The Importance of Individual and Territorial Differences on Water Footprint Calculations

ABSTRACT

The water footprint refers both direct and indirect water use in production process. Not only the water footprint of products but also the water footprint of nations can be determined. The major factors determining the water footprint (WF) of a country are as follows; dietary habits, sex, and Gross National Product (GNP). In this study, Germany, France, United Kingdom (UK), Spain, Italy, Turkey, Greece, Bulgaria, Ukraine and Poland were selected considering their development level, their geographical and cultural features. The WF values of these selected countries were calculated based on sex, dietary habits and the annual amount of income via "Your Water Footprint Quick Calculator". It was found that the country with the highest WF was Spain (3531 m^3/year), while the country with the lowest WF was UK (1711 m^3/year). It was calculated that Turkey's WF was 1626 m^3/year. The most important factors that change values of Turkey's WF were the consumption of meat and dairy products.

Keywords: Water Footprint (WF), Dietary Habits, Gross National Product (GNP), The Mediterranean countries, Turkey.

1. INTRODUCTION

Despite being necessary for the continuation of life, water does not spread over the world equally; it is emphasized as restrictive and suppressive factor in most ecosystems. Despite its vital role, freshwater makes up a very small fraction of all water on the planet. While nearly 70 percent of the world is covered by water, only 2.5 percent of it is fresh. The rest is saline and ocean-based. Even then, just 1 percent of our freshwater is easily accessible, with much of it trapped in glaciers and snowfields. Out of this 1 percent, approximately 70% of world fresh water resources are used for agricultural purposes, followed by 19% and 11% for industrial and domestic use [1].

In 2030, in the light of the scenarios prepared by taking into account economic development and effective use without considering other mechanisms, in addition to the current 4,500 km^3 of the global water demand forecast to rise to 6,900 km^3; Not only drinking water but also required for the creation of added water consumption has emerged as a commodity to be considered [2]. Taking stand from these considerations the factors that determine people's water needs is not only the volume of consumption, water needs should also be determined in the production phase of commodities [3]. Being defined, as water volume required producing a product or service, virtual water is closely related to the concept of water footprint [4]. Water footprint concept introduced in 2002 by Arjen Hoekstra [5].

Water footprint (WF), which refers measuring the amount of freshwater required to produce a product or service within the whole supply chain, comprises the whole process of a raw material from cradle to the grave. In this way, the concept of WF takes accounts of both direct and indirect water use during production process of commodities. WF is measured as the amount of consumed (including evaporation) and/or polluted water in a unit time. Not only WF of a person, society or commercial activity but also that of goods and service can be calculated [6]. In literature review, many studies have been conducted on calculations and assessment WF of cereal products, meat products, produced goods and services [3,4,7,8,9,10,11, 12,13,14,15] and also comparing WF change according to dietary habits of people in different countries [14]. In Turkey, on the other hand, the most comprehensive research on WF is Water Footprint Report (WWF-Turkey) of Ministry of Forest and Water Management (Turkey), General Manager of the Water Management Turkey, OMO and Unilever [5].

Due to limited number of reports WF studies carried out in Turkey could not be compared with other countries. Therefore, in this study the subtitles of the water footprint components of Turkey have been studied. Turkey is placed on the average level amongst world rankings with respect to cropping and water consumption therefore international comparison is made in terms of the average level WF countries.

2. MATERIAL AND METHODS

In this study, “water footprint calculator (WFC)” was used to calculate WFs of different European nations selected on the basis of their water shortage percentages [6]. Four main factors emerged in this calculations; countries, gender (since water footprint values for different dietary habits are also different from each other) dietary habits were assessed with the annual amount of income components.

Each nation’s level of economic development was considered as first factor to evaluate in assessing WF, which differs due to water shortages, adverse weather conditions and poor agricultural practices and policies [4]. Basing on the fact that as developed countries have more WF since they consume more goods and services; Germany, France and UK were selected under the category of developed countries and their WF were assessed.

