BIO Web of Conferences **85**, 01070 (2024) https://doi.org/10.1051/bioconf/20248501070
I-CRAFT-2023

A different perspective on agricultural products within the scope of water footprint intensity

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Abstract. Water is one of the most basic requirements for the sustainability of life on Earth. However, global climate change threatens this important resource by deeply affecting water resources and the water cycle. The sustainability of food production also depends on the proper management and protection of existing water resources. Therefore, it is important to know the amount of water required for agricultural production on a product basis and to prepare basin-based production plans taking into account water resources. The concept of water footprint (WF), which is used to express the amount of water consumed directly and indirectly in the process from the supply chain of goods and services to the end user or the extent of water pollution it causes, is presented as an important tool in water management. Nowadays, the WF calculations of agricultural products are also one of the most widely studied topics. In this study, Water Footprint Intensity is calculated for some agricultural products and the WFD of these products is evaluated through economic indicators and a different perspective is tried to be presented to the readers.

1 Introduction

As the world population is growing rapidly, the demand for food production is increasing at the same rate. This situation causes the agricultural sector to use more resources and especially to increase its dependence on water resources. Water, which is an indispensable requirement for plant growth and cultivation of crops, is a fundamental element of agricultural production. Although 75% of the Earth is covered with water, the amount of water available for agricultural activities (fresh water) constitutes 2.5% of all water and its distribution on Earth is not homogeneous [1]. Therefore, in many regions facing limited water resources, agricultural water consumption is a major concern in terms of sustainability. Therefore, measuring, evaluating and managing the water used in agricultural activities is important for a sustainable future.

While some of the methods developed for the environmentally friendly, economical and sustainable management of water are accounting tools used for water use and operational risks, other approaches are tools that reveal the effects of consumption or aim to encourage resource management [2-3]. One of these tools is the "water footprint (WF)", which offers an effective approach to sustainable water management and was introduced in 2002 as an indicator of water use [4-5]. Although the concept of WF is defined in various ways in the sources, in the most general sense, it is a term used to express the amount of water consumed directly and indirectly in process (including supply chain of goods and services) and the extent of water pollutionin caused from the process [6-8].

In general terms, while Hoekstra comprehensively created the terminology and methodology that forms the basis of WF research, it also divided WF into 3 categories taking into account the water source used: green (WF_{green}), blue (WF_{blue}), and gray (WF_{grey}) water footprint [9-10]. In later studies, the WF was elaborated with different sub-units that reveal the effect of water consumption. WF_{green} refers to water that is trapped in the soil by precipitation, stored in the root zone of the plant and evaporated by plants through metabolic activities. WF_{green} is particularly related to agriculture, horticulture and forestry products. WF_{blue} is water that is obtained from surface or groundwater sources, incorporated into a product or taken from one water body and returned to another or returned at a different time. Irrigated agriculture, industry and domestic water use can each have WF_{blue}. WF_{grey} is a measure of the volume of water required to dilute the concentration of pollutants contained in the volume of polluted water associated with the production of goods and services so that they remain above water quality standards. The sum of these three gives the total water footprint (WF_{total}) [11-12]

There are many studies on the WF_{green}, WF_{blue}, and WF_{grey} of agricultural products. Lovarelli et al. (2016)[13] conducted a comprehensive literature review on the WF of crop production. However, there is no study that evaluates the water consumption of agricultural products using Water Footprint Intensity (WFI), which is the subject of our study and offers a different approach to the assessment of WF. Therefore, in this study, it is aimed to evaluate the amount of water used in agricultural production from an economic perspective with the

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concept of WFI and to create a different idea for the readers.

2 Material and method

2.1 Data collection

Human beings have to produce and consume nutrients such as flour, fat, protein, salt and sugar in a regular and healthy way in order to carry out their daily, social and economic life in a healthy way. Therefore, while selecting the agricultural products subject to the study, care was taken to ensure that the crops consumed intensively in human and animal diet. In addition, in order not to be affected by climatic and topographical factors, it was also paid attention to be plants that can be grown in the same region. Therefore, wheat, barley, maize, sugar beet and sunflower crops, which are widely cultivated in Turkiye, were included in the study and the crops were not included in the scope of secondary cultivation. Information on the amount of crop production, cultivated area, etc. was taken from the database of the Turkish Statistical Institute (TurkStat) and the website of the Ministry of Agriculture and Forestry of Republic of Turkiye [14-15]. The WF values for these crops were obtained from the literature for Turkiye [16-17] Input costs and agricultural subsidies are excluded from the scope of the study and sales figures of crops are taken as market prices from the Turkish Grain Board Daily Market and Exchange Prices Bulletin [18]. All agricultural data belong to 2022.

