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Quantifying water footprint: A study on the academic and administrative personnel at Konya Technical University

Özgül Çimen Mesutoğlu*

Department of Environmental Engineering, Aksaray University, Aksaray, 68100, Turkey

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Abstract. This study endeavours to quantify the water footprint of academic and administrative personnel at Konya Technical University. Water footprint assessment, a critical metric for evaluating human impact on water resources, is increasingly recognized as a vital aspect of sustainable resource management. The research involves surveying participants on their water consumption habits, particularly focusing on preferences related to food and sugar intake. Preliminary findings indicate diverse responses in terms of food preference, with a majority favouring low intake. The study aimed to determine the water footprint of the campus in relation to personal consumption behaviours by asking the questions in the "Water Footprint Network (WFN)" to a total of 476 people at the campus, including both the academic and administrative staff. According to the WFN, the average water footprint of the staff was determined as 1694 m^3/year.

Keywords: Konya Technical University; sustainability; water footprint; water scarcity

1. Introduction

The degradation of natural resources due to human activities has heightened global awareness about environmental issues. Monitoring and undertaking significant measures to address this phenomenon in the air, water, and soil domains are crucial for the future of humanity (Mian *et al.* 2021). In this context, water scarcity emerges as a critical issue, with predictions indicating that the world's population will face water shortages in the coming years. Against this backdrop, the concept of "personal water footprint" has gained prominence as a valuable metric for evaluating and addressing individual contributions to water consumption (Wang *et al.* 2022, Rusli *et al*. 2023).

The personal water footprint represents the total volume of freshwater directly or indirectly used by an individual over a specified period (Muratoglu 2020). This measurement encompasses not only water consumed for direct activities like drinking, cooking, and personal hygiene but also the water embedded in the production of goods and services consumed by an individual (Lee *et al.* 2016). Addressing personal water footprints requires a multidisciplinary approach drawing from environmental science, economics, sociology, and public policy. This research aims to contribute to existing knowledge by synthesizing insights from diverse disciplines, providing a comprehensive understanding of the factors shaping personal water footprints, and proposing strategies for sustainable water use at the individual level (Pang *et al.* 2021). As the global

*Corresponding author, Ph.D., E-mail: ozgulcimen@gmail.com

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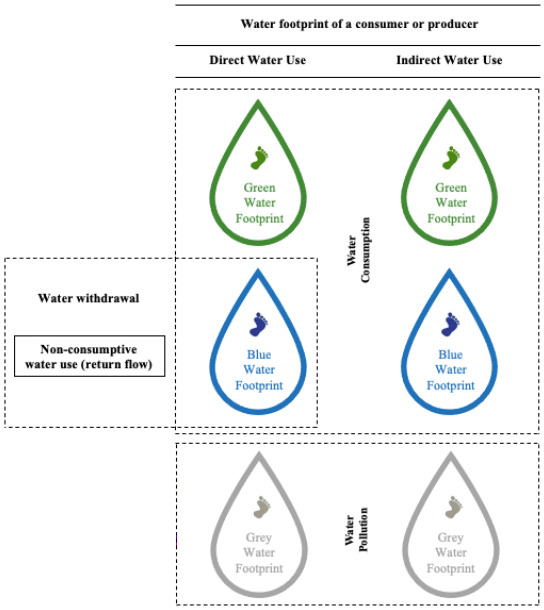


Fig. 1 Water footprint components

community grapples with the challenges posed by climate change and a growing population, unravelling the complexities of personal water footprints becomes imperative for formulating informed policies, fostering sustainable consumption patterns, and ultimately ensuring the long-term resilience of our planet's water resources (Santos *et al*. 2022). This study aspires to be a foundational step toward a more water-conscious society where individuals actively contribute to shaping a sustainable future for generations to come.