Considering gender as the basis of our argument the difference amongst the daily food consumption habits of men and women shapes the dietary habits. This dietary habit also shapes the WF of different countries since the consumption habits also differ amongst different nations in line with their GNP. Countries can also be classified under the headings of vegetarian diet types, moderate and high protein consumption medium categories according to their geographical locations, cultural features, dietary habits and incomes [16]. Sharing similar geographical regions and similar dietary habits Turkey; Bulgaria, Italy and Greece were groupped as Mediterranean Food Habit. Geography close to Turkey and Bulgaria, which are countries with similar dietary intake, Spain, Italy and Greece has been selected in this group. Mediterranean cousins mainly shapes the dietary habits of Turkey and countries sharing similar geography like Spain, Italy and Greece therefore these countries grouped all together. Poland and Ukraine are included in the computations as to reflect WFs of developing countries located at colder climate having similar but rather different dietary habits. In this research, web-based individual WFC was used in order to calculate WFs of countries. This research paper based on web based "Your Water Footprint Calculator (Water foot printing) developed by Hoekstra and Chapagain [4]. With this approach it's possible to reach sound results both for countries as well as for individual WFs. The calculation consists of two chapters. The first chapter is WFC which consists of 4 fundamental variables being countries, sex dietary habit and annual income amount. The second chapter of the calculation "Your Water Footprint Extended Calculator" was prepared according to the WF components and a total of 29 questions take place in food consumption (11 questions), domestic water consumption (17 questions) and industrial product consumption (1 question) categories.

The calculation consists of two parts. The first section, "Your Water Footprint Calculator Quick (Quick Water Footprint Calculator)"; takes into account four main variables. These are; countries, gender, dietary habits and the annual amount of income.

The second part of the calculation "Your Water Footprint Calculator Extended (Advanced Water Footprint Calculator)" is; prepared in accordance with the components of the water footprint, food consumption (11 questions) domestic water use (17 questions) and industrial products consumption (question 1) total of 29 questions in the category.

According to Mekonnen and Hoekstra [17] processed meat consumption in dietary habit possesses the largest WF than any other food. Next important parameter is the luxury food consumption of the individuals living in a country. The GNP values broadcasted by World Bank [18] is used for individual countries.

3. RESULTS

As mentioned the selected countries are Germany, France, UK, Spain, Italy, Poland, Turkey, Bulgaria Ukraine and Greece. The WF findings were assessed under 3 headings WF values by countries; WF values by gender and meat consumption of countries.

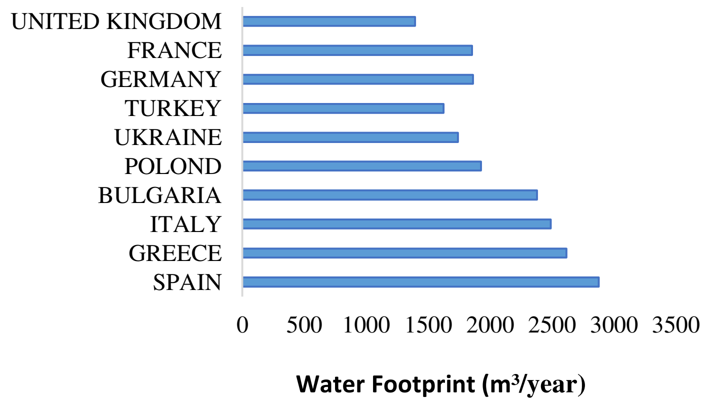

Fig. 1. WF distribution of countries

The results of countrywide "Your Water Footprint Quick Calculator" results are presented in Fig. 1. It appears that Spain has the highest WF with 2878 m³/year. The smallest value was calculated for UK as 1395 m³/year. The WF value of Turkey was found to be as 1626 m³/year.

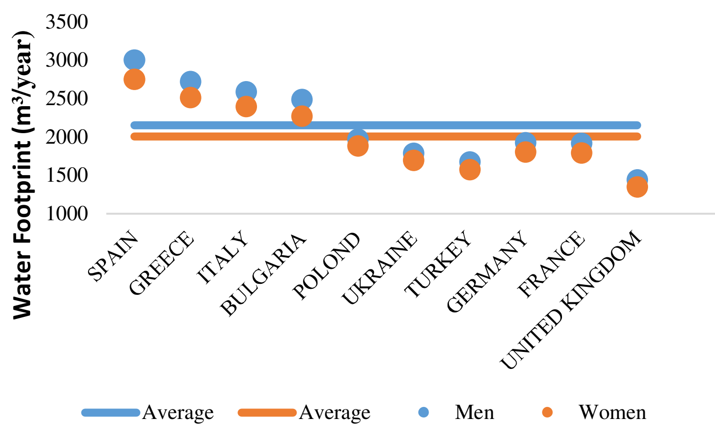

Fig. 2. WF distribution of countries by gender

The same calculator was used to compute WF distribution of countries by gender and the results are presented in Fig. 2. In WF of countries by gender distribution, it was found that WF of women is lower compared to that of men. Accordingly, the highest WF value of males is 3006 m³/year while the highest WF value of females is 2752 m³/year. The lowest water footprint value is 1442 m³/year for men while it is 1350 m³/year for women.