2.2 Water footprint intensity (WFI)

The WFI assesses the impact of the WF from an economic point of view. The higher the calculated intensity value, the higher the WFI per unit gain and vice versa. With WFI data, it is possible to compare the amount of water consumed and/or polluted to achieve the same economic output [19]. If a product sold to the consumer uses more water per unit of money than other products, it indicates that the water efficiency of the production of this product is lower. The WFI calculation method is shown in Equation 1 [20-21]

$$WFI = \frac{WF_{total}}{m_i} \quad (1)$$

In Equation 1;
WF_{total} : Total WF of product i (m^3)
m_i : Total monetary profit from product i (₺)

3 Results and discussion

3.1 General information about agricultural products subject to the study

Wheat, wheat products and bread have been one of the most important food sources of people from past to present. Among the cereals grown in the world, wheat is the most produced product after maize and rice. The demand for wheat as a human food is gradually increasing in the world, including countries whose climates are not suitable for growing wheat. In Turkiye, wheat production areas take the first place with approximately 20 per cent of all agricultural production areas. Approximately four out of every five farmers in Turkiye grow wheat [22]

Today, barley is one of the cereals used as animal feed (grain and straw), in brewing and, to a lesser extent, in human nutrition in some countries. Barley, which has 95% of the nutritional value of maize, is used in the world 65% as animal feed, 33% as raw material for malt beer and whiskey, and 2% in human nutrition in the food industry. In Turkiye, 90% of the consumption is used as animal feed and the other part is used as malt in the beer industry and food industry. Although the rate of barley use in the food industry is very low, it has been increasing in recent years [23-24]

Maize is mainly used as human food and industrial raw material. The stalks and leaves of maize are used as animal feed in the form of silage, in paper making in industry and in small-scale wicker handicrafts. In addition to its main uses, maize is also consumed as a snack. The oil and flavouring sector and biofuel-bioethanol production industry are also among the areas of use of maize [25]

The homeland of sunflower (Helianthus annuus L.), one of today's most important oil crops, is known as North America. Sunflower oil is obtained from the seeds of the H. annuus plant with an oil content ranging between 40-52%. Throughout human history, it has been used in the treatment of various diseases with herbal medicines and to increase body resistance by strengthening immunity. Since sunflower husks have the capacity to absorb liquid like straw, they are used as litter in cattle breeding, as filling and insulation material in the timber industry and as food colouring material. Sunflower meal is the most important raw material of compound feed industry as well as a rich food source directly for fattening and dairy cattle. As a green fodder plant, it can be given to livestocks in young periods of plant or livestocks can be fed by making silage. In addition, sunflower plant is used to remove pollutants such as heavy metals such as Cd, Pb, Zn, industrial, domestic and sewage wastes, artificial fertiliser residues, which cause pollution in terrestrial and aquatic environments [26]

Sugar has been an important nutrient for mankind throughout history, as people allocate a special place to dessert in their eating habits. There are two types of sugar production in the world, sucrose and starch origin. Sucrose-based sugar is produced from sugar beet and sugar cane; starch-based sugar is produced from maize syrup. Sugar beet, one of the important sources of sugar production, is an industrial plant. In addition to sugar production, it is an important plant for reasons such as obtaining animal feed from by-products such as molasses, bagasse, leaf and residues, alcohol and spirit from molasses, being suitable for modern agricultural techniques and creating employment [27]

The planting and harvesting periods of wheat, barley, maize, sunflower and sugar beet grown in Turkey are given in Table 1 [28]

Table 1. Planting and harvesting periods of the crops subject to the study.

Crops	October	November	December	January	February	Mart	April	May	June	July	August	September
Wheat	x	x	x	x					0	0	0	
Barley		x	x	x				0	0	0		
Maize							x	x		0	0	
Sunflwer							x	x			0	0
Sugar beets							x	x			0	0

X: Planting
0: Harvesting

As can be seen from Table 1, the planting times of some crops coincide with the same period. Therefore, it is possible for farmers to make a choice for the crop to be planted among these crops. The production amounts of the products subject to the study in Turkey in 2022, cultivated area sizes and yield information obtained from unit areas are given in Table 2.

