

**REPUBLIC OF TURKIYE
ANKARA UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF WATER POLICY AND SECURITY**

**FOOD EXPORT AND VIRTUAL WATER TRADE OF TURKIYE IN THE
CONTEXT OF CLIMATE CHANGE**

MASTERS THESIS

Buse UÇAR ISLAM

Ankara, 2023

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DECLARATION
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With this document, I declare that I collected and presented all the information here within and in accordance with the academic rules and ethical behavior. This is in accordance with the rules and principles, and that all information not belonging to me, I acknowledge and declare the source of ideas and conclusions.

04.09.2023

BUSE UÇAR ISLAM

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ACRONYMS/ABBREVIATIONS

IPCC: Intergovernmental Panel on Climate Change

FAO: Food and Agriculture Organization

MOAF: Ministry of Agriculture and Forestry

WWF: World Wildlife Fund

DSI: State Hydraulic Works

US EPA: United States Environmental Protection Agency

TAGEM: General Directorate of Agricultural Research and Policies

WFN: Water Footprint Network

WF: Water Footprint

WFgreen: Green Water Footprint

WFblue: Blue Water Footprint

WFtotal: Total Water Footprint

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1. INTRODUCTION

As the world population keeps growing, the demand for food is also increasing. However, food production is insufficient to meet the increasing demand. In recent years, food security has become an important issue that concerns the whole world. World Food Program (2022) indicates that conflict, climate change, disasters, inequality and the COVID-19 pandemic are causing one in nine people globally to still go to bed hungry and millions are facing famine. FAO (2022) revealed that 702- 828 million people were estimated to be affected by world hunger in 2021. Ending world hunger is also one of the Sustainable Development Goals of the United Nations by 2030 within the framework of Goal 2: Zero Hunger (UN, 2022). However, food security remains a major challenge as Global Hunger Index (2022) indicates that 47 countries have extremely alarming, alarming, or serious levels of hunger and will fail to reach the goal of Zero Hunger by 2030.

Climate change is one of the matters concerning all countries today. According to IPCC's definition, climate change means changes in the climate situation that persist over a long period of time, typically decades or more. It can be caused by natural processes or external factors which refers to human activities (IPCC, 2023). It is a fact that human activities have increased atmospheric CO₂ concentrations by more than 40%. The major fact responsible for this increase is the use of fossil fuels together with the industrial revolution. More than half of the increased CO₂ concentrations occurred after 1970 (NAS and The Royal Society, 2020). As US EPA (2022) indicates, the global average temperature has increased and there are observable changes on earth such as drought,

intense rain, floods, heat waves, warming of the oceans, ice melting and sea level rise. The future projections show that unless serious reductions occur in CO₂ and other greenhouse gas emissions, global temperature will increase and there will be 1.5-2°C global warming during the 21st century (IPCC, 2021). These projections are evidence that climate change poses a serious challenge for the whole world.

Climate change will affect the hydrological cycle through increasing surface temperatures, changing precipitation rates and evapotranspiration (ARIC and DEFRA, 2023). As Kazama and Oki (2006) listed, some of the negative impacts of climate change on water resources are large evapotranspiration, floods and overflows, decreased amount of water due to evaporation, increase in sediment and nutrients, decreased water quality, a boom in infectious diseases, ice and snow reduction, sea level rise, saline intrusion, decreased base flow and decrease in groundwater levels. There could be 5 billion people under the risk of exposure to a moderate level of water stress by 2050 (Schlosser et al., 2014).

The food sector is dependent on climate and it is one of the sectors most affected by the climate change. Climate change causes increase in both intensity and frequency of hydro-meteorological hazard which threatens water and food security (Frontiers, 2022). In addition to limited fresh water resources on earth, the impacts of climate change on water resources and precipitation regimes pose a challenge to sustain food production. The fact that over 70% of water used in the world is for agricultural irrigation reveals the importance of the food-water relationship (World Bank, 2017). According to US EPA (2023), changes in the frequency and severity of droughts and floods due to climate change could pose challenges for farmers and threaten food safety by increasing drought, preventing crop growth and reducing the yield. The Ministry of Agriculture and Forestry (MoAF) (2022) has indicated some negative impacts of climate change on agriculture as less precipitation, extreme climate events, decrease in water resources, degradation of

water quality and soil, shifting in production areas, reduction in production and quality, increase in plant diseases and fertilization problems. As a result of those expected impacts, food insecurity could be a global problem in the future.

Estimations show that the world population will be nearly 10 billion people by 2050 and to feed the population food production will need to increase by 56% compared to 2010. Additionally, there will be 593 million hectares land gap, which is an area equivalent to nearly twice the size of India (World Resources Institute, 2018). However, climate change will affect production and yield in negative ways. Every increase in the global average temperature reduces the yields of some crops. For instance, 1°C temperature increase will reduce maize yields by 7.4%, wheat by 6%, soybeans by 3.1% and rice by 3.2% (Zhao et al. 2017).

There is a strong relationship between food trade and virtual water trade. When countries engage in food trade, they are essentially exchanging virtual water along with the goods. This practice becomes particularly beneficial for water-scarce countries, enabling them to import water-intensive crops instead of cultivating them domestically, thus conserving their limited water resources. However, the concept of virtual water trade is not sufficiently considered in international trade practices. Emphasizing virtual water trade could serve as a valuable tool for water-scarce countries to optimize their water usage. In a world where water resources are dwindling, this aspect of trade may emerge as a crucial area of research in the future. This thesis aims to evaluate virtual water trade of Türkiye by identifying the key exported crops in terms of quantity, economic value and water footprint. By identifying products with high water footprints (WF), especially blue water, which shows the dependency on irrigation, it is aimed to provide suggestions and solutions for reducing the exported virtual water of Türkiye for sustaining water availability and mitigate the negative effects of climate change. Additionally, within the scope of the project “Cross-Border Climate Vulnerabilities and Remote Impacts of Food

Systems of the EU, Türkiye and Africa: Trade, Climate Risk and Adaptation (CREATE)” led by Ankara University Water Management Institute and financed by the H2020 ERANET FOSC program, four products with high economic values have been identified for Türkiye: hazelnuts, grapes, apricots and figs (Project Intermediate Report, 2022). In this thesis, there is also a comparative WF calculation for apricot, based on long term and current precipitation data. The calculation was made for Malatya province because most of the production occurs in the region.

In the literature review, no studies were found showing that virtual water is taken into account in international food trade. Nevertheless, given the scarcity of water resources and the increased stress caused by reasons such as climate change, it is probable that this concept will capture significant attention in the forthcoming years. From Türkiye’s perspective, there are also very few studies evaluating the virtual water trade of Türkiye. In a study conducted by Hoekstra and Hung (2005), it was stated that Türkiye is a virtual water importer country. In another study conducted by WWF (2014), it was discussed that the water budget is balanced in exports and imports. In this thesis, virtual water trade is examined only through the export of agricultural crops. The main argument of the thesis is “Does Türkiye’s most exported crops have high virtual water content so that it should be advised to involve virtual water concept in international trade practices?” To explore this argument, the main questions to be answered within the scope of the thesis are as follows:

- What are the water footprints of crops exported from Türkiye?
- How much is the virtual water of Türkiye’s most exported crops?
- How Türkiye's virtual water could be reduced?

When the existing studies are examined, there are only a few studies conducted to calculate the WF for certain products or areas in Türkiye (Muratoğlu, 2020; Engin, 2019; Esetlili et al., 2022). A study conducted by WWF Türkiye (2014) is one of the most comprehensive studies conducted in the field. Moreover, a very recent study published by Pilevneli and Capar (2023) on the impacts of climate change on agricultural production reveals that several river basins in Türkiye will suffer from water deficiency in the future as a result of increased production and negative impacts of climate change on water availability. The highest impact is anticipated to be seen in 2015-2040 period. It is also estimated that if no action is taken, the cost of climate change will be €14.15 - €18.01 billion per year. However, it is still necessary to carry out more studies examining WF and virtual water trade concepts from a climate change perspective and use them as a tool to sustain efficient water management and help provide food security for the future.

2. LITERATURE

2.1. Climate Change in Türkiye

Climate change has a tremendous impact on Earth. Türkiye is one of the countries being affected by these impacts. A study indicates that there are already some observable past changes in the climate of Türkiye. Temperatures have been increasing the most, especially in summer and the warm season also expands. Precipitation has increased in the northeastern parts of the country and mountain glaciers have been retreating about 10 m/year (Şen, 2013).

Mediterranean Basin is one of the regions expected to be most affected by climate change in the world and as Türkiye is located in this region, it is predicted that drought will impact larger areas and the number of extremely hot days will increase (MoAF, 2021). IPCC's 6th Assessment Report (2021) indicates that an increase in the main air temperature, extreme heat, hydrological, agricultural and ecological drought are expected for the Mediterranean region. The major effects of global climate change in this region are predicted as drought, water scarcity, loss of yield in agricultural production, loss of income in agriculture and tourism; increase in forest fires and loss of biodiversity (WWF, 2010).

There are several climate projection studies carried out by Turp et al. (2014), Öztürk et al. (2011), Demir et al. (2008), Demircan et al. (2017) evaluating the temperature and precipitation changes in Türkiye. The studies predict increases in temperature and decreases in precipitation in general. In a study conducted by the General Directorate of Meteorology (2013), two emission scenarios were applied, RCP4.5 and RCP8.5 (representative concentration pathway), for the 2013-2099 period. According to the RCP4.5 scenario the annual average temperature for the period 2013-2099 appears to be in an increasing trend. The average temperature increase is calculated as 2.5°C and the precipitation is expected to decrease by 50 mm/year. For the RCP8.5 scenario, the expected average temperature increase is 3.6°C and the precipitation decrease is 47 mm/year for the same period.

