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# ASSESSMENT OF WATER RESOURCES STATUS USING THE WATER FOOTPRINT CONCEPT: THE CASE OF TEKIRDAĞ PROVINCE

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**Abstract:** One of the fundamental steps in the protection and sustainability of water resources is monitoring and evaluation. By assessing the resources in terms of both quality and quantity, a clear depiction of the current situation can be established, which will form a solid inventory for the necessary actions. From the perspective of our country, the main issues concerning our water resources include the reduction in water quantity during periods of need due to excessive and uncontrolled use, the uncontrolled increase in pollution due to negligence linked to sectoral developments, and globally, the expected intense impact of climate change on the Mediterranean Basin, where we are located. The concept of the water footprint is one of the accepted methods for diagnosing the current state of water resources in terms of management planning and sustainability. The water footprint concept can effectively reveal how agricultural, industrial, and domestic uses impact water resources. In the present study, the agricultural water footprint of Tekirdağ, one of the most economically powerful provinces in the Thrace Region in terms of agriculture and industry, has been calculated and evaluated. Agriculture water footprint was found to be 1.33 billion cubic meters (BCM) in total, 0.61 BCM in crop production and 0.72 BCM in animal production. The green, blue and grey water footprint values for crop production were calculated as 0.11, 0.48 and 0.02 BCM, respectively. The results underscore the significant water demand of agricultural activities in Tekirdağ, highlighting the need for sustainable water management strategies to address resource utilization in crop and animal production.

**Keywords:** Water management, Agricultural water footprint, Water resources, Sustainability, Agriculture

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## 1. Introduction

According to UN-Water's progress on implementation of integrated water resources management report at the current rate, the world will not achieve sustainable water management until at least 2049 – 25 years from now. It is predicted that in 2030, not too far from today, approximately 3.5 billion people in the world will not be able to cope with the effects of water scarcity due to economic inadequacies and severe effects such as climate change. Political commitments at the global level for sustainable water management have never been higher, but they have not been matched by the required finance or action on the ground in the report the evaluation of scientists (UN-Water, 2024). As is evident from the studies of institutions and organizations working on the subject, in the near future, regions including our country will face serious problems in accessing usable water resources in terms of quality and quantity.

Considering the Sustainable Development Goals (SDGs), it is seen that food, energy, ecosystem and climate change are among the goals related to water. For this reason, the status of water resources and monitoring and evaluation studies are very important. In the last 20 years, terrestrial water storage, including soil moisture, snow and ice, has declined at a rate of 1 cm per year, with significant implications for water security (WMO, 2021). According to the World Meteorological Organization Report for 2023, our country, and especially the Thrace Region, including Tekirdağ Province, has shown an extreme negative impact in the period between 2020-2023 in terms of reservoir storage and river flows (WMO, 2023). As is evident from the studies of institutions - organizations and scientists on the subject, in the near future, regions including Türkiye will face serious problems in accessing usable water resources in terms of quality and quantity (UN-Water, 2024, DSI, 2022). In order to prevent this situation and to ensure the sustainable use of existing water resources for agriculture, industry and domestic use, there are institutional and personal efforts to be made.

The decrease in the water resources of Tekirdağ province and the subsequent excessive pollution due to the ever-increasing industrial areas show visible effects today. With the developed industrial complexes in the province and the parallel development of agriculture, the subsurface water layers, which were 30-50 meters in the 1980s, have now reached a depth of several hundred meters and have suffered a significant loss in quantity. Therefore, allocations for groundwater use have been suspended by the State Hydraulic Works (DSI). Surface water resources are also experiencing quality deterioration and pollution, especially at very serious levels, under similar effects to groundwater resources. The amount of wastewater discharged into the Ergene Basin from Tekirdağ province is 200 million $m^3$/year (Anonymous, 2023a). Although it is clearly seen that this situation is not sustainable, although various plans and projects have been made, unfortunately, the implementation of the necessary measures in practice does not show a rapid development.

Considering agriculture, Tekirdağ province is one of the important agricultural production areas in Thrace. In the province, which has favourable conditions for cultivation in terms of soil characteristics and topography, 81% of the cultivated agricultural land consists of I., II. and III. class soils. For this reason, 30% of the country's sunflower production and a significant portion of wheat, canola and paddy production is provided from here. Due to the variations in the climate, the production amounts of other product groups, such as fruits and vegetables, are at very high levels (TSI, 2024).