Table 2. Sown area sizes and production amounts of crops.

Crops	Production (ton)	Sown Area (decare)	Land Use Efficiency (ton/decare)
Wheat	19750000	66287386	0,30
Barley	8500000	31994876	0,27
Maize	8500000	9118849	0,93
Sunflower	2550000	9809742	0,26
Sugar beets	19253962	2975096	6,47

As can be seen from Table 2, wheat has the largest cultivated area and the highest production amount. Although the cultivated area of sunflower is larger than maize and sugar beet, the amount of production is less than the other crops. When all crops are considered in terms of land use, the yields per decare of sunflower, wheat and barley are almost the same. The yield of sugar beet is quite high compared to other crops (6.47 tonnes/decare).

3.2. WFI assessment

As in every sector, the main objective of the producer in agricultural production is to maximise the monetary profit from production. However, while doing this, there are some constraints in the objective function. One of the most important constraints in this objective function is whether the amount of water, which is a basic element of agricultural production, is sufficient for crop development and yield. Because the amount of water required by each crop during the development and maturation period is different. Therefore, the less the amount of water it will need to obtain the same yield, the more it will benefit from the water in the region to be planted. Therefore, WFI is an important indicator in making this choice.

The average WF_{green}, WF_{blue}, WF_{grey} and WF_{total} calculated for the crops subject to the study if grown in Turkiye are given in Table 3 [16-17].

Table 3. WF information of products.

Crops	WF_{green} (m^3/ton)	WF_{blue} (m^3/ton)	WF_{grey} (m^3/ton)	WF_{total} (m^3/ton)
Wheat	2052	125	192	2369
Barley	1431	17	123	1571
Maize	626	116	207	949
Sunflower	2504	137	141	2782
Sugar beet	57	88	12	157

As can be seen from Table 3, the crop with the highest water footprint is sunflower. The majority of this is due to WF_{green}. The WF_{blue} values resulting from the irrigation water requirement of the crops are lower than WF_{grey} except sugar beet. This situation shows that the amount of water required to balance the water pollution caused by the agricultural activities of these crops on the basis of concentration is above the irrigation water requirement.

Information showing the amount of water that a producer producing the crops subject to the study in Turkiye should consume in order to obtain the same monetary value is given in Table 4.

Table 4. Calculated WFI values.

Crops	WF_{total} (m^3/ton)	Price (₺/ton)	WFI (m^3/₺)
Wheat	2369	7537	0,31
Barley	1571	5718	0,27
Maize	949	5559	0,17
Sunflower	2782	11000	0,25
Sugar beets	157	1450	0,11

As can be seen from Table 4, wheat has the highest water footprint per unit monetary value. For the same monetary value, sugar beet has approximately 65% less water footprint than wheat. For the same monetary value, sugar beet is a product with approximately 65% less water footprint than wheat. When the selected products are ranked from highest to lowest according to WFtotal evaluation, they are listed as sunflower, wheat, barley, maize and sugar beet, while according to WFI they are listed as wheat, barley, sunflower, maize and sugar beet. Therefore, when choosing a product in regions with water stress, evaluating it not only according to its WFtotal but also according to its WFI, which is an economic indicator of the water footprint, will enable more comprehensive results to be obtained.

3.3. Conclusion and recommendations

In this study, wheat, barley, maize, sunflower and sugar beet plants, which have large cultivation areas in Turkey and are used as raw materials in various areas, were selected and an evaluation was made according to their water footprint data and market sales prices. The aim of the study is to evaluate water consumption, one of the most important parameters of agricultural production, through the concept of water footprint and the money income to be obtained from agricultural products. Thus, when choosing agricultural products planned to be planted, it will be possible to calculate how much water footprint the selected product will have and how much water will be needed for unit monetary return and make decisions accordingly. Because this calculation method will be important for producers and planners in case of water stress that is currently experienced on a regional basis or that may occur as a result of global climate change. In fact, input costs and agricultural state supports were not taken into account in this study. Evaluations based on net income will provide more stable results for producers and planners. In this way, more accurate decisions will be made for sustainable water consumption that will provide maximum economic benefit in agricultural production.

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