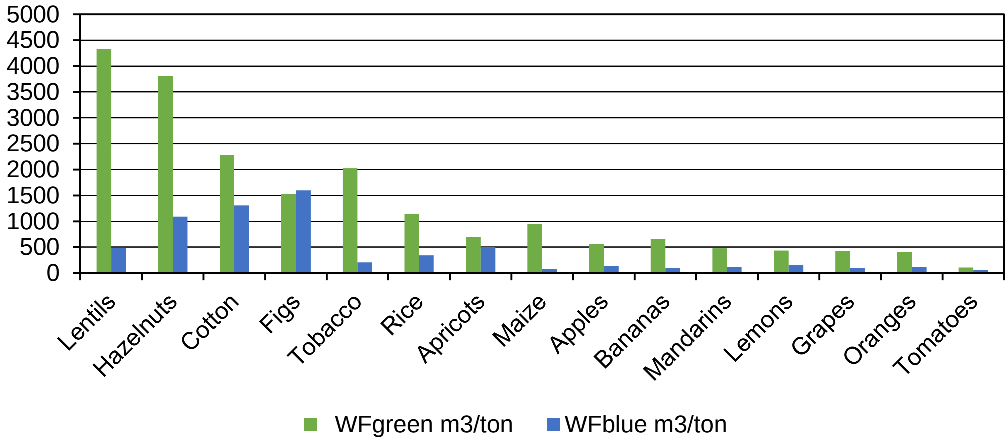

Figure 1. The global water footprint of the crops by m^3/ton [18]

In Figure 2, the water footprint of the determined crops is given according to the calculation of the global water footprint and export amounts of crops. The results show that the export of lentils, hazelnuts and mandarins has the highest total water footprint. Although the global water footprint of hazelnuts is seven times higher than that of mandarins, when the export amounts are considered, virtual water exported is similar for both crops. Additionally, the water footprint of maize is quite high, and it is exported in large quantities despite its little contribution to the economy. On the other hand, crops such as apricots, tobacco and tomatoes have a low water footprint, and they are also the crops that have a major contribution to the country's economy. Finally, despite the relatively low total water footprint of fig export, it is seen from the table that the share of blue water footprint is higher than the green water footprint, which means it is dependent on irrigation (surface or ground-water).

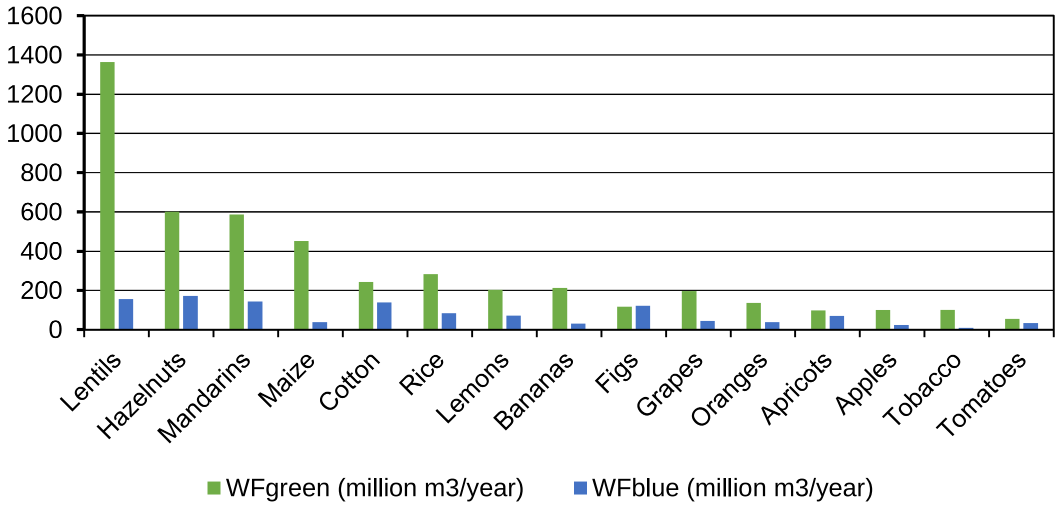

Figure 2. The virtual water export of the crops (million m^3/year)

In Figure 3, it is seen that the blue virtual water export associated with lentil is quite high, yet lentils remain one of Türkiye's most exported crops. Despite the high water footprint and huge amounts of export, it is not included in the list of products that contribute to the economy. In contrast, although crops such as tobacco, bananas, oranges, apples, and tomatoes are exported in large quantities, the blue virtual water export is low. The amount of water used for agriculture in Türkiye which represents irrigation water is 44 billion m^3 [8]. The blue virtual water export of the evaluated crops is more than 1.1 billion m^3. This means that 1.1 billion m^3 of the total water used in agriculture is exported virtually only through the export of the crops evaluated in the study.