**Table 1.** Changes in production area and quantity over the years in Tekirdağ Province

| Years | 2004 | | 2022 | |
|---|---|---|---|---|
| | Production area | Production quantity | Production area | Production quantity |
| Types | ha | tones | ha | tones |
| Orchards | 9.184 | 73.283 | 11.662 | 82.936 |
| Vegetables | 8.112 | 174.400 | 2.960 | 95.698 |
| Field Crops | 366.775 | 1.380.096 | 405.710 | 1.767.989 |

Table 1 shows the changes in the cultivation areas and production amounts of the crop groups in the last twenty years. Tekirdağ province's significant agricultural cultivation capabilities have encouraged the development of agriculture-based industry in parallel. The strength of agricultural production as well as industry makes the situation more complicated in this region where water resources are very limited and polluted.

The study will assess agricultural water use in Tekirdağ province from a different perspective and discuss the current situation. The water footprint approach will analyse water resource consumption at the province level and provide guidance for future projections. It will highlight practical successes and identify necessary actions if there are gaps, thus providing valuable insights to scientists and decision makers. In light of this information, it will help to better manage water resources and ensure the sustainability of food supply.

## 2. Materials and Methods

### 2.1. Materials

The study was conducted using data on agricultural production and water resources of Tekirdağ Province. Tekirdağ is located at 40° 59' north latitude and 27° 29' east longitude on the northern coast of the Marmara Sea. The province is only 4 m above sea level. The Mediterranean climate is generally dominant on the coasts of the Marmara Sea. However, unlike the coastline of the Mediterranean Region, snowfall can be seen in the coastal area in winter. In the interior of the province, continental climate is dominant with hot summers and cold winters. According to long-term meteorological data (1991-2020), the average annual temperature is 14.5 °C, the average sunshine duration is 5.7 hours and the average annual precipitation is 601.1 mm (TSMS, 2022). The changes in temperature, precipitation and daytime sunshine duration values, which can have a significant impact on plant water consumption and the use of water resources, are given in figure 1.

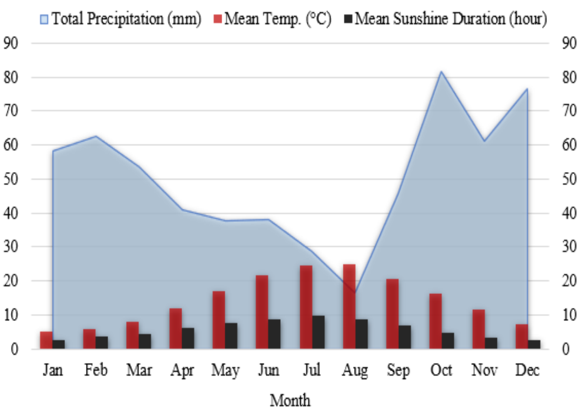


**Figure 1.** Change of meteorological parameters based on long-term averages.

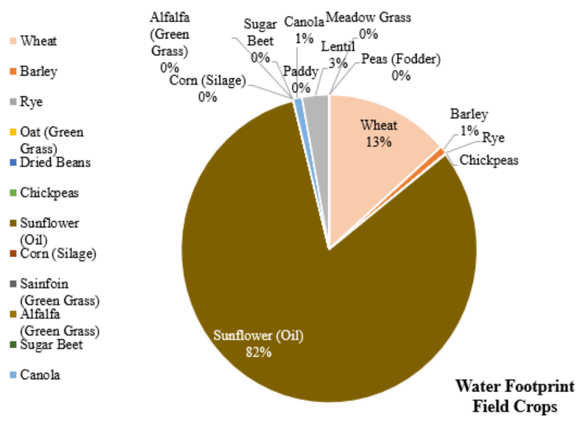


**Figure 2.** Water footprint of field crops

Tekirdağ province has a total water resource of 1.27 billion $m^3$, including approximately 1.1 billion $m^3$ of surface water and 263 million $m^3$ of groundwater. When surface water resources are evaluated, the Ergene River 26.49 $m^3$ $s^{-1}$ and Hayrabolu stream 4.4 $m^3$ $s^{-1}$ stand out among the rivers, which are trying to cope with a serious pollution load. Karaidemir Dam, Ferhadanlı Dam and Türkmenli Dam are important as large reservoirs and Hanoğlu, İnanlı and Yazır Ponds are important for large-scale irrigation and drinking water supply. Underground water resources are realized as 19 million $m^3$ irrigation water in 9 sections and 115 million $m^3$ for industrial use (DSI, 2022).