2. Water footprint

The concept of water footprint represents the quantity of water utilized in the production of a product or the water consumption by an individual. Additionally, it accounts for the indirect water consumption of an individual or product (WFN 2019, Malahayati 2024). The water footprint concept was formulated by Arjen Hoekstra, who served at the Institute for Water Education under UNESCO in 2002. In 2008, under the leadership of Hoekstra, a professor of water management at Twente University, the Water Footprint Network (WFN) was established to address the challenges of unsustainable water use. This initiative brought together various academicians, business professionals, and non-governmental organizations (Dursun 2019). The network has been recognized as a global standard in the literature, defining water usage comprehensively to encompass all direct and indirect water uses necessary for a service or product (Hoekstra *et al.* 2011, Mekonnen and Hoekstra 2015). The Water Footprint (WF) comprises elements known as blue, green, and grey water footprints (Fig. 1). The blue water footprint represents the volume of freshwater extracted from surface water bodies (lakes, rivers, reservoirs) and groundwater (aquifers) (Hoekstra *et al.* 2011, McLellan *et al*. 2014).

Table 1 Food consumption questions

Number	Question	Unit
1	Cereal products (wheat, rice, maize, etc.)	…… kg per week
2	Meat products	…… kg per week
3	Dairy products	…… kg per week
4	Eggs	…… number per week
5	How do you prefer to take your food?	Low / Average / High
6	How is your sugar and sweets consumption?	Low / Average / High
7	Vegetables	…… kg per week
8	Fruits	…… kg per week
9	Starchy roots (potatoes, cassava)	…… kg per week
10	How many cups of coffee do you take per day?	…… cup per day
11	How many cups of tea do you take per day?	…… cup per day

Table 2 Domestic water use - indoors consumption questions

Number	Question	Unit
12	How many showers do you take each day?	…… number per day
13	What is the average length of each shower?	…… minute per shower
14	Do your showers have standard or low-flow showerheads?	Standard shower head / Low flow shower head
15	How many baths do you have each week?	…… number per week
16	How many times per day do you brush your teeth, shave, or wash your hand?	…… number per day
17	Do you leave the tap running when brushing your teeth and shaving?	Yes / No
18	How many loads of laundry do you do in an average week?	…… number per week
19	Do you have a dual flush toilet?	Yes / No
20	If you wash your dishes by hand how many times are dishes washed each day?	…… number per day
21	How long does the water run during each wash?	…… minute per wash
22	If you have a dish washer, how many times is it used each week?	…… number per week

Within the domain of water resource management, the comprehensive framework of green, blue, and grey water footprints has surfaced to unravel the intricate facets of human-induced water interactions (Shu *et al.* 2021). The green water footprint delineates the symbiotic relationship between rainwater and soil, elucidating the pivotal role of this synergy in sustaining agricultural ecosystems (Velarde-Guillén *et al.* 2023). In contrast, the blue water footprint encompasses the consumptive use of surface water and

Table 3 Domestic water use - outdoors consumption questions

Number	Question	Unit
23	How many times per week do you wash a car?	…… number per week
24	How many times do you water your garden each week?	…… number per week
25	How long do you water your garden each time?	…… minute per watering
26	How long per week do you spend rinsing equipment, driveways, or sidewalks each week?	…… minute per week
27	If you have a swimming pool what is its capacity?	…… cubic meter
28	How many times per year do you empty your swimming pool?	…… number per year

Table 4 Industrial goods consumption questions

29	What is your gross yearly income? (Only that part of income which is consumed by you)	…… $ per year

groundwater, highlighting its relevance across diverse sectors, including industrial processes, domestic utilities, and irrigated agriculture (Bulut 2023). Concurrently, the grey water footprint delves into the environmental repercussions of human activities, quantifying the requisite volume of freshwater for diluting and assimilating pollutants discharged during production processes (Gu *et al.* 2014). Collectively, these footprints present a nuanced perspective on the entire spectrum of water resource utilization, furnishing invaluable insights for the formulation of sustainable water management strategies (Brumm and Fukushi 2023).