The most comprehensive study on this field is project entitled “The Impacts of Climate Change on Water Resources” conducted by the former Ministry of Forestry and Water Affairs (2016). It is predicted that there will be a significant warming on Türkiye in the 2015-2100 projection period. In the last 10-year of the projection period, the temperature increases will have the highest values and reach 3.4°C according to the RCP4.5 scenario and 5.9°C according to the RCP8.5 scenario. When the results of climate projections are evaluated with regard to the precipitation parameters, both regional increases and decreases are anticipated. In general, changes varying from -50 mm to 40 mm for the RCP4.5 scenario and from -60 mm to 20 mm for the RCP8.5 scenario are foreseen in the ten-year seasonal precipitation averages throughout the projection period. While it is predicted that the northern part of the country will receive more precipitation, severe drought is expected in the southern parts. In the study, it is also emphasized that the effects of climate change have started to be seen in Türkiye and this situation will become more evident in the next 10 years. Therefore, guaranteeing the sustainability of the water resources on a basin basis should become a priority. Within the scope of the

project, climate change projections of all basins and the changes on water resources in the basins were evaluated.

2.1.1. Impacts of Climate Change on Water Resources

Water is essential for all forms of life as a major resource for the ecosystem, biodiversity, food security and human health. However, freshwater resources are very limited on Earth. Over 96% of the Earth's total water is saline while only 2.5% of the water is freshwater. In addition, 68% of the total global freshwater resources are in ice and glaciers and 30% is under the ground. Freshwater resources such as rivers and lakes account for about 1/150th of 1% of total water which equals to about 22,300 cubic miles (U.S. Geological Survey, 2022).

Today, 1.42 billion people of which 450 million are children, live in areas with high or extremely high vulnerability to water (UNICEF, 2021). As 2030 Water Resources Group (2009) indicated, the global water demand will be 40% higher in 2030 and 1/3 of the world's population, mostly in developing countries, will live in basins where this deficit will be over than 50%.

Guaranteeing the availability and sustainable management of water takes place in United Nations Sustainable Development Goals #6 Clean Water and Sanitation. United Nations aims to improve water use efficiency in all sectors and ensure fresh water supply and sustainable withdrawal to eliminate water scarcity and reduce the number of people suffering from water scarcity by 2030 (United Nations, 2022).

Many reasons such as industrialization, energy consumption and the use of fossil fuels, the rapid increase in the world population and the urbanization rate lead to an

increase of greenhouse gases emitted into the atmosphere. These factors, which lead to an increase in greenhouse gases, become an element of pressure on water resources and lead to water problems. A study conducted by Yıldız (2017) indicates that the intensity of extreme hydrological events will rise as a result of the climate change's effects on the hydrological cycle. In this case, significant changes will occur in the quality and quantity of water resources. These changes will have negative effects on not only drinking purposes and agricultural production where water is of vital importance, but also on energy, health, tourism, transportation and ecosystem integrity due to flood and drought events.

Turkiye is one of the countries that already has limited water resources. Türkiye's annual water potential is 112 billion m³ and the average precipitation is 574 mm/year (DSI, 2022). The annual per capita water availability, which was 1652 m³ in 2000, decreased to 1346 m³ in 2020 and is expected to decrease to 1120 m³ in 2030 (DSI, 2022; WWF, 2014). An indicator created by Falkenmark used the level of 1700 m³ per capita/year as a threshold, the countries and regions which are categorized under 1700 m³/capita/year are considered to experience water stress, and if the level is below 1000 m³, it is evaluated as water scarcity (Nepomilueva, 2017). According to the Falkenmark Indicator, Türkiye is considered a country under water stress.

Considering the evaluations made by the ClimaHydro Project (2016) on water resources on a basin basis by taking into account the climate change projections, the Euphrates-Tigris Basin stands out with its significant water deficit estimation in all scenarios and projection periods. On the other hand, the basins where the most substantial water deficit is seen, although not in all periods, are generally the Eastern Mediterranean and Konya Closed Basins. When evaluating the water deficit/surplus situation by taking into account the amounts that Türkiye undertakes to release water from the Euphrates-

Tigris Basin to the downstream countries, it is seen that a water deficit is expected in the Euphrates-Tigris basin, reaching 2-12 billion m³/year in the 2015-2100 period.

As climate change directly affects the temperature and precipitation regimes, it makes water resources highly vulnerable to climate change. Reductions in the amount of precipitation and the amount of available water per capita are of great importance for Türkiye, which is a country that is already experiencing water stress. As the water demand of the sectors will increase due to reasons such as the increase in population and the development of industries, water problems can also be expected to increase. In this case, it is necessary to pay attention to the use of tools that contribute to the sustainability of water resources, such as WF.

2.1.2. Impacts of Climate Change on Agriculture

Agriculture is one of the most vulnerable sectors to climate change. Some of the negative impacts of climate change on agriculture are decrease in yield, increase in water demand for irrigation, shifts in planting and harvesting time, decreased ability to grow crops, and more diseases and pests (Federation of Food and Drink Industry Associations of Türkiye, 2017).

Water is essential for agricultural production. At the global level, the annual water withdrawal among the sectors is 69% agricultural, 19% industrial and 12% municipal (FAO, 2022). In Türkiye, 77% of the water is used for agriculture and 23% is used for municipal industrial (DSI, 2021). This is evidence that agriculture is the most water-consuming sector and is highly vulnerable to water. According to Zaimoğlu (2019), in contrast to gradually decreasing water resources, the demand for water increases rapidly.

If current trends continue, water use for agriculture is expected to increase by more than 70% in 2050. This situation endangers global food security for the future.

A study investigates the impacts of climate change on agriculture in different regions and countries of the world. According to the results, it negatively impacts agricultural productivity in 80% of all 43 selected countries including Türkiye in the study (Guo et al. 2022). Another study conducted by TUSIAD (2020) evaluates the negative impacts of climate change on Türkiye's agriculture. The study concluded that, based on the predictions showing Türkiye as a drier country, it is expected that there will be yield losses up to 10% at the regional level. Moreover, climate change will negatively affect Türkiye's major export products such as hazelnuts, apricots and raisins. It is predicted that there will be yield losses of around 10% for hazelnuts, 40% for apricots and 20% for fresh grapes in the future.

Due to the risks mentioned above, the need for tools to support decision makers for better management of water resources is increasing day by day. One of them is the water footprint indicator, which shows the pressures on water resources.

2.2. Water Footprint and Virtual Water Concepts

Water resources on earth are distributed unevenly. Some of the countries are water-abundant while some others are water-scarce. In addition to limited resources, many issues such as rapid population growth, climate change and increasing demand have led to serious water-related problems in many regions of the world. Limited and decreasing amount of available water resources is directly linked to various sectors such as agriculture, industry or domestic needs. However, it is a fact that agriculture is one of the most water-dependent sector and is highly affected by the water deficit. Water-scarce

countries are challenged with meeting the demand for agricultural products and under trigger to persist long-term food sustainability. Thus, new concepts such as “water footprint” and “virtual water” have emerged to minimize the negative impacts of these issues in water-scarce regions and provide effective and sustainable water use.

2.2.1. Water Footprint (WF)

Arjen Hoekstra was the one who introduced the term WF in 2002 (Hoekstra, 2007). According to Hoekstra et al. (2011), the WF concept is a measure for the amount of water utilized in relation to consumer goods. It quantifies the freshwater volume required to produce a particular product by considering the different stages of the production process. The measurement of water usage involves assessing the amount of water consumed or contaminated (Hoekstra, 2015). As Water Footprint Network (WFN) (2022) indicates, there are 3 components of WF:

Green WF represents the precipitation water stored in the soil’s root zone, which is either evaporated, transpired by plants or absorbed by them. It is significant for agricultural, forestry and horticultural products.

Blue WF represents water sourced from surface or groundwater reservoirs which can be evaporated, used in the production of goods, transferred between different bodies of water or returned at a different time. Examples of sectors contributing to the blue WF include agriculture, domestic water consumption and industry.

Grey WF is the volume of fresh water needed to assimilate pollutants in order to adhere to specific water quality standards. This measurement takes into account the

discharge of pollutants through direct pipe release, as well as indirect sources like runoff, impervious surfaces, leaching from soil or other diffuse origins.

WFN (2023) considers that there are four stages of WF assessment:

- setting the goals and scope to clarify what you will do in the subsequent steps
- WF accounting by collecting the necessary data and making the calculation
- sustainability assessment by considering environmental sustainability, resource efficiency, equitable allocation
- developing response formulation to reduce WF and improve long-term water sustainability

The WF can be calculated for a product and service, or it can be calculated for individuals, companies and nations. For instance, as a result of the calculation made according to the data of 1996-2005, on a global scale, each person has an average of 1385 m³ WF (Hoekstra and Mekonnen, 2012). For the average of the same period, the WF is 1624 m³ per capita in Türkiye, which is larger compared to the global average (WWF, 2014).

The WF concept has huge significance for sustainable water resources management. First of all, by identifying the WF of certain crops, products, or regions, policymakers can prioritize their strategies to reduce water consumption in water-scarce regions. Additionally, as the WF is highly affected by climate change, identifying the WF

helps to assess the vulnerability of that region and evolve adaptation strategies accordingly.

Agriculture is a major water-consuming sector and has the largest WF. As Hoekstra and Mekonnen (2012) indicated in their study, the global annual average WF was 9,087 Gm³/y for 1996-2005 period. The calculation included agricultural, domestic and industrial usage. Agriculture took the largest share (92%). In respect of virtual water flows, the largest share was related to international trade in crops and processed food with 76%. Based on a study conducted by Huang et al. (2019), crop WF especially blue WF is expected to increase in the future. It is estimated that the global blue WF of crop production will increase by 70.3% by 2099.

The WF of crops can be determined by using CROPWAT model developed by FAO or excel. In this thesis, the calculation was made by using excel. The methodology to calculate green and blue WF is given in Section 3.2. The data used in the calculation is also given in Annex 1 and Annex 2.

2.2.2. Virtual Water

The concepts of WF and virtual water were created for the same purposes and have similar characteristics. The term virtual water was first defined by Tony Allan as the volume of water consumed to produce a product from a set of goods, farm products, or services (Delpasand et al., 2021). For instance, it takes 1-3 tons of water to grown one kilogram of cereal. It takes up to 15 tons of water to produce one kilogram of beef (FAO, 2017). Virtual water points out the water in the product including all the production processes from start to end and cannot be seen directly. Each product contains virtual water in different proportions. The amount of virtual water in the products differs

depending on the processing methods of the products and the conditions of the production areas.