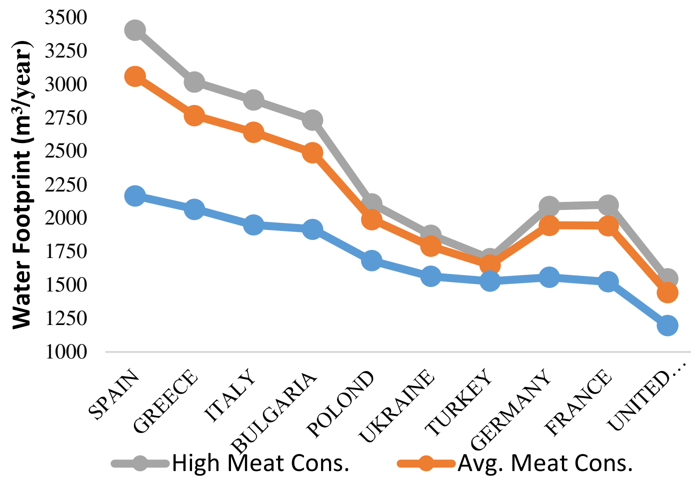

Fig. 3. WF distribution of countries by dietary habits

The same calculator was used to determine the changes of WF values of countries known to have different dietary regimes and related distribution is presented in Fig. 3. In general it can be seen that people having dietary habit based on high amount of protein consumption have higher WF values compared to those of vegetarian diets as presented in Fig. 3. The highest WF value was calculated in high meat consumption (3408 m³/year) while the lowest value was found in vegetarian group (1198 m³/year).

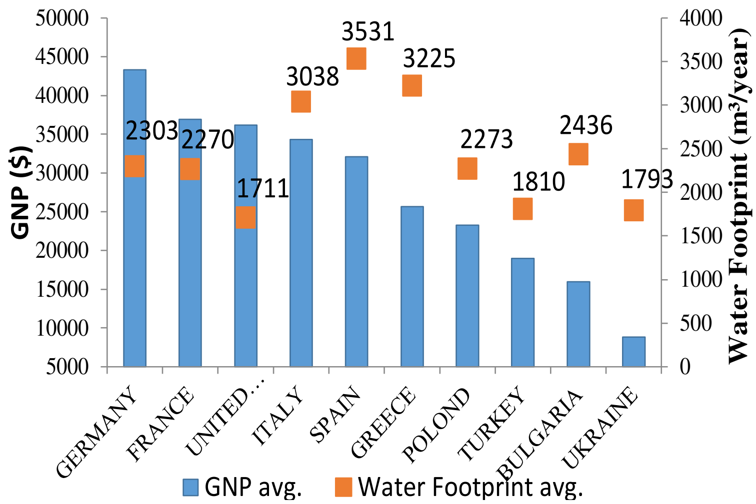

Fig. 4. WF distribution of countries by GNP

The distribution of countries' WFs calculated with "Your Water Footprint Quick Calculator" according to GNP values based on World Bank data [18] are presented in Fig. 4. According to GNP value, the lowest WF value was calculated in UK (1711m³/year) and the highest value was calculated in Spain (3531 m³/year). Studies always emphasize that the most essential factor that affects the WF values are luxury consumption of foods (meat, fruit, vegetable, dairy products and GNP values). Accordingly, the change of WF in Turkey. According to the dietary habits of the population in Turkey, in accordance with the studies conducted so far, the obtained variables were written under different groups according to the weekly consumption amounts. Considering the mean GNP values obtained from the World Bank [18]; the lowest WF value was calculated as 1167 m^3/year while the highest value was found as 1643 m^3/year through the calculation tool in this study. According to minimum GNP value, the lowest WF value was found to be 930 m^3/year and the highest value was found to be 1405 m^3/year.