National data used for the analysis were obtained from multiple data sources, while global data on water footprint indicators were obtained from the tables described by Mekonnen and Hoekstra (2011, 2012). Groundwater and surface water resource potential, water use, number of livestock and meteorological data for Tekirdağ province in 2022 were obtained from Turkish Statistical Institute, Ministry of Agriculture and Forestry General Directorate of State Hydraulic Works, General Directorate of Agricultural Research and Policies, Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology and Food and Agriculture Organization (DSI, 2022; TSMS, 2022; Anonymous, 2023b).

**2.2. Methods**

The study focused on calculating the volume-based blue, green, and grey water footprints described by Hoekstra et al. (2011). The blue water footprint (WFblue) indicates the portion of consumed groundwater or surface water. The agricultural water footprint has been determined by calculating the total green, blue, and grey water requirements of crops grown in the region. The Green Water Footprint (WFgreen) is considered as the total volume of rainwater used in the production of a product, while the grey water footprint (WFgrey) is calculated as the total volume of water needed to neutralize pollutants (Hoekstra et al., 2011; Ercin and~~ve~~ Hoekstra, 2012).

The method developed by Chapagain and Hoekstra (2004) for determining the water footprint of crop production has been used. In crop production, the water footprint largely depends on the water consumption of the plants. Plant water consumption consists of two main components: rainfall and irrigation water. In the research area, water footprint values in $m^3$/year and $m^3$/ton have been calculated using the water footprint method developed by Chapagain et al. (2006). The necessary meteorological data for the calculations were obtained from the General Directorate of Meteorology (TSMS, 2022). To determine the water footprint of crop production, plant water consumption and effective rainfall were first calculated using the TAGEM-SUET (tagemsuet.tarimorman.gov.tr) application, resulting in the green and blue water needs. The Penman-Monteith method was used for plant water consumption and the USDA-SCS method for effective rainfall in the application. Plant water consumption (ET, $m^3$/ha) is calculated as the sum of the blue and green water needs (Chapagain and Hoekstra, 2004).

**Table 2.** Annual water footprint of animal category and some selected food products

| Water footprint of animal type | | | | Water footprint of animal products | | | | |
|---|---|---|---|---|---|---|---|---|
| Animal category | Number of animal head | $WF_{mean}$ ($m^3$/animal) | $WF_{total}$ ($10^6$ $m^3$) | Product | $WF_{green}$ ($m^3$) | $WF_{blue}$ ($m^3$) | $WF_{grey}$ ($m^3$) | $WF_{total}$ ($10^6$ $m^3$) |
| Cattle | 146914 | 1889 | 277.52 | Milk | 196764000 | 19608000 | 16416000 | 232.8 |
| Buffalo | 1715 | 20558 | 35.26 | Eggs | 176256 | 16592 | 29172 | 0.2 |
| Sheep | 307050 | 141 | 3.31 | Chicken meat | 2176630 | 192182 | 286738 | 2.7 |
| Goat | 40887 | 76 | 43.29 | Beef | 90231640 | 3443000 | 2823260 | 96.5 |
| Broiler | 95178 | 6 | 0.57 | Sheep | 13683474 | 757706 | 87874 | 14.5 |
| Egg poultry | 272078 | 47 | 12.79 | Goat | 150240 | 14880 | 12576 | 0.2 |
| Total | | | 372.73 | | 303182240 | 24032360 | 19655620 | 346.87 |

$WF_{mean}$= average water footprint at end-of-life time by Mekonnen and Hoekstra (2012)

The water footprint components of crop water consumption ($m^3$/ha) are values dependent on the green and blue water needs of the crop during its growing season (crop water consumption ET, mm). Green crop water consumption is the amount of crop water consumption covered by effective rainfall. Green and blue plant water consumption values are calculated by using the relationships between the amount of water used by the plant, effective rainfall, and net irrigation water requirement as specified in the Lovarelli et al., 2016 literature.

