WATER IMPACTS OF FOOD PATTERNS: SUSTAINABLE DIETS AND FOOD WASTE WATER FOOTPRINTS

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Abstract

Global food demand is increasing and changing rapidly as a result of multiple drivers as population growth or urban dietary shifts. Managing food consumption (people's eating habits) might deliver important co-benefits from a water perspective. Many recent studies have addressed the relationship between diet habits and associated water impacts. The goal of this study is to assess and compare the water footprint (WF) of two recommended diets (Mediterranean and American) in Spain and US. Moreover also focuses on assessing the WF of the food consumption and its associated food waste in Spanish households during one year. Our results show that the American diet has a 29% higher WF, regardless of products' origin. Food consumption and waste WFs in Spain are 3,302 and 131 litres/person day respectively. A shift back to a Mediterranean diet, in which fruits, fish and vegetables account for a larger share of the food intake, would deliver great water savings.

Keywords: Dietary shifts, sustainability, virtual water, water savings, food waste.

1. Introduction

World population will reach 9.7 billion in 2050 (United Nations, Department of Economic and Social Affairs, 2015). Furthermore, humanity today is experiencing a dramatic unstoppable shift to urban living (Grimm et al., 2008). A growing and more urban population will not only create a strong pressure on food supply and demand, but will change this demand (food consumption) in a very significant way. Therefore, urban consumers are making significant changes in their diets; they are moving away from basic food products (vegetables, fruits…), towards to higher-value (meat, eggs, dairy products…) and more processed ones (FAO, 2017). This converts food "problem" (how much, what type, how or by whom this food is produced and consumed), a global obsession in recent years (Garnett, 2014).

On a related issue, in 2016, the number of chronically undernourished people in the world was estimated to have increased to 815 million (FAO, 2017). At the same time, global obesity prevalence more than doubled between 1980 and 2014, with more than 600 million adults being obese (FAO, 2017). On the other hand, there is a large proportion of food that is wasted or lost along the production chain. These losses are reported to be around 30-50% by some authors (Gustavsson et al., 2011; Lundqvist et al., 2008). The importance of avoiding food waste and investigating at which stage of the chain this occurs are major issues, also because all the resources embodied in them are wasted too.

Measures promoted by United Nations or the European Commission relied on a more efficient food demand's management in order to achieve environmental benefits. These measures include actions such as responsible consumption and food waste reduction, which can increase food production chain efficiency, and thus favour a change in the whole system and achieve full

and sustainable food security. Also, many authors reported that a change in diets and a reduction in food waste and loss produce many environmental benefits (Foley et al., 2011; Gephart et al., 2016; Godfray et al., 2010; Godfray and Garnett, 2014; Rockström et al., 2017; Tilman and Clark, 2014). For this reason, it is necessary to carry out a study of possible actions and measures within the management of food demand, such as: promoting the transition towards more sustainable food consumption patterns and reducing food waste to a minimum.

The way we eat has large implications on resource use, being an upcoming increasing competition for land, water, energy, and other inputs (Garnett et al., 2013; Tilman et al., 2001). These natural resources' use in agriculture has been studied within last decade's (Odegard and van der Voet, 2014) with a critical interest in water (Hoekstra and Chapagain, 2007; Konar et al., 2016; Rockström et al., 2009; Vanham and Bidoglio, 2015) and land use (Foley et al., 2005; Tilman et al., 2002). Water competition leads into increasing water scarcity problems in many parts of the globe (Jalava et al., 2014; Wada et al., 2011), being water one of the most limiting factors to agricultural production (Yang and Cui, 2014). This will require a rethinking of possible approaches to achieve healthy, but at the same time, sustainable and less water consuming diets. Many studies in the past years have addressed the relationship between diets and associated water impacts, using the Water Footprint Assessment methodology (Blas et al., 2016; Vanham, 2013; Vanham et al., 2013). Also, dietary shifts can cause important health problems such as coronary diseases, overweight and obesity.

This circumstance is driving national health and food agencies to raise awareness among citizens about the importance of adopting healthier food habits. Countries like Spain are putting efforts to highly reduce food loss and waste (Ministerio de Agricultura Alimentación y Medio Ambiente, 2015) and to reverse growing obesity problems and involving different public institutions in the promotion of the recommended and traditional Mediterranean diet. This one has been recognized as a key strategy to improve population´s health with local, traditional and seasonal products (Bach-Faig et al., 2011; Bonaccio et al., 2012), being the main one's vegetables, fruits and fish, and it has been recognized by UNESCO as a cultural World Heritage (UNESCO, 2016). In fact, the Med. diet is appreciated for its lower environmental impacts in relation with other (Blas et al., 2016; Capone et al., 2014; Sáez-Almendros et al., 2013).