If one country exports a water-thirsty product to another country, the water is also being exported in virtual sense. Trade of water in real form is generally impossible because of the costs and large distances, but trade of water-thirsty products is more realistic (Hoekstra, 2003). This is referred to as virtual water trade. For instance, if a country imports one ton of wheat instead of producing, it is saving approximately 1,300 m³ of domestic water. If that country is water-scarce, it can use the saved water for other needs (Ahmadpari et al. 2022). As evidence, Du et al. (2022) conducted a study that evaluates water stress changes under a set of trade scenarios. The study concluded that virtual water trade has reshaped the water stress pattern and reduced the global water stress in general. By understanding virtual water flow, countries can optimize their international trade patterns.

If a trade relationship is diverted from a relatively more productive country to a relatively less productive one, it contributes to global water savings (Dalin et al., 2012). The utilization of virtual water between nations or continents could serve as a means of enhancing global water efficiency and attaining water security in regions of the world that suffer from water deficit (Hoekstra and Hung, 2005).

Globally, the major water exporter countries are the USA, Canada, Thailand, Argentina and India. On the other hand, Japan, Netherlands, Korea, China and Indonesia are the major water importer countries. Wheat, soybean and rice are the main crops responsible for the virtual water trade between nations (Hoekstra and Hung, 2005). Another study conducted by Hoekstra and Mekonnen (2012) also has similar results which indicates that the major net virtual water exporter countries are found in North and South America, Southern Asia and Australia. The biggest net virtual water importers are

found in the Middle East and North Africa, Mexico, Japan, Europe and South Korea. When the result is examined, apparently, most of the countries exporting virtual water are water-rich countries, while the countries that import virtual water are water-scarce. For Türkiye, the virtual water imports and exports are almost equal to each other, which means virtual water budget is balanced (WWF, 2014).

Many countries in the world, including Türkiye, are at risk of water shortage. With the increase in population, the demand for water is increasing. However, there is a decrease in water resources due to some reasons such as climate change and the water consumed due to production of goods. Agriculture, one of the most vulnerable sectors to water, is also affected by these negativities. Climate change leads to changes in parameters such as precipitation and temperature which adversely affect water resources, and food safety is also endangered as being directly dependent to both climate and water. For this reason, virtual water trade gains importance for water-poor countries to use their domestic water resources more efficiently. These countries can save water by importing agricultural products that consume high amount of water from water-rich countries. By importing crops that require large quantities of water to produce, water-scarce countries can also secure their food supplies without putting their limited water resources under excessive pressure. Additionally, virtual water trade can have economic benefits to countries which they have comparative advantage. As Chapagain and Hoekstra (2004) stated, in an open world economy, nations will pursue profit by trading products that are produced with domestic resources that are abundantly available for the products that need resources that are scarcely available within their country. Therefore, virtual water trade could provide benefits not only to water-poor countries but also to water-rich countries in terms of economic growth and increasing productivity. Within the scope of the thesis, considering the concept of virtual water trade, Türkiye's virtual water trade related to most exported crops is discussed both in general terms and for the specific case of apricot as it

was identified as one of the four key exported crops of Türkiye within the scope of the CREATE project.

2.2.3. Virtual Water Trade in International Relations

The term international relations is both the practice and the study of the relations of nation-states and other entities in the international system such as intergovernmental organizations (IGOs), nongovernmental organizations (NGOs) and multinational corporations (MNCs) (Stephenson, 2022). On the other hand, international trade refers to the process of transferring money, products, and services among international borders or regions (Grozdanovska et al. 2017). International relations and international trade are closely interconnected and influence each other in various ways. Understanding this relationship is crucial for comprehending how nations interact with one another economically, politically, and diplomatically. Global trade opens doors for consumers and nations to explore new markets and products. Traditionally, national governments held the primary influence in shaping the global political and economic scenario. Nevertheless, in recent times, international organizations such as the World Bank, International Monetary Fund, and the World Trade Organization have gained prominence as influential players in this domain (Hosain, 2016).

Over the last fifty years, globalization has revolutionized organizations, forging international economic connections across the globe. This evolution has given rise to the concept of economic diplomacy, wherein the economy has become the principal driver of political influence. Major global economies have shifted their diplomatic efforts to

prioritize economic, trade, and private sector interests in their interactions with other nations (Aburesidze et al. 2022).

International trade promotes economic interdependence among nations. When countries trade, they become dependent on each other to exchange goods and services. This interdependence can create incentives for mutual interests and cooperation, leading to stronger diplomatic ties and a reduced likelihood of conflict as it can disrupt trade relationships and harm their economies. Even during the Cold War, it was believed that political tensions can be reduced through economic interdependence (Giles, 1970).

One of the most important sectors in international trade is food trade. Food trade is also an important part of food security. Access, which is one of the four key elements of food security stated by FAO (2008), can only be possible through trade. Even if there is enough food, the lack of access and transportation to food puts food security at risk. There are many factors affecting international food trade such as the Covid-19 pandemic which has led to food insecurity due to national and international restricts and lockdown especially in low and middle-income countries with the high populations (Kakaei et al., 2022). Additionally, remaining good international relations and avoiding conflicts plays crucial role to sustain food security. One of the greatest examples is the recent Ukraine-Russia war. The global food crisis was sparked by Russia's military intervention in Ukraine, as Ukraine is a major player in the international grain market, ranking as the fourth-largest grain exporter worldwide. Moreover, Russia itself is among the world's significant wheat exporters (Ay and Soylemez, 2023). As a result of the crisis, Grain Corridor Agreement was signed to establish a safe route for grain trade.

With the food trade, water is also being traded virtually. Therefore, the relationship between international relations and food trade should also be evaluated from the virtual water perspective. Virtual water trade can be considered as an important factor

in international relations as well as international trade. As water scarcity becomes more severe in many regions, disputes over water resources can escalate into diplomatic conflicts. For instance, there are many conflicts between countries regarding transboundary waters in international relations such as the Nile River, the Euphrates-Tigris River. These conflicts occur mostly in water-scarce areas. However, there is no study examining international relations from the perspective of virtual water trade.

Virtual water trade can act as a tool for conflict resolution, enabling nations to import water-intensive products instead of using their own limited water resources. Virtual water trade creates interdependencies among countries, as water availability and trade partnerships become critical factors in maintaining stable international relations.

Understanding the virtual water footprint of products can help nations identify the environmental impact of their consumption and production patterns. This awareness is essential for promoting sustainable development practices and mitigating water-related risks. Recognizing the role of virtual water in shaping international dynamics can inform better water management strategies and foster more sustainable international relations.

On the other hand, the prospect of a dependency arising from the implementation of virtual water trade between nations is met with disapproval, as countries are unenthusiastic about becoming reliant on each other. Given this factor, the feasibility of integrating this concept into international relations can be questionable by the countries.

2.3. Global Apricot Production and Consumption

Apricots are deciduous fruit trees which means losing its leaves in fall. They have chilling requirement in winter for proper flower bud development and dormancy which is 927-1149 hours below 7.2°C in winter (Sevil, 2019). It can be consumed throughout the year in its processed form and is used in different industries. The harvest period of apricot is short., It is produced as table or dried according to soil structure (Karabacak and Uzundumlu, 2020). Subtropical climate is not suitable for the cultivation of apricots (Indian Institute of Food Processing Technology, 2023). Apricot grows in places where the relative humidity of the air is at an appropriate level. Too low relative humidity of the air causes fruit drop, and in case of high humidity and high precipitation, the effects of diseases such as freckles and monilia are more severe (Kargı et al., 2015). The homeland of apricots, which have been cultivated since ancient times, stretches from Turkestan to Western China. Although apricots are grown geographically almost everywhere in the world, they are mostly grown on the continents of Europe, America and Africa in countries close to the Mediterranean Sea (MoAF, 2019).

When considering the world's apricot production, 2021 statistics show that 4.3 million tons of apricots were produced in an area of 572 thousand hectares. Türkiye ranked first in terms of area with 134 thousand hectares followed by Iran, Uzbekistan, Algeria and China. Regarding production, more than 3,6 million tons of apricots were produced in the world. As seen in Figure 1, in 2021, Türkiye was again ranked first with 800 thousand tons followed by Uzbekistan, Iran, Algeria and Italy (FAOSTAT, 2023).

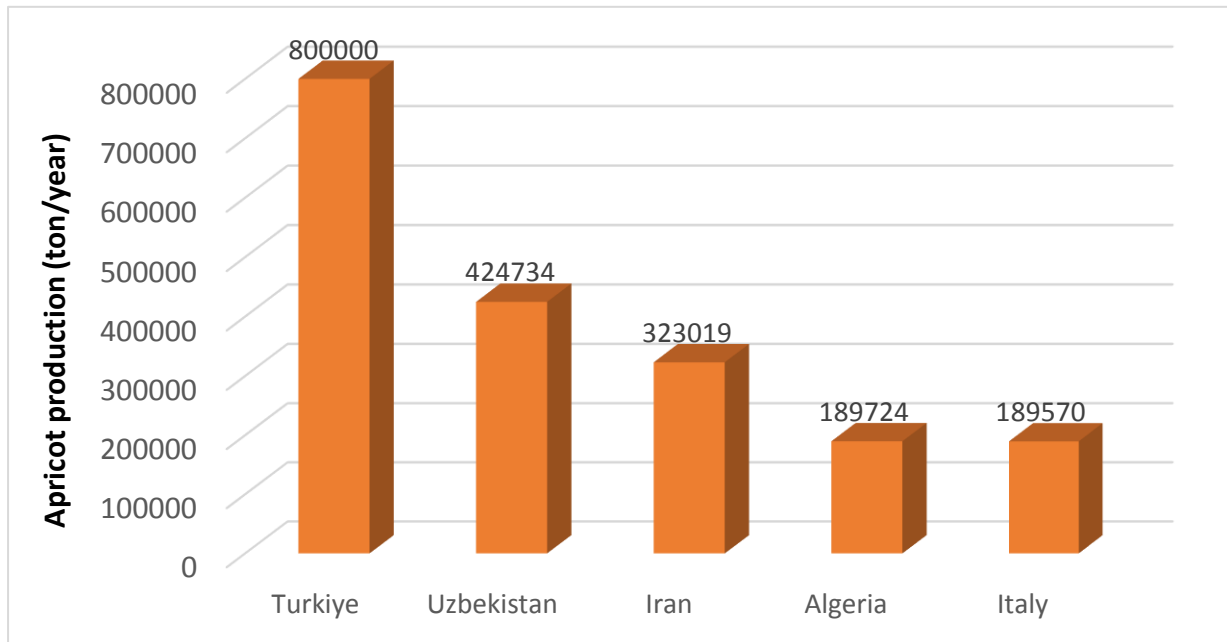


Figure 1. Top 5 apricot production by country

Turkiye is not only the major apricot producer but also one of the biggest apricot exporters in the world. On average (2013-2020), Turkiye has exported 140.823 tons/year of apricots and gained \$323 million/year from the export of those products. Especially, dried apricot production and export have an important place in Turkiye. Dried apricot export accounts for 62% of the total apricot export of Turkiye (UN COMTRADE, 2023). TEPGE (2021) revealed that Turkiye carried out 56.6% of the total world dried apricot exports with approximately 88 thousand tons.