Blue crop water consumption (dn, ETblue-theoretical) theoretically represents the amount of irrigation water needed by the crop. This amount includes the water losses that occur as the irrigation water delivery from the water source to the crop. Therefore, blue crop water consumption has been divided by the irrigation efficiency (E) to calculate the total theoretical irrigation water requirement using equations 1 (Hoekstra et al., 2012).

$$ETblue\text{-}theoretical = ETblue/E \quad (1)$$

Crop water use (CWU, $m^3$/ha) represents the total evapotranspiration amount (ET) during the crop growing season (lgp) and is determined by equations 2.

$$CWU_{green/blue} = 10 \times \sum_{d=1}^{lgp} ET_{green/blue} \quad (2)$$

The water footprint of crops is obtained from the sum of green, blue, and grey water footprint components throughout the crop growth process by equations 3. Green and blue water footprints ($m^3$/ton) are calculated by dividing crop water use ($m^3$/ha) by crop yield (ton/ha) using equationss 4 and 5. The green, blue, and total water footprint values during the growing season were calculated using equationss 6, 7 and 8, based on the total volume of water used for crop production (Hoekstra et al., 2011). Grey water footprint for crop production has been calculated using the average water footprint per ton of commodity per country, weighted based on origin (WF* in $m^3$/ton) values described in Mekonnen and Hoekstra (2011).

$$WFproc = WFproc\text{-}green + WFproc\text{-}blue + WFproc\text{-}grey \quad (3)$$

$$WFproc\text{-}green = \frac{CWU_{green}}{Y} \quad (4)$$

$$WFproc\text{-}blue = \frac{CWU_{blue}}{Y} \quad (5)$$

$$WFproc\text{-}green\ (m^3) = wFproc\text{-}green\ (m3/ton) \times Production\ (ton/year) \quad (6)$$

$$WFproc\text{-}blue\ (m^3) = wFproc\text{-}blue\ (m^3/ton) \times Production\ (ton/year) \quad (7)$$

$$WFgrey\ (m^3) = wFproc\text{-}grey\ (m^3/ton) \times Production\ (ton/year) \quad (8)$$

The water footprint of livestock includes the total amount of water used directly or indirectly in the production of beef, dairy, and other products from cattle, sheep, and poultry raised in the region. In animal production, the blue water footprint per animal is obtained by multiplying the number of livestock (HSi,j) by average water footprint at end of life time (HSUi,j, $m^3$/animal) reported by Mekonnen and Hoekstra (2012) using equations 9.

$$BlueSA_{animal} = \sum HS\dot{I}, \times HSUi,j \quad (9)$$

The blue, green, and grey water footprints of animal products such as meat, milk, and eggs were obtained by multiplying the water footprint values per ton described by Mekonnen and Hoekstra (2012) with the total production quantities in Bilecik province.