Turkey's water footprint was calculated by Extended Water Footprint calculation tool [6]. Using Extended Water Footprint calculation tool, it was tried to determine the effects of different dietary habits of Turkey's water footprint. Dietary habits

4. DISCUSSION

The concept of WF has been defined and developed in order to be an indicator of water consumption of people. WF of a country defines the volume of water required for the production of goods and services consumed by the citizens of that country. The global WF is 7450 Gm^3/year; while the WF per capita is 1240 m^3/year [3]. In this study, it was found that WF value of each country is different from the WF of other countries just as stated in the study of Chapagain and Hoekstra [3]. Income levels by persona, geographical characteristics and climate conditions of countries are effective to determine WF; in addition, agricultural production amounts, production of products which need much water and the irrigation

fact that these consumptions are different, the weekly consumption amounts were considered to be 1 kg and 2 kg; WFs were calculated through different combinations of kilogram amounts of these four products. Other variables in “Your Water Footprint Extended Calculator” were stabilized. According to were divided into vegetables, fruits, meat and dairy products. Firstly, water footprint was calculated based on the equal consumption for each product. Then, water footprint of the same products was calculated according to different weekly consumptions. Water footprint was determined 930 m^3/year for equal consumption of vegetables, fruits, milk and milk per week. Water footprint values for vegetable-based, fruit-based, milk-based and meat based dietary were respectively 944, 959, 1299 and 993 m3/year. Water footprint of meat-based consumption was found highest among the other food-based consumption.
systems used in agriculture also have impact on different WF values.

In other studies conducted on WF, [3, 19, 20] found that UK (1250 m^3/year) has the lowest WF while Spain (2450 m^3/year) has the highest WF value; these findings from the countries WF graphics are in concordance with the WF values found in the present study. Similarly, WF values of Turkey were found to be in close value with mean WF value of all countries (1626 m^3/year) (Fig. 1).

According to Mekonnen and Hoekstra [7] WFs per capita in developed countries are lower than those in developing countries. According to the analysis conducted on countries in the present study, it was found that developed countries like Germany, France and UK have lower WF compared to developing countries. The main reasons for this can be as follows; the agricultural and animal products which require much use of water are less in developing countries [21] and while developed countries use modern techniques in agriculture, developing countries continue agricultural activities through traditional techniques to increase their WF. The sector-based water use of countries reflects their development level to some extent. As the economy of developed countries is based on industry, they import raw material and agricultural products, have more comprehensive water management plans, conscious water consumption is more common in fields where water is mostly used; especially in agriculture; for these reasons, WF values are lower in such countries.

In developed countries having high level of income, agricultural water use is replaced by industrial sector [22]. Furthermore, the increase in consumption need and water shortage in developed countries turned water into a global resource [14]. Accordingly, purchasing water through imported products or selling water through exported products will play a significant role in countries' strategies to decrease WF, measures to be taken against water shortage and the water management plans to be applied [3]. It can be seen that WF volume which differs by export and import is higher in developed countries; so is the purchased and sold WF volume. Each country has a different water-balance characteristics and this balance is more stable in developed countries.

It can be seen that WF values of Mediterranean countries such as Spain, Italy, Greece and Turkey are higher than other countries. The WF is related with geographical features of Mediterranean and cultural characteristics and dietary habits of people living in this geography. Dietary habit of Mediterranean countries is mostly based on vegetable or fruit agriculture and their consumption within the country [23] and this is a factor which increases the WF. Especially in Mediterranean countries, there is need of plans towards water need in agricultural production and water management [4]. The high temperature values in Mediterranean countries compared to others are in parallel with the increase in WF values. Especially Spain fulfills 5% of cereal production of Europe [24]. Another important factor in high WF of countries having Mediterranean climate is high production and consumption of olive which is a fruit having high WF; also the fact that Mediterranean region is the most active region in olive oil production. The water used for irrigation in agriculture which can be commonly observed in Mediterranean countries is among the most characteristic factors to increase WF value [23].

In consideration of WF calculation of countries, one of the most important factors which have impact on WF is agricultural activities. The consumption of agricultural products comprises 92% of global WF which depends on consumption. According to the levels of product categories; cereal consumption comprises the largest part (27%) of global WF which is followed by meat (22%) and dairy products (7%) [13]. To conduct agricultural activities in accordance with natural condition and climate conditions can have effect in decreasing WF [4, 20].