In Turkiye, apricot is produced in mainly Malatya, Erzincan, Elazig, Kars, Sivas, Iğdır provinces and Aegean, Central Anatolia, Mediterranean and Marmara regions (Figure 2 and 3). A significant part of the apricot produced is exported after drying, and the rest is mostly used as table food and some of it is used in industrial production (Ministry of Trade, 2017). There are many apricot varieties grown in Turkiye which are

Hasanbey, Şekerpare, Şalak, Şam, Tokaloğlu, Turfanda İzmir, Ethembey, Alyanak, Karacabey, Mahmudun Eriği, İri Bitirgen, Adilcevaz, Precoce de Tyrinthe, Precoce de Colomer, Canino, Luizet, Roxana, Ninfa, Aurora for table and Hacıhaliloğlu, Soğancı, Kabaası, Çataloğlu for drying (Kargı et al., 2015).

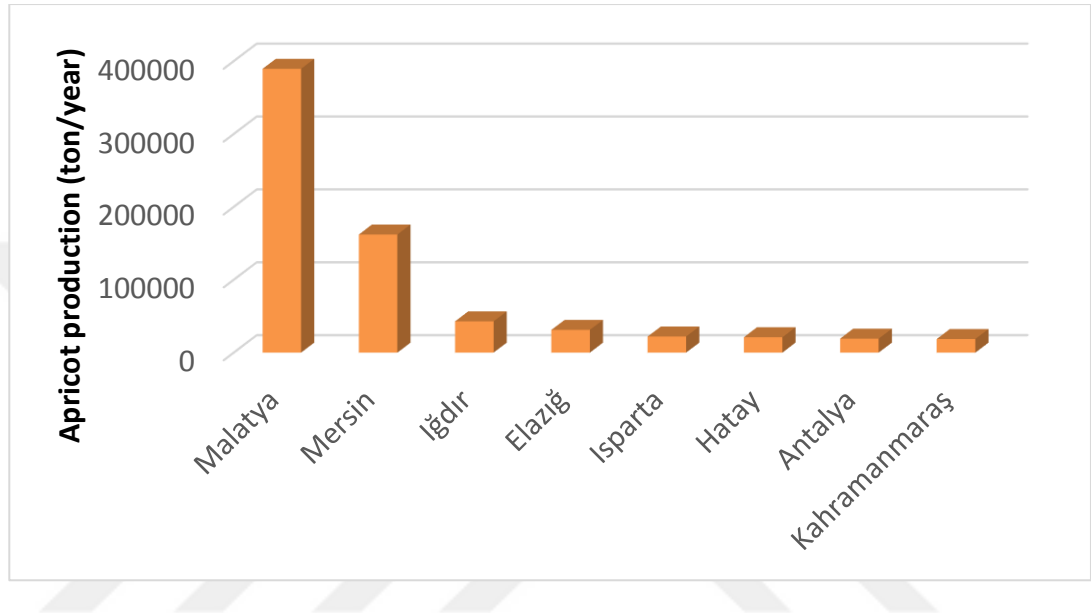


Figure 2. Apricot production by provinces in Türkiye (2021)

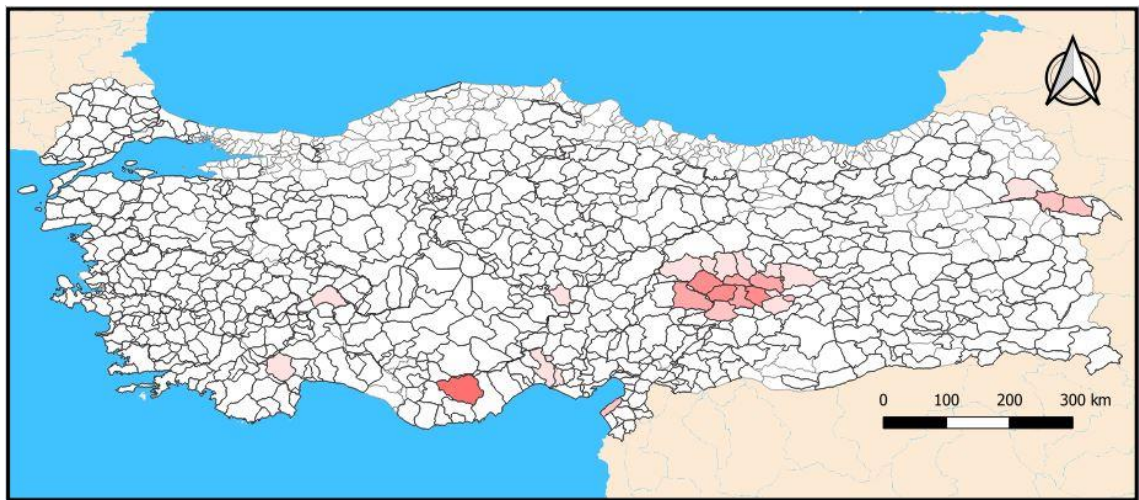


Figure 3. Apricot production map of Türkiye

Resource: <https://www.create4climate.com/2022/06/14/key-crops-of-turkey-apricots/>

As seen from Figure 2 and Figure 3, Malatya province is the major apricot production area in Türkiye. It is especially suitable for dry apricot production thanks to its fertile soils and its climate, which include cool winters and warm, dry summers (Asma et al. 2016). On the average, 734 thousand tons of apricots are being produced in Türkiye annually (2013-2020). A total of 373 thousand tons of apricots are produced annually in Malatya, which accounts for almost 51% of the total production (TURKSTAT, 2023).

While the dry matter ratio of apricots in other regions of Türkiye and the world is 15% on average, the dry matter ratio of Malatya apricots is 25-30% on average. Although, 1 kg of dried apricots is obtained from 6-7 kg of fresh apricots all over the world, including other provinces of Türkiye, 1 kg of dried apricots is obtained from 3-4 kg of fresh apricots in Malatya (Ünal, 2010). This characteristic is what makes Malatya apricots different from other apricots and the main reason why dried apricots are mostly produced in Malatya.

The major apricot variety produced in Malatya is Hacıhaliloğlu. Nearly 90% of the apricots produced in Malatya are made from this variety (MoAF, 2023). According to TURKSTAT (2023) statistics, the most apricot production in Malatya occurs in Akçadağ, Battalgazi, Darende and Yeşilyurt districts. The production in these districts is equal to 63% of the total production in Malatya.

For apricot production in Türkiye, there are different threats such as losses caused by late spring frosts, changing consumer demands in domestic and foreign markets, orchard disease (plum pox virus) that started to be observed in the Aegean, Mediterranean and Central Anatolian regions. Additionally, progress in the production and export of dried apricots in some Central Asian countries, especially in Uzbekistan, poses a threat in terms of competition in recent years (Asma et al. 2017).

Apricot production is very sensitive to climatic conditions. A study conducted by Uçar and Engindeniz (2019) shows that some of the highest risks to apricot production are climate and irrigation conditions. The major risk in terms of climate is frost. As evidenced, there was 90-95% damage in production after the frost experienced in Malatya in 2014 (MoAF, 2014). According to TURKSTAT (2023), productivity decreased to 5 kg/tree in 2014, which was 58 kg/tree the previous year.



3. METHODOLOGY

For the first part of the thesis, a literature review was made to determine the impacts of climate change on Türkiye and how Türkiye's agricultural production and food trade would be affected by climate change. Additionally, WF and virtual water concepts were examined above. Next, the most exported crops were determined to examine Türkiye's virtual water trade. Finally, the WF of apricot, as an example of key exported crop of our country, was calculated. The information on provided data and methodology is given below.

3.1. Agricultural Virtual Water Export Assessment for Türkiye

In order to examine Türkiye's agricultural virtual water exports, the quantities and economic values of the exported crops were obtained from UN Comtrade (2021). The data of 2013-2020 period was taken and processed products were not included. Then, the obtained data were averaged over the years 2013-2020 on excel and put in two ranks in terms of quantity and economic value. The products in the top ten according to the ranking were included in the study.

To determine how much water is used on average in the production of the detected crops, the global green and blue WFs (m^3/ton) of these crops were analyzed (the WF may differ from country to country depending on the climate and production conditions). Global average WF data was provided from the study conducted by Mekonnen and Hoekstra (2010). Then, the WF data was multiplied by the values (ton/year) exported by Türkiye to find out how much water was averagely exported in

total. According to the result, a ranking was made from the highest WF to the lowest and the result was evaluated.

3.2. Water Footprint Assessment

Within the scope of the WF concept introduced by Prof Arjen Hoekstra in 2002 and the WF Assessment Methodology developed by the WFN, the components of the green WF, blue WF and total WF of apricot production in mm, m³/ha, m³/year and m³/ton of Malatya, which equals to 51% of Turkey's total apricot production and 62% of dried apricot exports, have been calculated.