To discern the water footprint of all academic and administrative personnel at Konya Technical University, a survey was conducted focusing on individual consumption habits related to food consumption, household water consumption (indoors and outdoors), and industrial product consumption (WFN 2008). WFN questions were directed to the participants, totalling 476 individuals who responded to inquiries related to their water footprint. The water footprint survey questions are provided in Tables 1-4.

3. Results

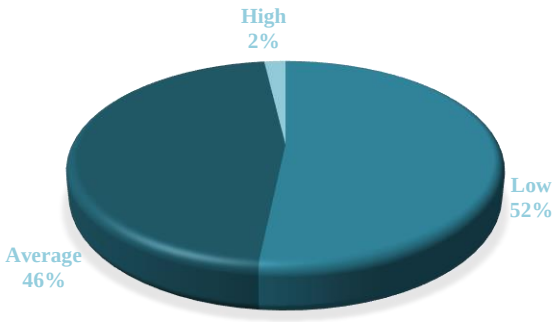
The answers of the participants were processed to the WFPN, and the WF of Konya Technical University academic and administrative staff were calculated. The findings obtained are comprehensively evaluated in three headings below.

3.1 Food consumption

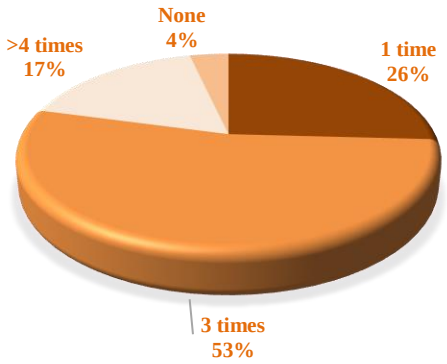
Consumption of food, serving as the foundation of human needs, establishes a direct relationship between human activities and the soil. Nutrient consumption is not only tied to food sources but also encompasses other natural resources such as energy, soil, and water throughout the food supply chain. While the concept of water footprint contributes to consumer awareness, it is not yet an effective tool for guiding consumers in making choices among different products. Over time, as methodologies develop and become more standardized, the water footprint concept may evolve into a more effective

Table 5 The average of open-ended questions in the field of food consumption

Question Numbers	1	2	3	4	7	8	9	10	11
Average	2.6 kg	2.4 kg	2.1 L	13	3.7 kg	3.3 kg	2.8 kg	2	7



(a) Fat content



(b) Sugar consumption

Fig. 2 Results of food consumption questions 5 and 6

instrument. Currently available data can provide guidance to businesses and other water users on how to optimize their operations in the context of water resources (Water Footprinting Report 2009). Future demands for water can potentially be met by implementing water management strategies at local and regional levels, ensuring sufficient food production (Table 5).

In responses to questions 5 and 6, the query "How do you prefer to take your food?" elicited responses with 52% indicating a preference for low, 46% for average, and 2% for high (Fig. 2(a)). Similarly, in response to the question "How is your sugar and sweets consumption?" participants reported 53% consuming three times per week, 26% consuming once per week, 17% consuming over four times per week, and 4% reporting no sugar and sweets consumption (Fig. 2(b)).

Table 6 The average of open-ended questions in the field of domestic water consumption-indoor

Question Numbers	12	13	15	16	18	20	21	22
Average	1	12 min	1	2	3	1	9 min	4

Table 7 The average of open-ended questions in the field of domestic water consumption-outdoor

Question Numbers	23	24	25	26	27
Average	0.34	0.25	55 min	8 L	-

Table 8 The average of open-ended questions in the field of industrial product consumption

Question Numbers	29
Average	2351.3 $

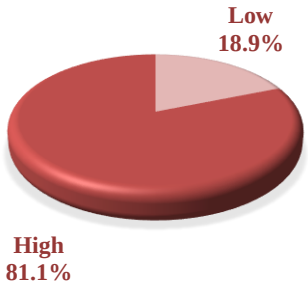
3.2 Domestic water consumption (indoors and outdoors)