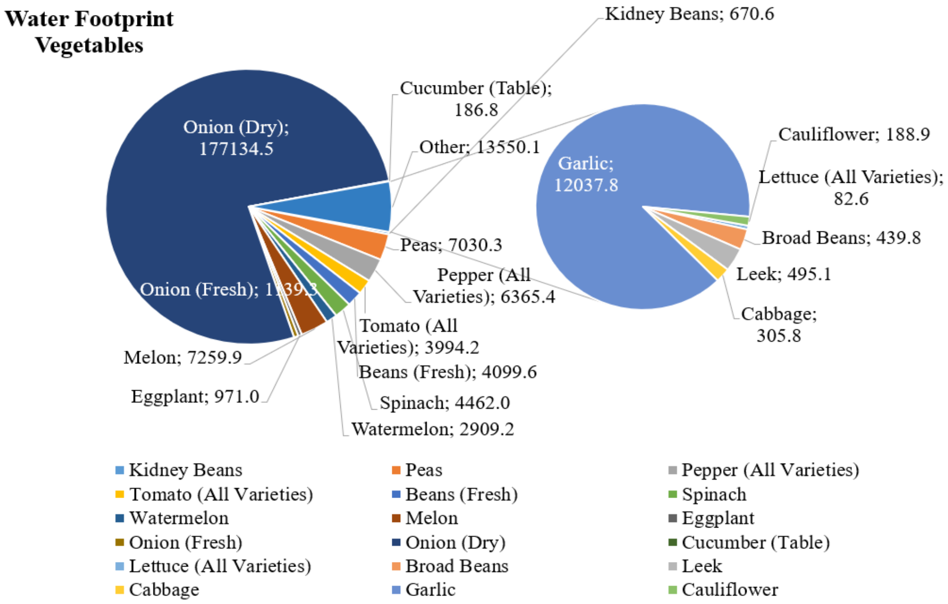


**Figure 3.** Water footprint of vegetables.

**Table 3.** The green, blue and grey water footprint along process of growing crops

| Crop Category | Crop variety | Cultivated area (ha) | Crop Production (ton/year) | WFproc-green (m3/ton) | WFproc-blue (m3/ton) | WFgreen (m3) | WFblue (m3) | WFgrey (m3) | WFproc (million m3) |
|---|---|---|---|---|---|---|---|---|---|
| | Wheat | 192782.00 | 45772.40 | 377.52 | 1158.66 | 17279771.55 | 53034770.55 | 8788300.64 | 79.10 |
| | Barley | 14496.10 | 3089.48 | 338.87 | 1197.76 | 1046925.33 | 3700453.05 | 71057.96 | 4.82 |
| | Rye | 60.00 | 11.84 | 313.82 | 1357.89 | 3716.24 | 16080.33 | 1717.11 | 0.02 |
| | Oat (Green Grass) | 2015.00 | 79.76 | 62.94 | 228.79 | 5019.97 | 18248.71 | 11565.32 | 0.03 |
| | Dried Beans | 83.30 | 44.48 | 849.02 | 3833.94 | 37764.43 | 170533.71 | 11075.54 | 0.22 |
| | Chickpeas | 206.60 | 92.19 | 709.49 | 1767.03 | 65407.28 | 162901.15 | 35308.43 | 0.26 |
| | Sunflower (Oil) | 170920.60 | 87059.73 | 809.88 | 4563.85 | 70507836.78 | 397327180.85 | 12275422.54 | 480.11 |
| | Corn (Silage) | 4135.50 | 87.20 | 33.53 | 160.67 | 2923.28 | 14009.70 | 14300.29 | 0.03 |
| | Sainfoin (Green Grass) | 6.00 | 0.26 | 69.13 | 155.65 | 18.03 | 40.60 | 28.70 | 0.00 |
| Field Crops | Alfalfa (Green Grass) | 1807.40 | 37.44 | 116.31 | 115.38 | 4354.74 | 4319.84 | 1123.19 | 0.01 |
| | Triticale | 520.40 | 114.12 | 348.69 | 1508.79 | 39793.63 | 172188.77 | 43709.48 | 0.26 |
| | Sugar Beet | 221.80 | 3.09 | 44.94 | 131.89 | 139.03 | 408.03 | 1184.87 | 0.00 |
| | Canola | 8944.80 | 2789.24 | 769.90 | 973.53 | 2147451.11 | 2715408.00 | 694521.61 | 5.56 |
| | Paddy | 68.60 | 10.31 | 370.97 | 1499.82 | 3823.75 | 15459.15 | 1979.01 | 0.02 |
| | Lentil | 2855.10 | 2676.66 | 1490.63 | 4500.00 | 3989890.72 | 12044953.13 | 1025159.34 | 17.06 |
| | Sorghum (Green Grass) | 19.00 | 0.66 | 111.10 | 117.10 | 72.79 | 76.72 | 125.79 | 0.00 |
| | Triticale (Green Grass) | 59.00 | 2.36 | 128.62 | 152.33 | 302.92 | 358.77 | 902.05 | 0.00 |
| | Meadow Grass | 833.40 | 36.64 | 246.84 | 285.30 | 9043.26 | 10452.50 | 7034.22 | 0.03 |
| | Peas (Fodder) | 1205.50 | 45.54 | 93.28 | 136.84 | 4248.12 | 6231.95 | 17442.95 | 0.03 |
| | Total | 54240.20 | 141953.39 | 7285.46 | 23845.23 | 95148502.97 | 469414075.52 | 23001959.02 | 587.56 |
| | Kidney Beans | 5.50 | 0.58 | 72.63 | 303.19 | 151.92 | 494.82 | 23.85 | 0.00 |
| | Peas | 83.60 | 8.10 | 177.68 | 461.71 | 1936.95 | 3076.84 | 2016.51 | 0.01 |
| | Pepper (All Varieties) | 87.70 | 6.14 | 293.45 | 675.31 | 1062.46 | 2513.92 | 2789.01 | 0.01 |
| | Tomato (All Varieties) | 204.50 | 6.43 | 68.95 | 274.85 | 498.70 | 1361.78 | 2133.75 | 0.00 |
| | Beans (Fresh) | 64.10 | 6.09 | 28.98 | 113.23 | 1427.21 | 2544.58 | 127.83 | 0.00 |