Dietary habits of people in a country, consumption of products having high WF such as meat are important in calculation of that country's WF. It can be seen that WF of countries having high level of meat consumption in geographical, cultural and tradition way generally have higher WF [16]. According to the dietary habit based on meat consumption; the findings obtained in the present study are in concordance with the findings of Vanham et al. [16]. The increasing meat consumption having high WF leads to increase in WF value of a country (Fig. 3). In this study, WF values obtained for high meat consumption are higher than the values calculated for the group having less meat consumption and vegetarian group in all countries. Economic development brings along changes in food and consumption habits. The increasing and diversifying consumption of middle class in developing countries has increased the meat consumption worldwide. In countries having high level of income, annual mean meat consumption per capita increased to 93.5 kg in 2002 compared to 55,9 kg in 1990. According to the values of the year 2012, annual mean meat consumption per capita is 110.2 kg in Spain, 91.4 kg in Italy, 88.7 kg in France, 87.7 kg in Germany and 85.8 kg in UK [25]. The importance of these values for water consumption is closely related with 15.000 m^3water consumption for the production of a ton of beef [26, 27]. The environmental effects of meat production can be seen in deterioration of environment and increase in greenhouse gas emission apart from water shortage (800 million tones methane/year) [27].

One of the reasons of different WF values of countries is the annual income levels of countries. National revenues of countries not only determine consumption volumes but also affect WF values. Citizens in each country have different income amounts and purchasing power. Therefore, the mean gross national product (GNP) values of countries were used to calculate WFs. Mean and low GNP values of countries were analyzed in order to determine the effect of incomes of citizens on WF. While the contribution of people having high annual income is much on WF, those having low income have less WF. As stated in the study of Hoekstra and Chapagain [4] the present study also found that WF values of countries differ by national incomes of countries (Fig. 4).

Considering the lowest and mean GNP values of countries, it was calculated that WF of Bulgaria is 2398, 2362 m^3/year and that of Ukraine is 1793 and 1693m^3/year, respectively. It is assumed that the main factor of these very close calculations is the fact that mean and minimum GNP values of these countries are very close to each other (the mean 15941 $ and minimum 7907 $; the mean 8788 $ and minimum 4394 $ for Bulgaria and Ukraine, respectively) and this rate positively affects the income distribution within the country. This income distribution leads to close values in WFs as well. Due to the high difference between income levels of developed countries and other countries selected for this study, the difference between the WFs calculated according to minimum and mean GNP values is very high as well. The difference between income levels directly affects the luxury consumption title; therefore it has clear impacts on WF values as well. In Spain and UK where the WF values show the biggest difference according to the mean GNP values, footprint values were determined as 3531 m^3/year and 1711 m^3/year. In addition, in Bulgaria and UK where the WF values show the biggest difference according to minimum GNP values, footprint values were determined as 2362 m^3/year and 1080 m^3/year. In Turkey, these values are within the range of 1810 m^3/year and 1442m^3/year and this situation makes our country take place in the group of countries having different income distribution. In calculations of WF through sex, it is possible to see less WF of women compared to men is related to women's dietary habits. In order to keep body weight relatively stable, energy intake should be in same amounts with daily consumption. The mean energy intake is 2600 kcal/day for an American man; this figure is 1900 kcal/day in average for a female. Men consume foods having more fat and energy compared to women; and men spend more energy [28]. Daily water consumption is also directly related with daily calory need; daily water consumption is 1-1,5 ml per 1 kcal energy for a person [29]. Therefore, it is possible to assume that daily water consumption can be higher for men. For that reason, this study conducted based on the sex difference can predict that the main factors in higher WFs of men are related to their different dietary habits and the energy of the consumed foods.