Accordingly, the main objective of this study is to estimate water savings due to the consumption of sustainable diets and/or reducing food waste. Therefore, two assessments were applied. The first one was the calculation of the WF of two recommended diets i.e., Mediterranean and American, and to evaluate the water savings of possible dietary shifts in two countries (Spain and US). Moreover a second study attempt to identify and analyse the consumption patterns and food waste of Spanish consumers using household data for one year and the water footprint and origin of these consumed and/or wasted products, in order to evaluate water consumption and savings at a home level.

2. Methodology

Water Footprint Assessment approach was used in both studies, particularly focusing on the phase two (i.e. water accounting), as defined in the Global Water Footprint Standard (Hoekstra et al., 2011). The WF of a product is understood as the direct and indirect appropriation of freshwater resources required to produce a good, being the final result the sum of three

components: green, blue and grey (Hoekstra et al., 2011). Green WF refers to the rainwater stored in the soils and directly evapotranspired by crop products. The blue WF refers to the volume of surface and groundwater embedded in the production of a good. In agriculture, the blue WF of a food product refers to the total volume of irrigated water that is evapotranspired by a crop, and embedded in the production of livestock products. Finally, grey WF is an indicator of water quality degradation, and refers to the volume of freshwater required assimilating the load of pollutants generated along the production chain of a product, in order to reach the quality standards established in the environmental regulations(Hoekstra et al., 2011). The WF of a product is the sum of all the water consumed along its different production steps (Hoekstra et al., 2011).

2.1. Mediterranean and American recommended diets study

To characterize the composition and product quantities of the Mediterranean diet, two seasonal week menus were defined (i.e. winter and summer) using the food guidelines elaborated by the Mediterranean Diet Foundation (Fundación Dieta Mediterránea, 2015). The American recommended diet (USDAr) was configured following the guidelines of the Center for Nutrition Policy and Promotion (CNPP) of the US Department of Agriculture (USDA, 2015) and the study of Haven et al., (2015). When calculating the WF of these diets, we have only considered the amount of water consumed in the production of each food item, but without considering additional water requirements for cooking purposes (e.g. boiling, washing, etc.). This assumption was made due to the lack of detailed data regarding the amount of household water used for cooking purposes and the fact that the largest fraction of the WF of food products lies at the field level i.e. agricultural production (Chico et al., 2010).

To estimate the WF of the different week menus we relied in the global WF database of crops (Mekonnen and Hoekstra, 2011), and livestock products (Mekonnen and Hoekstra, 2012). Both databases provide average values of green, blue and grey WF of each product (in m^3/t or l/kg) for the time series 1996-2005. To assess the water impacts of changing diets we also estimated the WFdiet associated to a potential shift in the diets in the two countries i.e. Spain adopting an American diet and the US adopting a Mediterranean diet. We assumed that all consumed products are also produced nationally, except for those products which are not produced in none of the two countries and necessarily need to be imported.

2.2. Food consumption and waste in Spanish households

In the second study, data has been collected using five main databases, which refer to food waste and consumption statistics, food import trade matrix, water footprint data for crops (Mekonnen and Hoekstra, 2011) and animal products (Mekonnen and Hoekstra, 2012) and Spanish national crop and food production. The first step was to analyse food waste data per household. Spanish government has been doing in the last four years an effort to quantify all food waste in households, industry and field, with the program called "More food, less waste" (Ministerio de Agricultura Alimentación y Medio Ambiente, 2015). Only the date of the first two semesters was considered (October 2014 through September 2015). This database on food waste contains information on both raw and cooked food waste per household (kg/household and year) and was gathered from a sample of 4000 households of varying sizes and income per capita, distributed randomly across different parts of Spain.

Food consumption statistics per household were also collected for the period October 2014 to September 2015, and they were extracted from the program "Consumption, commercialization and food distribution: Household consumption database" (Ministerio de Agricultura Alimentación y Medio Ambiente, 2016). Samples of 8000 households with data collection based on daily note-taking on household food shopping were surveyed.

To estimate the origin of the virtual water embedded in food consumption and waste, we analysed the matrix of trade food products (exports and imports) of Spain (Ministerio de Economía, 2016). We analysed the origin of the products that accounted for the most part of the final household consumption (70%); a total of 84 products from 199. To determine the origin of the most consumed food products, we used the trade information from Datacomex. Finally, we estimated the WF of food consumption and waste in Spanish Households from October 2014 to September 2015. We took into account for this calculation the proportion of food consumed and waste linked to national production, but also linked with the imports (international production).