In the thesis, official sources were used for agricultural production, irrigation and meteorological data of Türkiye for 2021. In this context, the data produced by the Turkish Statistical Institute (TURKSTAT) regarding the amount of apricot production was used (TURKSTAT, 2022). In addition, the data for the water consumption of apricot was provided from “Manual of Crop Water Use of Irrigated Plants in Türkiye” prepared by the General Directorate of Agricultural Research and Policies (TAGEM) and DSI (2017). In addition to these, irrigation facilities located in Malatya and operated by DSI were determined and the data of the transmission systems and irrigation methods in those facilities were obtained from DSI. Finally, precipitation data of the climate stations in the apricot production areas in Malatya were provided by the General Directorate of Meteorology.

After gathering the necessary data, the utilization rates of transmission systems (classical, ducted and piped) and irrigation methods (surface, sprinkler and drip irrigation) in the facilities were examined. In addition, irrigation efficiency was calculated by taking the transmission and application efficiency values from the literature (DSI, 2008; FAO,

1989). Additionally, the share of irrigated fruit areas has been taken into account according to the plant distribution of the areas irrigated by DSI.

3.2.1. Average Irrigation Efficiency Calculation for Malatya

To determine the irrigation facilities operated by DSI in Malatya province, where the highest apricot production is carried out, the “Evaluation Reports of Irrigation Facilities Operated and Transferred by DSI” were examined for 2018. In the report, irrigation facilities are included based on DSI Regional Directorates. Malatya is numbered 9 out of 25 regional directorates. In this context, the irrigation facilities located in Malatya were identified among the irrigation facilities provided based on DSI Regional Directorates and the necessary data were provided (Annex 1).

Firstly, irrigation areas according to transmission systems and total irrigated areas according to irrigation methods related to irrigation facilities located in the apricot irrigated area in Malatya province were examined. The average irrigation efficiency values in these facilities have been calculated. The efficiency of the transmission systems and irrigation methods used in the irrigation efficiency calculation were taken from the literature (Table 1 and Table 2).

Table 1. Transmission System-Efficiency Values (DSI, 2008)

Transmission System	Water Transmission Efficiency (Ec) (%)
Classical	84
Ducted	92
Piped	98

Table 2. Irrigation Method-Water Application Efficiency Values (FAO, 1989)

Irrigation Method	Water Application Efficiency (Ea) (%)
Surface	60
Sprinkler	75
Drip	90

3.2.2. Calculation of the Water Requirement of Apricot

Green, blue and total water requirements of apricot produced in Malatya both for long-term average and for 2021 were calculated. In the calculation, the data belonging to the local climate stations in Malatya were used from the Manual of Crop Water Requirement of Irrigated Plants in Türkiye (TAGEM and DSI, 2017). In the mentioned guide, water requirement values and precipitation values were taken for 10-day periods on a monthly basis during the apricot growing season at the climate stations where apricots are grown in Malatya. Additionally, the precipitation data for 2021 was provided by the General Directorate of Meteorology.

The green water requirement (the amount of water met by precipitation, mm) and blue water requirement (the amount of irrigation water, mm) were theoretically calculated by using apricot water requirement (ET, mm) data of the apricot production season in the designated regions and long-term precipitation (P, mm). Then, the total irrigation water requirement (blue WF, mm) was determined by considering the calculated irrigation efficiency values and irrigation losses. In the study, the grey WF component (dilution water requirement) originating from the pollution due to apricot production was excluded. In the following sections, the method of the thesis study is explained in stages. CROPWAT model was not used for WF calculation, instead, calculations were carried out in excel with the help of the aforementioned data.

3.2.2.1. Crop Water Requirement (Evapotranspiration) (ET, mm)

Water requirement of apricot was determined from the “Crop Water Requirement of Agricultural Products by Climatic Regions” table in the “Crop Water Requirement Guide” regarding the climate stations in the regions where apricot production takes place in Malatya (TAGEM and DSI, 2017). At the relevant climate stations in each district, reference crop water requirement values for 10-day periods on a monthly basis during the apricot production season are given in Appendix 2. Accordingly, the average apricot water requirement based on those districts was calculated by using the reference apricot water requirement values of the climatic stations.

3.2.2.2. Precipitation (P, mm)

Both the long-term precipitation (1987 – 2017) and the data of 2021 were used to calculate the WF. Then, the outcomes were compared to have more accurate results. Firstly, the data of the General Directorate of Meteorology was used for the precipitation of the apricot growing season in Malatya. During the production season in each district where apricots are grown, the precipitation values for 10-day periods at the relevant climate stations are given in Appendix 2. For long-term precipitation data, the table "Long-Years Average Precipitation Amounts by Stations of Climatic Regions in Türkiye" was used (TAGEM and DSI, 2017). Since the plant cannot uptake all the water from precipitation, effective precipitation was used, where 80% of the falling precipitation was accepted as effective precipitation (P_e , mm). During the production season in each district where apricots are grown, the precipitation values for 10-day periods at the relevant climate stations are given in Appendix 2.

3.2.2.3. Green Water Requirement

Green water requirement was calculated following Bocchiola and Soncini (2013). According to their study, if evapotranspiration (ET) is higher than or equals to effective precipitation during the growing season, green WF is equal to effective precipitation (P_e). Conversely, if the ET is less than the effective precipitation (P_e) during the growing season, the green WF is equal to the ET.

$$\text{If } ET \geq P_e, WF_{\text{green}} = P_e \quad \text{Equation 1}$$

$$\text{If } ET < P_e, WF_{\text{green}} = ET \quad \text{Equation 2}$$

3.2.2.4. Net Irrigation Requirement (dn)

For calculating net irrigation requirement (dn), Bocchiola and Soncini (2013) indicated that if evapotranspiration (ET) is higher than or equals to effective precipitation during the growing season (P_e), dn is equal to the difference between evapotranspiration (ET) and effective precipitation (P_e). If evapotranspiration (ET) is less than the effective precipitation (P_e) during the growing season, dn is equal to zero.

$$\text{If } ET \geq P_e, dn = ET - P_e \quad \text{Equation 3}$$

$$\text{If } ET < P_e, dn = 0 \quad \text{Equation 4}$$

3.2.2.5. Total Irrigation Requirement (dt)

According to a study conducted by Güngör et al. (2004), total irrigation water requirement (dt) is calculated by dividing the net irrigation water requirement by the water application (E_a) and water transmission (E_c) efficiencies.

$$dt = dn / (E_a * E_c) \quad \text{Equation 5}$$

3.2.3. Water Footprint Calculation (m^3/ton)

The value of green and blue water requirement in m^3/ha should be calculated first to find the green and blue water components. The green and blue WF in crop water use (CWU) (m^3/ha) are calculated by using this formula conducted by Hoekstra et al. (2011):

$$CWU_{\text{green}} = 10 \times \sum_{d=1}^{l_{gp}} ET_{\text{green}} \quad \text{Equation 6}$$

$$CWU_{\text{blue}} = 10 \times \sum_{d=1}^{l_{gp}} ET_{\text{blue}} \quad \text{Equation 7}$$

Factor 10 is used to convert water depths in millimeters into water volumes per land surface in m³/ha and l_{gp} stands for the length of the growing period in the formula. After calculating the WF (m³/ha), the following formula is being used to calculate the WF in m³/ton (Hoekstra et al. 2011):

$$WF_{\text{green}} = CWU_{\text{green}} / \text{Yield (ton/ha)} \quad \text{Equation 8}$$

$$WF_{\text{blue}} = CWU_{\text{blue}} / \text{Yield (ton/ha)} \quad \text{Equation 9}$$

Production and cropped area data required for yield (ton/ha) were obtained from TURKSTAT (2023).

4. RESULTS AND DISCUSSION

4.1.Virtual Water Trade of Turkiye by Agriculture

By exporting the agricultural products produced in Turkiye, virtual water is also being exported. According to the study conducted by WWF (2014), the WF of Turkiye's exports of unrefined agricultural products equals to 19% of the total.

The average agricultural export of Turkey is 32.907.488 ton/year and the revenue generated from the export of these crops is 32.3 billion US \$/year (2013-2020). Table 3 and Table 4 show the top 10 exported agricultural products ranked by their net weight and value for the 2013-2020 average. It is seen from the tables that the most exported crops in terms of value bring almost two times more income than the most exported crops in terms of quantity. Hazelnuts, tobacco, apricots, figs and cotton do not take place in the most exported crops in terms of their quantity. However, those crops have importance in terms of their economic value.

Table 3. Top 10 exported crops (Net weight) (2013-2020 average)

Crops	Net Weight (tons/year)	Trade Value (US\$/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 4. Top 10 exported crops (value) (2013-2020 average)

Crops	Trade value (US \$/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 term of net weight

The study calculating Türkiye's WF, conducted by WWF (2014), indicated that while the share of processed and unprocessed agricultural products in the total WF of exports is 53%, the total export value is only 10%. It is evident that exporting products that do not add value to the country but have a high share in water consumption is not good practice when considering that Türkiye is not a water-rich country.

In Table 5, the global WFs of the products determined in terms of both quantity and value are given and listed from the largest to the smallest. When the export amounts of the crops are considered, it is seen from the table that lentil has the biggest WF. Additionally, crops such as hazelnuts, cotton, figs, tobacco and apricots have high global WFs. Figs are also the only crop that has more blue WF than its green WF, which means it requires more irrigation water than the precipitation. On the other hand, crops such as mandarins, lemons, grapes and tomatoes have lower WFs.

Table 5. The global WF of the crops by m³/ton (Mekonnen and Hoekstra, 2010)

Crops	WF _{green} m ³ /ton	WF _{blue} m ³ /ton	WF _{total} m ³ /ton
Lentils	4324	489	4813
Hazelnuts	3813	1090	4903
Cotton	2282	1306	3588
Figs	1527	1595	3122
Tobacco	2021	205	2226
Rice	1146	341	1487
Apricots	694	502	1196
Maize	947	81	1028
Apples	561	133	694
Bananas	660	97	757
Mandarins	479	118	597
Lemons	432	152	584
Grapes	425	97	522
Oranges	401	110	511
Tomatoes	108	63	171

In Table 6, the WF of the determined products is given according to the calculation of the global WF and data of crop export amounts. The results show that the export of lentils, hazelnuts and mandarins has the highest total WF. Although the global WF of hazelnuts is seven times higher than mandarins, when the export amounts are considered, they both have similar WFs. On the other hand, crops such as apricots, tobacco and tomatoes have a low WF and they are also the crops that have major contribution to the country's economy.