| | Spinach | 68.80 | 6.33 | 198.80 | 530.40 | 925.46 | 663.54 | 2872.97 | 0.00 |
| | Watermelon | 723.80 | 16.93 | 165.70 | 15.11 | 978.12 | 1236.81 | 694.27 | 0.00 |
| | Melon | 284.00 | 14.06 | 30.78 | 62.89 | 1718.93 | 4345.71 | 1195.22 | 0.01 |
| | Eggplant | 38.80 | 1.99 | 80.05 | 273.88 | 251.00 | 551.21 | 168.82 | 0.00 |
| Vegetables | Onion (Fresh) | 15.50 | 2.18 | 59.86 | 191.75 | 759.86 | 289.91 | 89.55 | 0.00 |
| | Onion (Dry) | 742.60 | 109.92 | 74.88 | 59.52 | 40169.62 | 133117.79 | 3847.10 | 0.18 |
| | Cucumber (Table) | 37.60 | 0.98 | | | 63.21 | 102.96 | 20.60 | 0.00 |
| | Lettuce (All Varieties) | 53.30 | 1.85 | 259.20 | 12.25 | 48.20 | -4.35 | 38.76 | 0.00 |
| | Broad Beans | 19.00 | 1.97 | 63.60 | 17.94 | 325.65 | 45.06 | 69.04 | 0.00 |
| | Leek | 26.30 | 1.69 | 4118.80 | 1.39 | 268.50 | 82.87 | 143.75 | 0.00 |
| | Cabbage | 59.00 | 1.88 | 50.00 | 1.80 | 148.16 | 80.53 | 77.15 | 0.00 |
| | Garlic | 80.10 | 11.22 | 2.30 | 133.04 | 3878.17 | 7699.79 | 459.89 | 0.01 |
| | Cauliflower | 12.70 | 0.65 | 3115.80 | 12.07 | 81.57 | 52.27 | 55.06 | 0.00 |
| | Total | 2606.90 | 198.98 | 2600.30 | 1.59 | 54693.68 | 158256.04 | 16823.14 | 0.23 |
| | Cherry | 259.20 | 21.17 | 263.12 | 442.29 | 5569.51 | 9362.03 | 1799.21 | 0.02 |
| | Peach and Nectarine | 63.60 | 3.55 | 179.60 | 336.45 | 636.69 | 1192.75 | 301.33 | 0.00 |
| | Olive (Oil) | 4118.80 | 2959.10 | 2314.80 | 1606.43 | 6849734.92 | 4753571.47 | 251523.40 | 11.85 |
| | Olive (Table) | 50.00 | 27.78 | 1790.00 | 4242.22 | 49722.22 | 117839.51 | 2361.11 | 0.17 |
| | Sour Cherry | 2.30 | 0.02 | 24.22 | 39.21 | 0.42 | 0.68 | 1.47 | 0.00 |
| | Grape | 3115.80 | 258.20 | 267.00 | 196.90 | 68941.65 | 50839.65 | 21947.33 | 0.14 |
| | Walnut | 2600.30 | 1637.97 | 2029.59 | 5754.93 | 3324424.90 | 9426426.41 | 139227.86 | 12.89 |
| | Quince | 38.90 | 1.27 | 105.06 | 187.69 | 133.26 | 238.06 | 107.81 | 0.00 |
| Orchards | Apple | 340.70 | 6.27 | 59.29 | 102.98 | 371.74 | 645.64 | 532.92 | 0.00 |
| | Plum | 29.40 | 0.59 | 65.06 | 119.05 | 38.62 | 70.68 | 50.46 | 0.00 |
| | Pomegranate | 18.90 | 1.55 | 263.62 | 686.95 | 407.65 | 1062.27 | 131.44 | 0.00 |
| | Pear | 318.40 | 14.64 | 148.14 | 282.12 | 2168.73 | 4130.14 | 1244.36 | 0.01 |
| | Apricot | 20.20 | 0.94 | 149.28 | 273.16 | 139.70 | 255.65 | 79.55 | 0.00 |
| | Strawberries and Blackberries | 8.3 | 0.50 | 193.79 | 246.35 | 96.74 | 122.98 | 42.43 | 0.00 |
| | Almonds | 239.20 | 55.88 | 752.64 | 1157.69 | 42054.18 | 64686.69 | 4749.43 | 0.11 |
| | Dates | 8.30 | 0.39 | 150.24 | 270.26 | 58.15 | 104.60 | 32.90 | 0.00 |
| | Total | 11232.30 | 4989.80 | 8755.45 | 15944.67 | 10344499.07 | 14430549.20 | 424133.02 | 25.20 |
| | Total Water Footprint of the process of growing crops. WFproc. million m3 | | | | | | | | 612.99 |