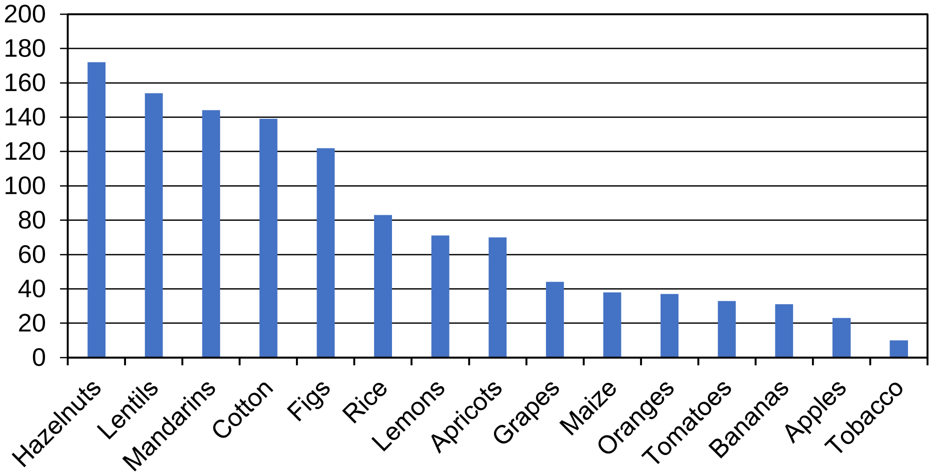

Figure 3. The blue virtual water export of crops (million m^3/year)

The grey water footprint of the most exported crops is found as 1 billion m^3 which is the amount of water used to dilute the water pollution caused by the production of these crops. However, it was not included in the virtual water trade calculation as it corresponds to the pollution created by crop production and while the green and blue water of the country is exported, pollution remains in the country.

As Figure 4 shows, the export of rice needs to be reduced due to its high water footprint, large export volumes and low economic value. Additionally, in terms of economic return, cotton exports need to be reduced due to their large water footprint. However, despite hazelnuts and figs having large blue water footprints like cotton, they have been determined as two of the most important crops in Türkiye's exports, within the scope of the CREATE (Cross-Border Climate Vulnerabilities and Remote Impacts of Food Systems of the EU, Türkiye and Africa: Trade, Climate Risk and Adaptation) project (The project was funded by H2020 ERANET FOSC program, carried out under the coordination of Ankara University Water Management Institute with partners from the Netherlands, Türkiye and Morocco, and led by Prof. Gökşen Çapar in the period of 2021-2024). On the other hand, exports of low water footprint, and high-income crops such as tobacco, grape and tomato should continue. At the same time, exports of crops such as bananas, oranges and apples need to be increased since they have a low water footprint even though they are exported in large quantities. In Figure 4, the data in the area outside the intersection of the blue water footprint with export and income is not available since it was out of the scope of the study.

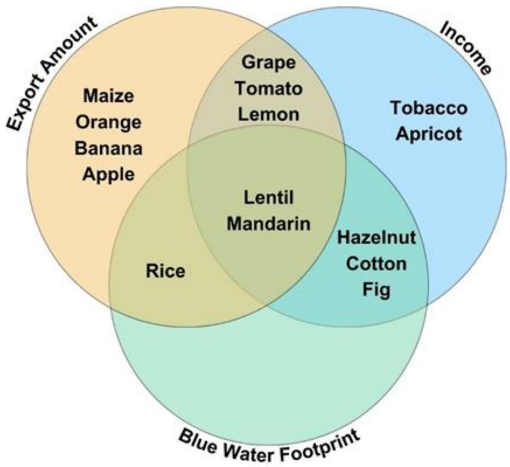

Figure 4. Crops with respect to export amount, income, and blue water footprint of export

Overall, when Türkiye's exported crops are examined in terms of both quantity and income, it is seen that some of the top-ranked crops are exported in high quantities despite their low income, while some crops have high income despite their small export quantities. One of the most important factors that stands out when examining these crops is the blue water footprint which represents irrigation water demand. Although some crops are exported in low quantities, virtual water exports are high when considered their blue water footprint. On the other hand, although the export amounts of some crops are high, virtual water exports are low because of the low blue water footprint.

CONCLUSION

The importance of water is inevitable in meeting the increasing food demand and ensuring food security. However, agriculture is very sensitive to climate change and the availability of water resources. To reduce the associated risks, it is necessary to focus on the efficient and sustainable use of water in areas where it is used intensively. For this reason, the importance of decision support tools such as water footprint and virtual water trade is becoming more significant to ensure sustainable management of water resources.

Türkiye is not a water-rich country. Therefore, the concept of virtual water can be a useful tool for more effective and efficient use of water. In this study, the crops highly exported by Türkiye were examined and it was determined how much water is exported with these crops on the average. The most exported crops were evaluated in terms of economic return, export amounts and global water footprint.

The product with the highest water footprint is lentils. Although it brings economic value, its large share in exports in terms of quantity also makes its share in virtual water exports high. Products such as tangerines, lemons, grapes, and tomatoes, which are among the most exported products in terms of quantity, have the lowest water footprints. While these products are exported the most in quantity, they are also among the products that contribute the most in terms of income. On the contrary, although the water footprints of crops such as hazelnuts, cotton, figs, and tobacco are high, their value in exports is low in quantity. Although they are exported in small quantities, they have high economic value.

This study examined whether Türkiye's most exported crops have high virtual water content and therefore whether the concept of virtual water should be recommended for inclusion in international trade practices. As a result of the calculations made in response to this, it was revealed that the virtual amount of water exported by the evaluated crops was 5.9 billion m^3 annually. This value is high enough to meet the domestic water needs of a metropolitan city like Istanbul for 7 years [21]. When the blue water component was compared with agricultural water use, the amount of virtual blue water exported was determined to be 1.1 billion m^3 per year. This corresponds to 2.5% of Türkiye's annual agricultural water use, which is reported to be 44 billion m^3. Based on the data obtained, the virtual water of exported crops is likely to become an important factor and a binding criterion in international trade practices. In this way, Türkiye will be able to make informed decisions on water allocation and sustainable practices that take water scarcity into account. This could help a water-stressed country like Türkiye to manage its limited water resources more efficiently and save significant amounts of water.

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