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# The water footprint of Bursa province

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**Abstract**

Water is the most important environmental resource and is invaluable because it is an important factor for the continuation of life. The proposed water footprint as an indicator for assessing the allocation of freshwater resources to a producer or consumer and it takes into account direct and indirect water consumption and helps in managing water resources. The WF of Bursa province was calculated. Its total surface area is 11,027 square kilometers. The total population of the province in 2021 is 3 million 56 thousand. In the calculations, domestic, agricultural and industrial water footprints water footprints were evaluated separately.The average WF of Bursa province was found 105,417 billionm3. Throughout the province, 77% of the WF is composed of WF Industrial, 21% is WF domestic and 2% is WFagricultural. The average per capita water footprint of Bursa province was found to be 7220 m3 year-1. The total water footprint of the industrial sector has been calculated as 80.952 billion m3. The amount of industrial gray water footprint in Bursa has been calculated as 80.822 billion m3. Total domestic water footprint is calculated as 22.0645 billion m3. Gray water footprint was determined as the majority of the domestic water footprint (75%). Direct and indirect water footprints account for 24% and 1% of the total domestic water footprint, respectively. It is important to reduce the use of blue water in agriculture, domestic and industrial sectors.

## Introduction

Water is the most important environmental resource and is invaluable because it is an important factor for the continuation of life as a result of the need for living organisms to survive. Only 0.3% of the total fresh water resources are suitable for human use on a global scale [1]. Therefore, many scientists and researchers have studied this subject and how to reduce water waste with the increase in global warming, the lack of rain and the increase in the population. The proposed water footprint as an indicator for assessing the allocation of fresh water resources to a producer or consumer from a virtual water perspective [2]. The water footprint is divided into three components: the blue, green and gray water footprint. The blue water footprint is the volume of fresh water that has evaporated from surface and ground water resources. The green water footprint is the volume of water evaporated from rainwater stored in the soil. Gray water footprint is the volume of water required to dilute pollutants [2]. Muradoğlu analyzed the water footprint in the Diyarbakir region between 2008 and 2019. He found that the water footprint in the agricultural sector consumes most of the region's water resources [3]. Zhao and others. They assessed the water footprint of Leshan City in China from 2001 to 2012. They found that the production of crops and animal products are among the most important sectors that consume large amounts of water [4]. The aim of this study is to calculate and analyze the water footprint of production and consumption in Bursa, and to calculate green, blue and gray water footprints by evaluating plant and animal production and domestic and industrial water use separately. The purpose of water footprint calculation and evaluation is to see the impact of certain activities or products on water scarcity and pollution, and formulate responses to these effects to prevent them and avoid unsustainable water use.

## Material and Method

In calculating the water footprint of any area, the accuracy of the analyzes is directly related to the quality of the data used. In this study, many data obtained from national and international institutions and databases in Bursa province were used. The water footprint approach developed by Hoekstra It was used in this work to calculate the water footprint [2]. The total area water footprint (WFtotal) consists of the crop production water footprint (WFcrop), the livestock water footprint (WFlivestock), the domestic water footprint (WFdomestic) and the industrial water footprint (WFindustrial).

### Water footprint analysis of crop production and livestock production

The agricultural products data for Bursa province for the year 2020 were obtained from [5]. The water footprint of each agricultural product was calculated using the method of Chapagain and Hoekstra [6]. The CROPWAT program developed by the Food and Agriculture Organization of the United Nations was used [7]. ETO, reference evapotranspiration values were obtained by entering climatic data into the CROPWAT software using the Penman-Monteith method [8]. Monthly mean climate and precipitation data were obtained from the long-term CLIMWAT database for the period (1971-2000) [9]. The vegetative evapotranspiration (ETc) values of the herbal products were calculated by entering the coefficient (Kc), growth period lengths, ET0 values and rainfall data into the CROPWAT 8.0 software. The blue and green ET values were estimated using equation 1, 2. Equation (3) was used to calculate the consumption of blue and green plant water, $m^3$/ha (CWU). The green and blue water footprint of each vegetable product (m3/ton) was calculated using equation (4). Y is crop yield. The green and blue water footprint for each product was done by using the tons of the plant production using equation (5). The water footprint of plant production was calculated by collection the green and blue water footprints of all plants. To calculate the animal's water footprint, the total number of each of cattle, sheep, and poultry raised in the region [5], and the global average water footprint, were calculated from the literature published by Mekonnen and Hoekstra [10]. An animal's water footprint was calculated by multiplying the average annual water footprint of an animal by its annual number.