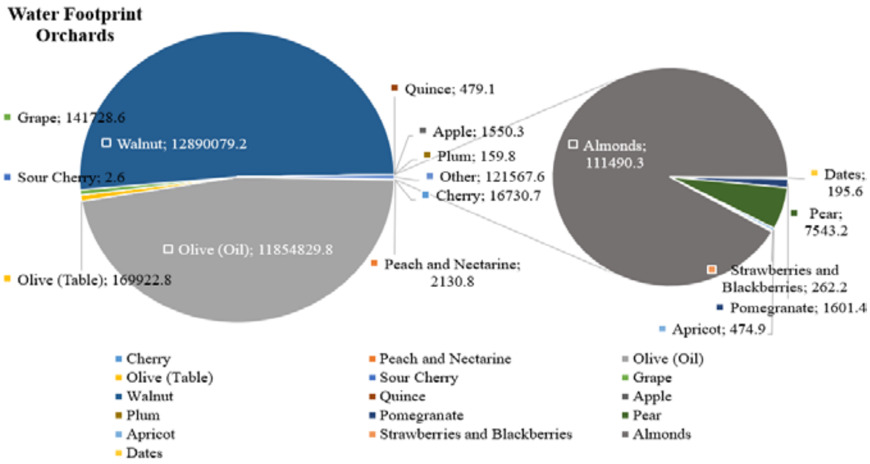


**Figure 4.** Water footprint of orchards.

## 3. Results

The total values of the water footprint of crop production, animal husbandry and general agricultural production in Tekirdağ province for 2022 are given in detail in Tables 1 and 2. The water footprint of crop production is calculated as 0.613 billion $m^3$, the water footprint of animal husbandry as 0.720 billion $m^3$ and the total agricultural water footprint as 1.33 billion $m^3$. Crop production water footprint share is 46% and animal production water footprint share is 54%. The distribution of crop production water footprint is as follows: green water footprint 17%, blue water footprint 79% and grey water footprint 4%. A summary of the distribution of the total water footprint of crop production among different crop groups and crops in the province is shown in Figure 2, 3 and 4. Based on the graph, field crops have the largest total water footprint in the province with 588 million $m^3$, followed by fruits with 25 million $m^3$ and vegetables with 0.23 million $m^3$. The total water potential of the province in 2022 is reported as 374.7 million $m^3$ by the State Hydraulic Works (DSI). Even excluding the green water footprint in crop production, the sum of blue and grey water footprints is calculated as 410.3 million $m^3$.

In animal production, the water footprint calculated according to the water requirement per animal is 372.7 million $m^3$ in total, while the water footprint of animal products such as milk, eggs, chicken meat and veal is calculated as 346.8 million $m^3$. The total water footprint of animal production is 719.6 million $m^3$. Considering the total water footprint of animal product production, the share of green water footprint is 93%, blue water footprint is 4% and grey water footprint is 3%.

## 4. Discussion

When previous studies are analysed, it is seen that agricultural production has the largest share among the components of the water footprint. On a global scale, agricultural production accounts for 70% of water use and 90% of indirect water use. In Türkiye, agricultural production accounts for 74% of direct water use, which can be as high as 86% in arid regions with continental climates (DSI, 2022).

Alongside the intensity of water use for agricultural purposes, rainfall anomalies are increasing in the gateway regions where the study was conducted. In addition to classical methods to examine how water is used, the use of techniques such as water footprint, which can distinguish between more uses and assess the impacts on the ecosystem, has increased especially in the last decade. There is a need for detailed studies on the agricultural sector, which is the main user of water in our country and in the world (Ababaei and Etedali, 2017; Novoa et al., 2019; Hossain et al. 2021; Yang et al., 2020; Cai et al., 2022). This situation is similar to the official institutional statistics where water use is announced and reveals the reliability of the study results.