Table 6. The Virtual Water Export of the Crops (m³/year)

Crops	WF _{green} (m ³ /year)	WF _{blue} (m ³ /year)	WF _{total} (m ³ /year)
Lentils	1.364.455.496	154.305.906	1.518.761.402
Hazelnuts	602.698.032	172.289.760	774.987.792
Mandarins	587.976.332	144.845.944	732.822.276
Maize	452.089.277	38.668.671	490.757.948
Cotton	243.083.204	139.117.732	382.200.936
Rice	282.129.156	83.949.426	366.078.582
Lemons	204.449.616	71.935.976	276.385.592
Bananas	213.327.840	31.352.728	244.680.568
Figs	117.461.421	122.692.185	240.153.606
Grapes	195.315.975	44.577.999	239.893.974
Oranges	136.393.333	37.414.630	173.807.963
Apricots	97.731.162	70.693.146	168.424.308
Apples	100.565.982	23.841.846	124.407.828
Tobacco	101.415.801	10.287.105	111.702.906
Tomatoes	56.765.664	33.113.304	89.878.968
Total	4.755.858.291	1.179.086.358	5.934.944.649

In addition, in Table 6 it is seen that the WF of maize is quite high, yet maize ranks third in the list of the most exported products in terms of quantity. Despite the high-WF and huge amount of export, it is not included in the list of products that contribute to the economy. In contrast, although products such as bananas, oranges, apples and tomatoes are exported in large quantities, the WF is low. Finally, despite the relatively low total footprint of fig export, it is seen from the table that the share of blue WF is higher than the green WF, which means it is dependent on irrigation.

The amount of water used in Türkiye for agriculture is 44 billion m³ (DSI, 2021). This amount represents irrigation water. Considering the blue water footprint of the most exported crops, it is more than 1.1 billion m³. This means that, 1.1 billion m³ of the total water used in agriculture is exported only with the export of the crops evaluated in the thesis.

Grey water is not calculated in the virtual water trade, as it deals with the pollution created by the production process, not the water that is virtually present in the product. The grey water footprint of the exported products is 1 billion m³ which is the amount of water is used to dilute the water pollution caused by the production of these products. So, during export of crops, green and blue water of the country is exported whereas corresponding pollution remains in the country as indicated by grey water footprint.

4.2.WF Assessment of Apricot Production in Malatya Province

4.2.1. Apricot production by districts in Malatya

As seen from Table 7, almost 390 thousand tons of apricots were produced in Malatya in 2021. Battalgazi, Akçadağ and Darende were the major districts where apricot grows in the region. The distribution of fruits, including apricot, in the agricultural areas where the first product is irrigated by the irrigation facilities in Malatya is shown in Appendix 1.

Table 7. Apricot Production of Malatya in 2021

Districts	Amount (ton)
Akçadağ	70854
Battalgazi	81988
Darende	48280
Yeşilyurt	40885
Yazıhan	40965
Doğanşehir	31875
Hekimhan	33881
Pütürge	13674
Doğanyol	12833
Kuluncak	2005
Kale	6992
Arguvan	4824
Arapgir	340
Total	389396

4.2.2. Irrigation Efficiency in Malatya

The usage rates of the transmission systems (classical, canal, tubular) and irrigation methods (surface, sprinkler, drip) of the irrigation facilities in Malatya are shown in Annex 1. The average transmission efficiency was calculated according to the distribution of transmission systems in the areas irrigated by irrigation facilities in Malatya regarding the transmission efficiency in the Irrigation Drainage Conference Proceedings Book (2008).

4.2.3. Crop Water Requirement (Evapotranspiration) (ET, mm)

Apricot production in Türkiye takes place between April and October (see Annex 2). Due to seasonal conditions in Malatya, water consumption reaches higher amounts in the June-August period compared to other periods. According to the calculations, during the apricot growing season, the apricot water requirement amount in Malatya is 865 mm on the average.

4.2.4. Precipitation (P, mm)

Both the long-term precipitation and 2021 data were taken into account and compared to get an accurate result. According to the long-term precipitation data, the average precipitation in Malatya during the apricot production season (between April-October) is 591 mm. Effective precipitation was accepted as 80% (TAGEM and DSI, 2017). As a result of the calculation, the average effective precipitation was accepted as

472 mm. On the other hand, precipitation data for 2021 shows that the average precipitation in Malatya during the apricot production season is 163 mm. Effective precipitation is 147 mm which is quite less than the long-term average. This is the evidence that the drought was dominant in Malatya in 2021.

4.2.5. Green Water Requirement

Within the scope of the study, the green water requirement, which represents the part of the apricot production in Malatya that is met by the effective precipitation, has been calculated for both the long-term average and 2021 and given in detail in Annex 2. According to the calculation, in the long-term average, the amount of green water required for apricot production in Malatya is 140 mm. Furthermore, the green WF of apricot production was almost 45 mm in 2021. From the data, it is observed that there was very little precipitation in Malatya in 2021, accordingly, the green WF in apricot production was very low. Due to the lack of precipitation, rainwater could not be used in sufficient quantities in apricot production.

4.2.6. Net Irrigation Requirement

Net irrigation requirement is the amount of water required to meet the actual water requirements of the crops and is calculated by subtracting the effective precipitation from evapotranspiration. According to the long-term data, the net irrigation requirement of apricot produced in Malatya is 724.6 mm. On the other hand, the net irrigation requirement was 819.7 mm in 2021.

4.2.7. Total Irrigation Requirement

Total irrigation requirement refers to the blue water requirement of the crop. Total irrigation requirement includes both net irrigation requirement and losses in the irrigation system. According to the calculations, apricot production in Malatya requires 1462 mm of blue water for the long term and 1653 mm for 2021.

4.2.8. WF of Apricot Production in Malatya Province (m³/ton)

The green, blue and total WF components required for apricot production are calculated in m³/ton and given in Table 8. The calculation was made for both the long-term average and 2021. The data used for WF calculation is given in Annex 3.

Table 8. Green, Blue and Total WF Components of Apricot Production in Malatya

	WFgreen (m ³ /ton)	WFblue (m ³ /ton)	WFtotal (m ³ /ton)
Long-Term (1987 – 2017)	311	3283	3594
2021	100	3714	3814

Overall, in this thesis, an evaluation was made for the WF of apricot, which is one of the most revenue-generating exported products in Türkiye. Table 9 and Table 10 show the water requirement of apricot in Malatya divided by three climate stations according to the long-term average precipitation and 2021. As the results show, the need for blue water for apricot is higher than the need for green water. This is the evidence that apricot

production is highly dependent on irrigation. Additionally, in 2021, Malatya had an arid year compared to the long-term average. This situation has led to an increased demand for irrigation water than usual in apricot production.

Table 9. Water requirement of apricot and its components (Long-term)

Climate Stations	Crop Water Requirement (mm)	Precipitation (P, mm)	Effective Precipitation (Pe, mm)	Green Water Requirement (mm)	Blue Water Requirement (mm)
Doğanşehir	774	180	144	129	1260
Malatya	957	166	132.8	129	1535
Arapgir	860	245	196	163	1592
Average	863	197	157.6	140	1462

Table 10. Water requirement of apricot and its components (2021)

Climate Stations	Crop Water Requirement (mm)	Precipitation (P, mm)	Effective Precipitation (Pe, mm)	Green Water Requirement (mm)	Blue Water Requirement (mm)
Doğanşehir	774	35.4	28.32	28.32	1455
Malatya	957	69.2	55.36	55.36	1687
Arapgir	860	79.4	63.52	51	1818
Average	863	61.3	49	44.9	1653

The WF of apricot production in Malatya and globally is given in Table 11 below. The calculations show that blue WF of apricot is the highest which means apricot production is highly dependent on irrigation in Malatya. Looking at the long-term average, the green WF is higher due to higher precipitation. However, the lack of precipitation in 2021 led to a decrease in green WF. While the share of the green WF in total was 9% on the long-term average, it became only 3% in 2021.

Table 11. Comparison of Green, Blue and Total WF of Apricots (m³/ton)

	WF _{green} (m ³ /ton)	WF _{blue} (m ³ /ton)	WF _{total} (m ³ /ton)
Malatya (Long-Term)	311	3283	3594
Malatya (2021)	100	3714	3814
Global Average	694	502	1196

When the results are compared to the global WF, apricot is more dependent on precipitation globally and it requires less irrigation water. However, in Malatya, the green WF is pretty low and blue WF is six times higher than the global average.

The fact that apricot production is severely dependent on irrigation in Malatya puts great pressure on the water resources in the region. Especially in dry years, a very large part of its production is carried out with irrigation water. Such a high WF in Malatya, which is one of the most important regions both in apricot production and export, has negative consequences for water resources. Therefore, there is a need for approaches that will increase water efficiency in apricot production.

4.3.Evaluation of the WF of Apricot in Terms of Virtual Water Export

According to Firat Development Agency (2018), Malatya alone meets more than 50% of Türkiye's total apricot production and is also the largest dried apricot exporter. Malatya's production and exports, especially in dried apricots, have enabled Türkiye, and Malatya in particular, to dominate approximately 75% of world trade in dried apricot. In the same study, Türkiye's competitors in apricot exports were examined and it was stated that in the world's second largest producer Uzbekistan, the dried apricot market share is

2.5%, while it is more than 50% in Türkiye. These data show that Türkiye is the dominant country in world apricot exports, especially in dried apricots.