Domestic water consumption, encompassing both indoor and outdoor usage, constitutes a critical dimension of sustainable water management and environmental stewardship. Indoor water consumption typically involves activities within residential structures, such as bathing, dishwashing, and toilet flushing, reflecting essential daily practices that significantly impact overall water demand. Outdoor water consumption, on the other hand, pertains to the utilization of water in domestic landscapes, gardening, and recreational spaces. Understanding the dynamics of domestic water consumption is imperative for devising effective water conservation strategies and implementing environmentally conscious practices. It involves not only quantifying the volume of water used but also delving into the behavioural aspects and preferences that influence individual and household water-use patterns. Comprehensive studies in this realm contribute invaluable insights toward promoting water efficiency, mitigating environmental impacts, and fostering a sustainable approach to domestic water resource utilization. For this purpose, a total of 17 questions regarding water usage in indoor and outdoor settings were posed. The averages of the responses to these queries are provided in Tables 6 and 7.

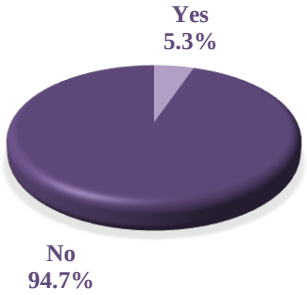
Participants were queried with question 14, "Which shower head do you use?" and, as depicted in Fig. 3(a), 80.1% (386 individuals) indicated a preference for standard shower heads, while 18.9% (90 individuals) expressed a preference for low-flow shower heads. Question 17, "Do you leave the tap running while brushing your teeth or shaving?" was posed, and as illustrated in Fig. 3(b), 5.3% (25 individuals) responded affirmatively, while 94.7% (451 individuals) indicated a negative response. Question 19, "Is there a dual flush toilet (with a full flush and a half flush) in your bathroom?" was directed, and as shown in Fig. 3(c), 46.6% (222 individuals) responded affirmatively, while 53.4% (254 individuals) declared a negative response.

3.3 Industrial product consumption

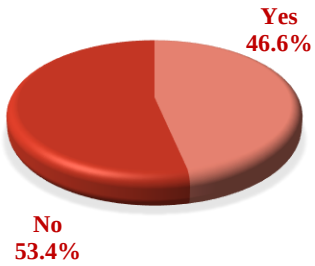
One open-ended question was posed regarding industrial product consumption: "What is your gross annual budget (only the portion consumed by you)?" The average response to this question was



(a) Which shower head do you use?



(b) Do you leave the tap running while brushing your teeth or shaving?



(c) Is there a dual flush toilet in your bathroom?

Fig. 3 Results of Results of domestic water use - indoor

reported as 70350.5 Turkish Lira. As the question was originally asked in the Water Footprint Network in US dollars, calculations were conducted based on the exchange rate as of January 8, 2024 (Table 8).

3.4 Water footprint impacts assessment

In the conducted study, a total of 1694 m^3/year of Water Footprint (WF) has been calculated. Within this obtained result, three categories of water usage have been identified based on the water consumption habits of the academic and administrative staff of Konya Technical University, namely Food, Domestic, and Industrial. The detailed results provided by the WFN calculation engine are

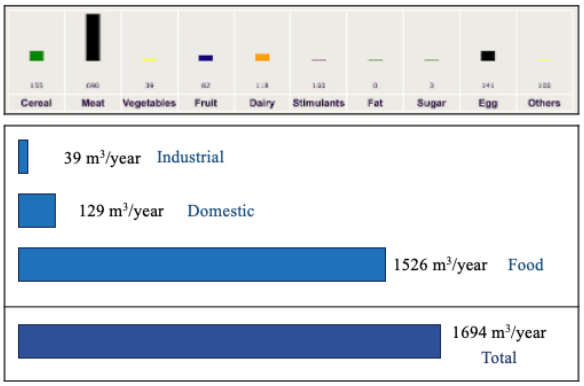


Fig. 4 Categories within water footprint and food consumption

presented in Fig. 4. The highest proportion is attributed to food consumption because of consumption habits. Examining the details of food consumption, the highest amount in the total WF is 690 m^3/year, which is associated with meat. Subsequently, water consumption has been calculated as 160 m^3/year for stimulants, 155 m^3/year for grains, 141 m^3/year for eggs, and 118 m^3/year for dairy products. The water usage for fruits, vegetables, and sugar is 82 m^3/year, 39 m^3/year, and 3 m^3/year, respectively.