$$ET_{blue}=\max(0,ETc-P_{eff}) \quad (1)$$

$$ET_{green}=\min(0,ETc,P_{eff}) \quad (2)$$

$$CWU_{blue,green} = 10 \times \sum ET_{blue,green} \quad (3)$$

$$WF_{blue,green}= CWU_{blue,green}/ Y \quad (4)$$

$$WF_{blue,green}= WF_{blue,green} \times \text{production} \quad (5)$$

### Water footprint of domestic and Water Footprint of Industries

When calculating the household water footprint, the direct use of water and the indirect use of water by individuals must be taken into account. The direct water footprint of individuals was calculated by means of a questionnaire that includes the number and duration of activities people use on a daily or annual basis such as showering, washing dishes, watering the garden and flushing the toilet. The amount of effluent water was obtained directly for each activity from the literature [11]. By collection the volumes of water flowing for each activity, the direct water footprint of each person was calculated. The indirect water footprint is the use of water related to the production of goods and services used by the consumer such as food consumption, clothing consumption and energy consumption. The quantities of each individual's diet and other consumables such as clothes, shoes and household energy consumption were done by making a questionnaire to know the quantities consumed annually by the individuals. The average global water footprint of the diet consumed by a resident of Bursa governorate was used [10]. In this study, the total amount of ground and surface water allocated to industry throughout the province (including districts) was used to calculate the blue water effects of industries in Bursa. to calculate the gray water footprint of the industrial and domestic sector, the total amount of wastewater from industries was taken and homes and the concentrations of pollutants it contains used [12]. Equation (6) was used to calculate the gray water footprint of the domestic and industrial sectors.

$$WF_{gri}=\frac{W}{C_{max}-C_{net}} \quad (6)$$

W is the amount of pollutant load, $C_{Max}$ (ton\year) is the maximum acceptable pollutant concentration, $C_{nat}$(ton\year), is the natural concentration in the receiving water body.

## Results

The average annual water footprint for the Bursa region was determined to be 105.417 billion cubic meters for the year 2021. The industrial sector is the most water consuming sector as it is responsible for 77% of the total water footprint. The total industrial water footprint reached 80.95 billion cubic meters. The domestic sector ranks second in terms of water consumption. The household water footprint amounted to 22.06 2,604 billion cubic meters / year, which constitutes 22% of the total water footprint of the governorate, and the gray household water footprint was the first contributor in terms of water consumption required to reduce the number of pollutants in wastewater. Food was the second most important contributor. The water footprint from food consumption was 1,580 m3/year in indirect water consumption. The agricultural water footprint amounted to 2.429 billion cubic meters/year. Wheat is the most important crop in plant production, being responsible for 18% of water consumption in the vegetable sector, followed by olives. The water footprint of livestock production is 0.865 billion cubic meters/year. Cattle are the largest consumer of water in livestock production, as they are responsible for 55% of water consumption.

## Conclusion

The results show that industrialization, rapid urbanization and population increase in Bursa require a large amount of fresh water resources. It was found that the water footprint in the industrial sector is the largest sector in water consumption. It was found to have a high-water footprint compared to the literature and other regions, due to the fact that Bursa has as many factories as it contains 7000 factories. It was found that the water footprint in domestic consumption is the second largest in water consumption, due to the bulk of the water consumption needed to dilute pollutants in wastewater. Food is the main component in the indirect consumption of water. Therefore, it is important to know that a food ingredient has a higher water footprint that can be avoided, reduced, or substituted. Where meat is considered to have a higher water footprint, this is due to the consumption of feed which has a higher water footprint. As for direct use, it was found that a large part of it is due to long periods of showering. As for the agricultural sector, it was found that the consumption of water from rain water is approximately equivalent to the consumption of surface and ground water. As for the animal sector, the highest water footprint is found from livestock, and the reason is due to livestock consumption of feed with a higher water footprint. The high-water footprint of the region depends mainly on the characteristics of the climate, the hypothetical water content of the produced products used, the lifestyle, and food habits of the inhabitants of the region.

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