The amount of apricot sent to the dryer and the amount of dried apricots produced was shared in the 2021 yield forecast table by Malatya Commodity Exchange (2023). According to these data, 1 ton of dried apricot comes out from 4 tons of fresh apricots grown in Malatya. Most of the apricots produced in Malatya are dried and exported. According to Malatya Commodity Exchange data (2022), Malatya exported 90.203 tons of dried apricots in 2021. This corresponds to an estimated 360 thousand tons of fresh apricots. According to the WF of apricot production in Malatya in 2021, the total WF of exported apricots was 1.3 billion m³ of which only 2.6% is green and the rest is blue WF. As seen in Figure 4, the virtual water of apricot is almost four times higher than the domestic water used by the provinces in the Euphrates-Tigris basin (Adıyaman, Batman, Bingöl, Diyarbakır, Elazığ, Hakkari, Malatya, Muş, Şanlıurfa, Siirt, Şırnak, Tunceli). It is also equivalent to meet the domestic water needs of Malatya for approximately 25 years. (TURKSTAT, 2023)

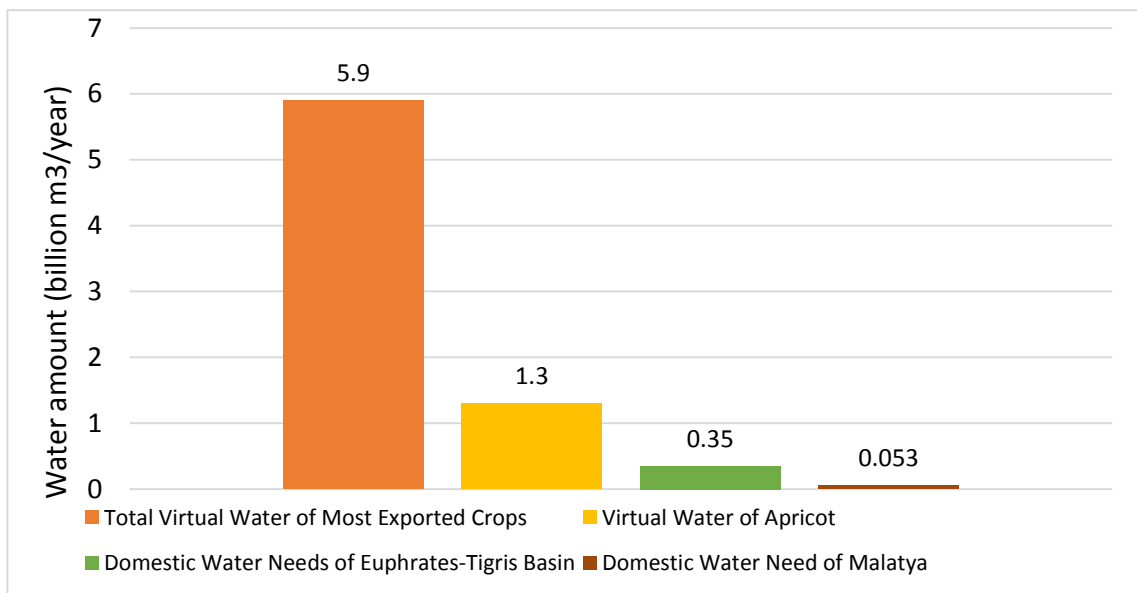


Figure 4. Comparison of virtual water of exported crops with domestic water needs (billion m³/year)

Considering Türkiye's virtual water exports, as stated in section 7.1, apricot is one of the most economically valuable products, but it is not included in the list of the most exported products in terms of quantity. Despite its high WF and dependence on irrigation, Malatya, which is the biggest building block of apricot exports, may continue to occupy an important position in exports due to the low amount of export and high income.

In the studies carried out in our country for apricot production and export, no detailed analysis was encountered in terms of WF. While determining policies to increase apricot export and production, water should also be kept in the foreground and evaluations should be made by giving importance to water footprint concept in production and virtual water in exports. Considering that the apricot, which has such an important place in the economy, will face situations such as water shortages and drought in the future, policies should be determined to minimize these effects.

Water is a complex issue posing significant challenges for countries. Throughout the years it contributed to political tensions between different countries. There are many conflicts over water. However, virtual water offers policymakers a genuine perspective on water scarcity. By understanding the indirect flow of water with international trade and quantifying the WF of crops or products, policymakers can develop better implications for water management, sustainability and trade decisions.

5. CONCLUSION

Nowadays, with the development of industry and rapid population growth, the water demand is increasing every day. However, due to the unconscious use of resources and the negative effects of climate change, water resources that are already scarce are insufficient to meet the increasing demand and global freshwater resources are rapidly being depleted. The depletion of water resources, which are the most basic requirements for life, creates negativities in many areas.

Globally, agriculture is the sector that needs water the most. The importance of water is inevitable to meet the increasing food demand and guarantee food security. However, the agriculture sector is highly vulnerable to climate change and water resources as it depends on temperature and precipitation. Water resources are under risk for many reasons and this situation also threatens agriculture. To reduce the potential risks affecting agricultural activities and ensure food security, priority should be given to the efficient and sustainable use of water in areas where water is used extensively. For this purpose, tools such as WF and virtual water trade have emerged to ensure the sustainable management of water resources.

Considering Türkiye's water resources, it is seen that Türkiye is not a water-rich country. Therefore, the virtual water concept can be a useful tool for more effective and efficient use of water. This thesis aims to evaluate top ten crops that are important both economically and in terms of quantity in Türkiye's exports in the context of virtual water trade.

As the crops that play an important role in Türkiye's exports are being evaluated, it is seen that lentils are the crops with the highest WF. Although it brings value from an

economic point of view, its place in exports is also large in terms of quantity which makes its share in virtual water exports high. The crops such as mandarins, lemons, grapes, and tomatoes, which are among the most exported products in terms of quantity, have the lowest WFs. As these products are exported the most in terms of quantity, they are also among the products that contribute the most in terms of income. On the contrary, although the WFs of crops such as hazelnuts, cotton, figs and tobacco are large, their value in terms of quantity is low in exports. Although they are exported in small amounts, their economic values are high.

The main argument of the thesis was “Does Türkiye’s most exported crops have high virtual water content so that it should be advised to involve virtual water concept in international trade practices?” As a result of the calculations made in response to the argument, the exported virtual water of top 15 crops was found as 5.9 billion m³ per year. This value is high enough to meet the domestic water needs of a metropolitan city like Istanbul for 7 years. When the blue water component was compared to agricultural water use considered, the exported virtual blue water was found as 1.1 billion m³ per year. This corresponds to 2.5% of annual agricultural water use of Türkiye, reported as 44 billion m³. Based on the data obtained and considering the current limited water availability of Türkiye, the virtual water contents of exported crops and goods seem to become a recognized factor and possibly a binding criteria in international trade. In this way, Türkiye can make informed decisions about resource allocation and sustainable trade practices that take into account water scarcity. This can help a water-stressed country like Türkiye to manage its limited water resources more efficiently and save considerable amount of water. Therefore, some suggestions given below to reduce virtual water export of Türkiye. The export of maize and rice should be reduced because of their high WF, large quantity of export and low economic value. Additionally, the export of cotton for its economic return should be reduced because of its high WF. On the contrary, the export

of crops such as apricots, tobacco and tomatoes which have low WF and high income should be continued. At the same time, exports of crops such as bananas, oranges and apples should be increased as their WF is low even though they are being exported in large quantities.

When the WF of the apricot is examined and compared to the global average, it is seen that for both the long-term average and the data for 2021, the WF of apricot production in Malatya is quite high especially for blue water. While the global blue WF is only 502 m³, for long-term accounts, the blue WF of the production of apricot in Malatya is 3200 m³. This result shows that apricot production in Malatya is highly dependent on irrigation. Therefore, irrigation conditions need to be improved to reduce the blue WF and more efficient irrigation methods such as drip irrigation should be used. Concepts such as WF and virtual water should be used as effective tools in sustainable water management. According to the WF amounts in production, solutions that will increase productivity should be produced, and efficiency should be increased by reducing the losses in irrigation.

In the thesis, Türkiye's virtual water trade is calculated according to global data. However, when the global water footprint and the water footprint calculated for apricots are compared, it is seen that there are major differences. The results change even for the long-term and current precipitations. Therefore, up-to-date and local data is needed to obtain more accurate results. The concept of virtual water trade should take place more effectively in Türkiye's food trade. Agricultural policies targeting the water footprint should be developed. The water footprint calculations should become widespread using current data for the crops produced in Türkiye.

**ANNEX 1. INFORMATION OF IRRIGATION FACILITIES OF
TURKISH STATE HYDRAULIC WORKS LOCATED IN MALATYA
PROVINCE**



Table 1: Irrigation Facilities of Turkish State Hydraulic Works Located in Malatya Province

Irrigation Facility	Irrigated area (ha)	Fruit Distribution	Irrigated Fruit Production Area	Transmission System (Classic, Ducted, Piped)	Rate	Transmission Efficiency	Average Transmission Efficiency	Irrigation Method (Surface, Sprinkler, Drip)	Rate	Application Method Efficiency	Average Application Method Efficiency	Irrigation Efficiency
Derme	1653	0.84	1388.52	Classic	0.92	0.84	0.7728	Surface	0.88	0.6	0.618	0.47759
				Piped	0.08	0.98	0.0784	Sprinkler	0.12	0.75		
Doğanşehir	1809	0.35	633.15	Classic	1	0.84	0.84	Surface	0.97	0.6	0.609	0.51156
								Drip	0.03	0.9		
Akçadağ	7191	0.74	5321.34	Classic	1	0.84	0.84	Surface	0.96	0.6	0.606	0.50904
								Sprinkler	0.04	0.75		
Şahnahan	5794	0.35	2027.9	Classic	0.94	0.84	0.7896	Surface	0.97	0.6	0.6045	0.477313
				Piped	0.06	0.98	0.0588	Sprinkler	0.03	0.75		
Yazıhan	6142	0.42	2579.64	Classic	1	0.84	0.84	Surface	0.97	0.6	0.6045	0.50778
								Sprinkler	0.03	0.75		
Polat	1341	0.39	522.99	Classic	1	0.84	0.84	Surface	1	0.6	0.6	0.504
Suçatı	2215	0.69	1528.35	Classic	1	0.84	0.84	Surface	0.99	0.6	0.6015	0.50526
								Sprinkler	0.01	0.75		
Sultansuyu	4299	0.69	2966.31	Classic	1	0.84	0.84	Surface	0.98	0.6	0.588	0.49392
								Sprinkler	0.02	0.75		
Çerkezyazısı	4465	0.85	3795.25	Piped	1	0.98	0.98	Sprinkler	1	0.75	0.75	0.735
Gökpınar	3188	0.47	1498.36	Piped	1	0.98	0.98	Sprinkler	1	0.75	0.75	0.735