The water footprint method can be used robustly and reliably to assess the impacts of crop and livestock production on water resources, either in watersheds or in specific production regions. This method provides a good description of the responses of crop and livestock production (Novoa et al., 2019; Yang et al., 2020, Gedik et al. 2023). In the study, field crops, vegetables and fruit cultivation and similar groups were analysed and total water footprint values of 390.16, 56.72, 8.10 and 152.84 million $m^3$ were obtained, respectively. It is seen that the values are high in field crops and fruit cultivation. This situation is similar to the production statistics and the results of other studies. In the study conducted by Novoa et al. in 2019, the agricultural water footprint was obtained as 18,221 $m^3$. In the study where water footprints were calculated, the highest values were reached in the Thames, Scheldt, Rhine and Po basins, which are the main river basins in Europe, and the water footprint values were 130,363 $m^3$ /$km^2$, 200,524 $m^3$ /$km^2$, 109,720 $m^3$ /$km^2$ and 219,630 $m^3$ /$km^2$, respectively (Vanham and Bidoglio, 2014). In another study, Cai et al. (2022) examined the agricultural water footprint in China between 2000 and 2017 and the average value was explained as 5.039 x 109 $m^3$/year. In the study by Çakmak and Torun (2023), agricultural water footprint for irrigation networks in the Konya closed basin in our country was evaluated. The agricultural water footprint in the Konya Closed Basin was calculated as 1.09 million $m^3$/ha. Muratoğlu (2020) calculated the average agricultural water footprint value as 3.43 billion $m^3$/year in his study to evaluate the agricultural water footprint and utilization in Diyarbakır. Erdem (2021) conducted a water footprint assessment for the Seyhan, Ceyhan and Asi Basins. The water footprint values in these basins were calculated as 3.53, 6.58 and 2.51 billion $m^3$ respectively. When the studies and data obtained are examined, it is seen that water footprint data vary according to the plants grown in the relevant region, plant planting rates, agricultural techniques, irrigation methods, and are also significantly affected by arid and normal precipitation conditions. The fact that it depends on many natural and artificial parameters is considered as a positive factor in reflecting natural conditions.

In addition to sectoral data, the water footprint concept includes green, blue and grey water footprint components. The components reflect the utilization characteristics of water resources more accurately and reliably. Studies show that the total water footprint of crop production varies between 2.13 and 114.79 billion $m^3$, while the total water footprint of animal production is between 0.43 and 9.98 billion $m^3$ (Çakmak and Torun, 2023; Erdem, 2021; Muratoğlu, 2020; Ahi and Çakmak, 2023). The results obtained under similar conditions in the literature by Egea et al. (2024), Cai et al. (2022), Yang et al. (2020), Hossain et al. (2021), Novoa et al. (2019), Ababaei and Etedali (2017) and Lovarelli et al. (2016).

## 5. Conclusion

In conclusion, the water footprint analysis for Tekirdağ province in 2022 highlights the significant role of agricultural activities in water resource utilization, with crop production accounting for 54% and animal husbandry for 46% of the total agricultural water footprint. The results underscore the substantial contributions of field crops and fruit cultivation to water consumption, consistent with global and regional studies. Furthermore, the green, blue, and grey water footprint components provide a nuanced understanding of water resource utilization, with variations influenced by factors such as crop type, agricultural techniques, and climatic conditions. These findings emphasize the importance of adopting sustainable water management practices and innovative agricultural methods to optimize water use efficiency. Future studies should further explore the impacts of rainfall anomalies, irrigation technologies, and policy interventions to mitigate the strain on water resources, particularly in regions with high agricultural activity and limited water availability. This comprehensive approach is vital to ensure the sustainable development of the agricultural sector and the preservation of critical water resources.

**Author Contributions**

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

| | H.T.G. | Y.A. | B.Ç. |
|---|---|---|---|
| C | 70 | 20 | 10 |
| D | 80 | 10 | 10 |
| S | 30 | 40 | 40 |
| DCP | 90 | 5 | 5 |
| DAI | 70 | 15 | 15 |
| L | 100 | - | - |
| W | 80 | 10 | 10 |
| CR | 50 | 20 | 30 |
| SR | 100 | - | - |
| PM | 100 | - | - |
| FA | 100 | - | - |

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

**Conflict of Interest**

The authors declared that there is no conflict of interest.

**Ethical Consideration**

Ethics committee approval was not required for this study because there was no study on animals or humans.

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