4. Discussion

Reviewing the existing literature, Natyzak *et al.* (2017) undertook a study in which they directly computed the water footprint of the University of Virginia (UVA), combining both direct water usage and virtual water usage. Employing Water Footprint Statistics (WaterStat), they assessed and documented water bills associated with facility management, encompassing purchases for public services, food, transportation, paper, research animals, and hospital acquisitions within the university. The overall water footprint was distributed as follows: 10.06% direct water usage, 45.77% in the public service sector, 23.34% in the food production sector, 16.88% in the health sector, and 3.95% in the paper, transportation, and research animal's sector. The direct water usage segment of the footprint was identified as 1.7 million m3, while the virtual water footprint was estimated at 15.2 million m3. In a separate investigation, Allison *et al.* (2018) at Emory University implemented a water reuse system known as WaterHub to achieve innovative water reclamation across the campus. This system yielded a daily recovery of 151 liters, recycling two-thirds of the university's wastewater production equivalent, resulting in a reduction of the campus water footprint by up to 40%. In her research, Dursun (2019) utilized the WFN method to calculate the water footprint of Ardahan University's staff and students. Surveying a total of 320 individuals, including 160 staff members and 160 students on campus, through WFN-related queries, the study aimed to determine the campus's water footprint based on their personal consumption behaviors. According to WFN, the average water footprint was calculated as 1420.4 m3/year for staff, 1490.1 m3/year for students, with a total average water footprint of 1455.2 m3/year. In another study, Osorio-Tejada *et al.* (2022) conducted a water footprint analysis at the Technological University of Pereira (Colombia). Utilizing the AWARE method for calculations, they assessed the impacts on human health and the ecosystem using the ReCiPe method. The findings

revealed a total water footprint of 102,670 m3/year for the campus, with a per capita consumption of 17.3 m3/year, of which 86.2% was attributed to indirect activities.

The recommendations that can be made because of this study are as follows. Developing strategies to reduce personal water consumption can contribute to the effective and sustainable management of water resources. Practical measures such as using water-efficient devices, choosing appliances with low water consumption, and adopting conscious garden irrigation methods can assist individuals in achieving water savings in their daily lives. Furthermore, habits like promptly repairing water leaks and regularly maintaining water heaters are significant steps toward the efficient use of water resources. Making food choices based on lower water intensity is highlighted as a key strategy in reducing water consumption. These measures encourage individuals to reassess their water usage habits and cultivate a conscious approach toward more sustainable water consumption.

5. Conclusions

The sustainable management of water resources is crucial to address the challenges of supporting the growing global population and meeting environmental needs. Numerous strategies have been employed worldwide throughout history to achieve sustainable water management; however, these efforts have fallen short. Despite significant strides in legislation and water efficiency technologies in recent years, water scarcity and pollution persist as widespread issues. Hoekstra *et al*. (2011) have introduced the concept of the water footprint for sustainable water usage, contributing to the ongoing discourse on addressing these pressing global concerns. According to the WFN calculation engine, the water footprint of the academic and administrative staff at Konya Technical University had been determined as 1694 m3/year. As indicated in the results section of the components of the personnel's water footprint, 90% corresponds to the domain of food consumption, 7.6% to domestic water use within indoor and outdoor environments, and 2.4% to the domain of industrial product consumption. The corresponding distribution of water consumption quantities in these areas is identified as 1526 m3/year for food consumption, 129 m3/year for domestic water use in indoor and outdoor environments, and 39 m3/year for industrial goods consumption.

Studies on water footprint calculation using WFN in the literature are limited. It is anticipated that the results obtained in this study will contribute to future research conducted using WFN. In this context, it is recommended that further comprehensive research be conducted to contribute to academic literature on sustainable water management practices.

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