**ANNEX 2. REFERENCE CROP WATER REQUIREMENT VALUES
BASED ON CLIMATE STATIONS IN MALATYA AND
CALCULATED WATER NEED REQUIREMENTS FOR APRICOT**



Table 2. Long-Term Calculation for Doğanşehir Station

Doğanşehir Station- Güneydoğu - Geçit Area	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	13	15	15	20	26	40	48	54	58	59	58	62	53	50	50	41	35	29	22	17	8	774
Precipitation (P,mm)	21	15	20	21	18	10	10	4	1	2	0	0	1	0	0	2	2	5	10	14	24	180
Effective Precipitation (Pe, mm)	17	12	16	17	14	8	8	3	1	2	0	0	1	0	0	2	2	4	8	11	19	144
Green Water Requirement (mm)	13	12	15	17	14	8	8	3	1	2	0	0	1	0	0	2	2	4	8	11	8	129
Net Irrigation Requirement (mm)	0	3	0	3	12	32	40	51	57	57	58	62	52	50	50	39	33	25	14	6	0	644.8
Irrigation Efficiency																						0.51156
Total Irrigation Requirement (mm)																						1260.458

Table 3. Long-Term Calculation for Malatya Station

Malatya Station- Güneydoğu - Geçit Area	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	14	16	17	21	30	44	51	58	63	63	65	69	60	57	57	47	41	34	26	18	10	957
Precipitation (P,mm)	17	17	17	18	16	11	9	8	1	2	0	0	1	0	1	1	1	5	9	13	19	166
Effective Precipitation (Pe, mm)	14	14	14	14	13	9	7	6	1	2	0	0	1	0	1	1	1	4	7	10	15	132.8
Green Water Requirement (mm)	14	14	14	14	13	9	7	6	1	2	0	0	1	0	1	1	1	4	7	10	10	129
Net Irrigation Requirement (mm)	0	2	3	7	17	35	44	52	62	61	65	69	59	57	56	46	40	30	19	8	0	733
Irrigation Efficiency																						0.477313
Total Irrigation Requirement (mm)																						1535.68

Table 4. Long-Term Calculation for Arapgir Station

Arapgir Station- Güneydoğu - Geçit Area	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	15	18	20	24	32	46	53	61	67	69	72	78	69	67	67	53	48	39	30	21	11	860
Precipitation (P,mm)	30	32	26	28	21	14	8	8	4	3	1	1	0	1	0	3	2	6	9	16	32	245
Effective Precipitation (Pe, mm)	24	26	21	22	17	11	6	6	3	2	1	1	0	1	0	2	2	5	7	13	26	196
Green Water Requirement (mm)	15	18	20	22	17	11	6	6	3	2	1	1	0	1	0	2	2	5	7	13	11	163
Net Irrigation Requirement (mm)	0	0	0	2	15	35	47	55	64	67	71	77	69	66	67	51	46	34	23	8	0	796
Irrigation Efficiency																						0.50778
Total Irrigation Requirement (mm)																						1592

Table 5. 2021 Calculation for Doğanşehir Station

Doğanşehir Station	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	13	15	15	20	26	40	48	54	58	59	58	62	53	50	50	41	35	29	22	17	8	774
Precipitation	0	7.4	0.2	9.6	0	0	0.8	0.6	0	0.2	0	0	2	3.2	0	0	0	6.8	0	0	4.6	35.4
Effective Precipitation (Pe, mm)	0	5.9	0.2	7.7	0	0	0.6	0.5	0	0.2	0	0	1.6	2.6	0	0	0	5.4	0	0	3.7	28.32
Green Water Requirement (mm)	0	5.9	0.2	7.7	0	0	0.6	0.5	0	0.2	0	0	1.6	2.6	0	0	0	5.4	0	0	3.7	28.32
Net Irrigation Requirement (mm)	13	9.1	15	12	26	40	47	54	58	59	58	62	51	47	50	41	35	24	22	17	4.3	744.68
Irrigation Efficiency																						0.51156
Total Irrigation Requirement (mm)																						1455.704

Table 6. 2021 Calculation for Malatya Station

Malatya Station	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	14	16	17	21	30	44	51	58	63	63	65	69	60	57	57	47	41	34	26	18	10	957
Precipitation	0	8.9	0.6	14	0.5	6.1	1.3	1.9	5.9	0.2	0	0	6.2	15	1.8	0.1	2.3	3.3	0.9	0	0	69.2
Effective Precipitation (Pe, mm)	0	7.1	0.5	11	0.4	4.9	1	1.5	4.7	0.2	0	0	5	12	1.4	0.1	1.8	2.6	0.7	0	0	55.36
Green Water Requirement (mm)	0	7.1	0.5	11	0.4	4.9	1	1.5	4.7	0.2	0	0	5	12	1.4	0.1	1.8	2.6	0.7	0	0	55.4
Net Irrigation Requirement (mm)	14	8.9	17	9.8	30	39	50	56	58	63	65	69	55	45	56	47	39	31	25	18	10	805.64
Irrigation Efficiency																						0.477313
Total Irrigation Requirement (mm)																						1687.865

Table 7. 2021 Calculation for Arapgir Station

Arapgir Station	April			May			June			July			August			September			October			Total
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Crop Water Requirement (Et)	15	18	20	24	32	46	53	61	67	69	72	78	69	67	67	53	48	39	30	21	11	860
Precipitation	1.2	9.4	3.2	2.8	0	1	0.2	3.2	0.8	0	1	0	9.6	9.2	0	0	0	7.2	0.2	1	29.4	79.4
Effective Precipitation (Pe, mm)	0.96	7.52	2.56	2.24	0	0.8	0.16	2.56	0.64	0	0.8	0	7.68	7.36	0	0	0	5.76	0.16	0.8	23.5	63.52
Green Water Requirement (mm)	0.96	7.52	2.56	2.24	0	0.8	0.16	2.56	0.64	0	0.8	0	7.68	7.36	0	0	0	5.76	0.16	0.8	11	51
Net Irrigation Requirement (mm)	14	10.5	17.4	21.8	32	45.2	52.8	58.4	66.4	69	71.2	78	61.3	59.6	67	53	48	33.2	29.8	20.2	0	909
Irrigation Efficiency																						0.5
Total Irrigation Requirement (mm)																						1818

**ANNEX 3. GREEN, BLUE AND TOTAL WATER FOOTPRINT
CALCULATIONS AND NECESSARY DATA**

Table 8. Green, Blue and Total Water Footprint Calculations of Apricot Production in Malatya

Time Period	Apricot Production (ton)	Y(ton/ha)	Green Water Requirement (mm/year)	Total Irrigation Requirement (dt) (mm/year)	Total Water Requirement (mm/year)	Total Area (ha)	Green WF (m3/ha)	Blue WF (m3/ha)	Total WF (m3/ha)	Green WF (m3/ton)	Blue WF (m3/ton)	Total WF (m3/ton)	Green WF %	Blue WF %
Long-Term	389,396	4.5	140	1478	1618	85642	1400	14776	16176	308	3250	3558	9	91
2021	389,396	4.5	45	1671	1716	85642	449	16714	17163	100	3714	3814	3	97

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ABSTRACT

Although Türkiye is already experiencing water scarcity, the water resources are decreasing even more due to the impact of climate change. To meet the growing demand, there is a need for more effective water management by making use of the WF and virtual water trade concepts. When we look at the virtual water trade of Türkiye, besides the crops with low WF, the water-thirsty crops are also being exported because their economic return is high. With the export of agricultural products, Türkiye also exports water virtually. When the virtual water exports of the selected crops examined, it can be perceived that the exported virtual water is equivalent to the domestic water needs of Istanbul for almost 7 years. To use water resources more efficiently, attention should be given to the concept of WF in exported agricultural products. The WF of the production of apricots in Malatya, which has an important place in exports and economic value, has been examined as a case study. According to the calculations, while the global green WF is 694 (m³/ton), Malatya's long-term average green WF is 311 (m³/ton). Besides, the blue WF is 502 (m³/ton) globally and 3283 (m³/ton) in Malatya. It has been seen that the blue WF of apricot production in Malatya is very high when compared to the global WF. The fact that apricot production is highly dependent on irrigation water has a negative impact on the water resources in the region. For this reason, more efficient irrigation methods should be used to reduce irrigation water in production and the blue WF should be minimized for the sustainability of water resources.

ÖZET

Türkiye zaten su kıtlığı çeken bir ülke olmakla birlikte iklim değişikliğinin etkisiyle su kaynakları daha da azalmaktadır. Artan ihtiyacın giderilmesi için su ayak izi ve sanal su ticareti kavramlarından yararlanılarak daha etkili bir su yönetimine ihtiyaç vardır. Türkiye'nin sanal su ticaretine bakıldığında az su tüketen ürünlerin yanında ekonomik getirisi yüksek olduğu için bol su tüketen ürünler de ihraç edilmektedir. Tarım ürünlerinin ihracatıyla Türkiye aynı zamanda sanal olarak su da ihraç etmektedir. Seçilen ürünlerin sanal su ihracatı değerlendirildiğinde, Türkiye'nin ihraç ettiği sanal suyun, İstanbul'un yedi yıllık evsel su tüketimine eşit olduğu görülmektedir. Ayrıca ihracatta önemli bir yere sahip olan kayısının en önemli üretim yeri olan Malatya'da üretiminin su ayak izi örnek bir çalışma olarak incelenmiştir. Hesaplamalara göre küresel yeşil su ayak izi 694 (m³/ton) iken Malatya'nın uzun dönem ortalama yeşil su ayak izi 311 (m³/ton)'dir. Öte yandan mavi su ayak izi küresel olarak 502 (m³/ton) iken, Malatya'nın 3283 (m³/ton)'dür. Küresel su ayak iziyle kıyaslandığında Malatya'da kayısı üretiminin mavi su ayak izinin çok yüksek olduğu görülmektedir. Kayısı üretiminin çok yüksek oranda sulama suyuna dayanması bölgenin su kaynaklarına olumsuz bir etki yaratmaktadır. Bu sebeple üretimde sulama suyunun azaltılması için daha verimli sulama yöntemleri kullanılmalı ve su kaynaklarının sürdürülebilirliği için mavi su ayak izi azaltılmalıdır.