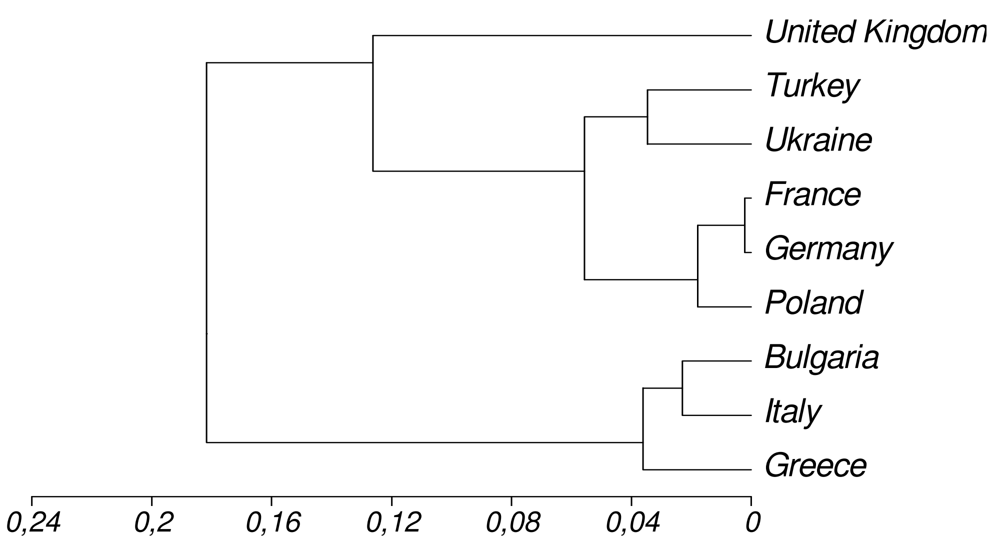

Fig. 5. The Bray-Curtis similarity index among countries

In the analysis of WF data of countries through Bray-Curtis similarity dendogram (Fig. 5); the group of Mediterranean countries having similarities (Bulgaria, Italy, Greece and Spain) is remarkable. France and Germany are the two closest countries in terms of similarity in WF values and Poland can be included in the same group. Turkey and Ukraine can be assessed as two countries having mean but incompatible values in terms of similarity. UK is a different country and has very little similarity among all groups. The consistency between the statistical results of the values detected in this study and the cultural-dietary habits of countries makes the calculations of this study reliable.

At the end of the calculations, the WF of Turkey was found as 1626 m^3/year. In comparison of WF values determined for other countries in the study, it was found that Turkey has a mean WF value. In addition, the main variables of “Your Water Footprint Extended Calculator" used for Turkey were investigated. Just like in the assessment conducted among countries, generally as GNP increased, WF values increased as well. Meat, vegetable, fruit and dairy products which have a significant place in dietary habits of Turkey were determined as the most effective factors in the calculation of WF of Turkey. According to GNP values; it was found that WF value of Turkey increased as the consumption of meat, vegetable, fruit and dairy products increased. The WF value of Turkey reached above the mean value through the increase in meat consumption which has a common production and consumption field and has a high WF. In specific to Turkey, the second most important factor which affects WF was assumed to be the increase in dairy product consumption.

5. CONCLUSION

Traditionally, there are efforts to make policies towards decreasing water demand according to nation or region and increasing the need supply [14]. In studies to be conducted related to determining or decreasing WFs of Turkey, each country is assessed by her own characteristics. Traditional dietary habits of countries should be compared according to the mostly consumed product on country basis and the WF of that product. In calculation of WF of countries, development level of each country, income levels of citizens, traditional consumption habits, and therates of traditional and modern methods used in agriculture should be considered to calculate WF amount of each country.

Meat and dairy products have the highest value among intense water consumption products and national water plans cannot reach the aim without these two factors. The increasing need of meat and dairy products should be controlled in correct way in order to decrease the shortage of usable water resources [9]. A suitable water policy should include the limitation of meat and dairy sector. The possible effects can be different as the dietary habits of each country are different. However, meat consumption-derived WF can be decreased by changing dietary habits in nations and regions having relatively high meat consumption per capita. However, new discussions emerged related to changing dietary habits for partial solution of water shortage [30]. Such a change is out of the question for countries having mean world values of WF such as Turkey. However, the suggestion of vegetarian diet in both approaches related to obesity and suggestions towards healthy living of people, created a dominant effect on Turkish press and people.

While making national water planning, states adopt a traditional attitude towards fulfilling national water need with a solely national perspective. States look for ways to satisfy water users with total amount of water need [13]. Anticipations about climate change indicate that Mediterranean Basin (including Turkey) will be seriously affected by temperature rise and decrease of raining. It is assumed that this situation will increase water stress, will lead to more frequent and serious dimensions of drought, as a result, water shortage, forest fires will increase, biologic variety will be lost and income loss will be experienced in agriculture and tourism [2]. Considering all these anticipations, it is very important to make and apply policies towards reducing long-term water need of Turkey and decrease Turkey's WF.

In “Your Water Footprint Extended Calculator”, factors such as garden irrigation frequency, car washing frequency, swimming pool use and capacity under the subtitles of fundamental variables cannot be calculated through an anticipated mean value for each household considering general life habits of Turkey. For that reason, as one of the main suggestions of this study, these variables were considered as variables which should not be included in the assessment in terms of calculation method for Turkey. One of the important factors to be emphasized is the fact that subtitles of each fundamental variable in WF calculations may not be suitable for each country. It is suggested that these variables to be selected for each country should be selected in accordance with characteristics of each country, life standards and habits; private variables of related country.

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