3. Results

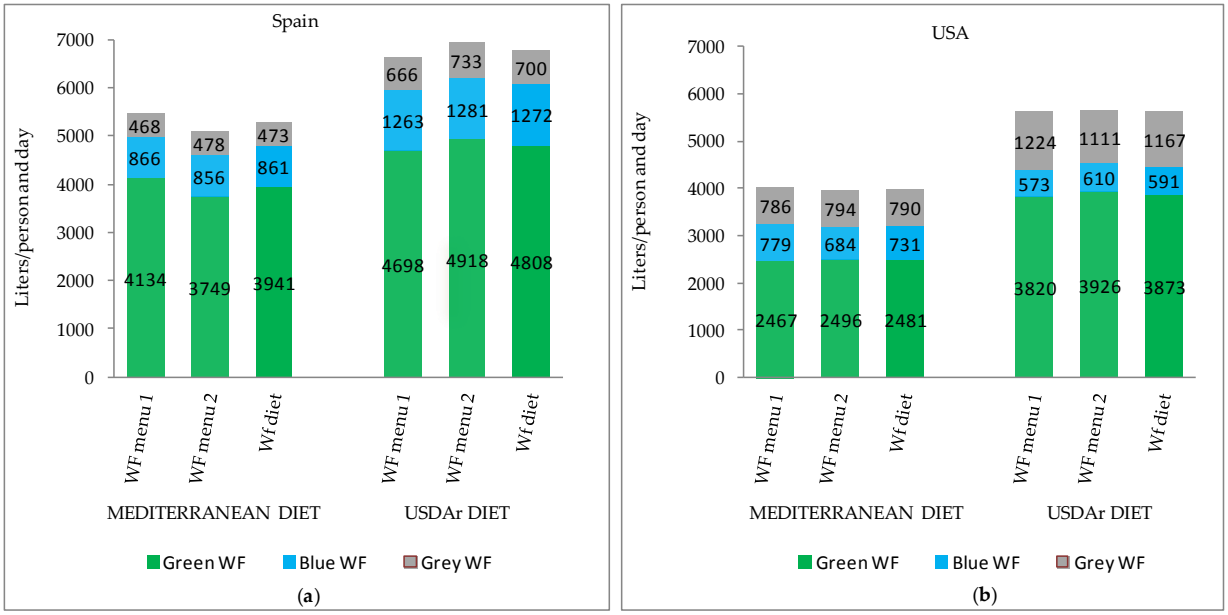
3.1. Mediterranean and American recommended diets study

Results from the comparison between the two recommended diets (Figure 1), show that the WF of the American recommended diet (USDAr) is higher than the Mediterranean one, irrespectively of where products' origin (Spain or US). In Spain, the WF of the Mediterranean diet is 5276 litres per person and day, but adopting an USDAr diet will increase the WF nearly 29%, up to 6780 litres per person and day. The majority of this increase is because of the rise in green water, followed by blue water, and to a lesser extend grey water. In the US the WF of the USDAr is 5632 litres per person and day. Shifting towards a Mediterranean diet (4003 litres per person and day), will decrease the WF by 29 %. Larger savings will be achieved in terms of green (-1392 litres /person and day) and grey water. However, in this diet shift scenario blue WF will increase of 24%.

Green WF accounted for the largest share of both menus and diets in the two countries. In Spain green WF contributes to 75% of WF for the Mediterranean diet and 71% for the USDAr diet. In the US green WF accounted for the 62% of WF in the Mediterranean and 69% in the USDAr diet. Blue WF was the second largest fraction in WF in Spain for both Mediterranean (16%) and USDAr diet (19%).

On the other hand grey WF, accounted for the second largest fraction of WF in the US for Mediterranean (20%) and USDAr diets (21%). If we only took into account the blue and green WF components of the diets, in order to discern the impacts of water resources quantity, there would be water savings equivalent to 1277 litres per person and day in Spain consuming a Mediterranean diet instead of an USDAr diet. Similar values were obtained in the US for green and blue WFs, where changing from an USDAr to a Mediterranean diet will imply a net reduction of 1252 litres of water per person and day.

Figure 1. Green, blue and grey water footprint for WFmenu1, WFmenu2 and the total WF diet of Mediterranean diet (WFdiet), and WFmenu1, WFmenu2 and the total WF diet of USDAr diet (WFdiet), for: (a) Spain; (b) the US.



Fuente: (Blas et al., 2016)

The analysis of the individual products' WF reveals that the five products that contribute the most to the green, blue, grey and total WF account up to 36-46% of the total in both countries and dietary options. Olive oil is the product which accounts the most to the WF of the Mediterranean diet, both in Spain and the US. Despite olives being a millennial, local and landscape adapted trees, its high green WF values make olive oil one of the major water consuming products, even more than meat and dairy ones. Olive cultivation as a low-intensity production system, and usually associated with old trees, small yields, and receiving low inputs for both labour and materials (Blondel 2006). These factors (mainly low yields) probably explain the large WF (particularly green water) of olives and olive oil. In view of the above, further research is needed to evaluate the high green WFs.

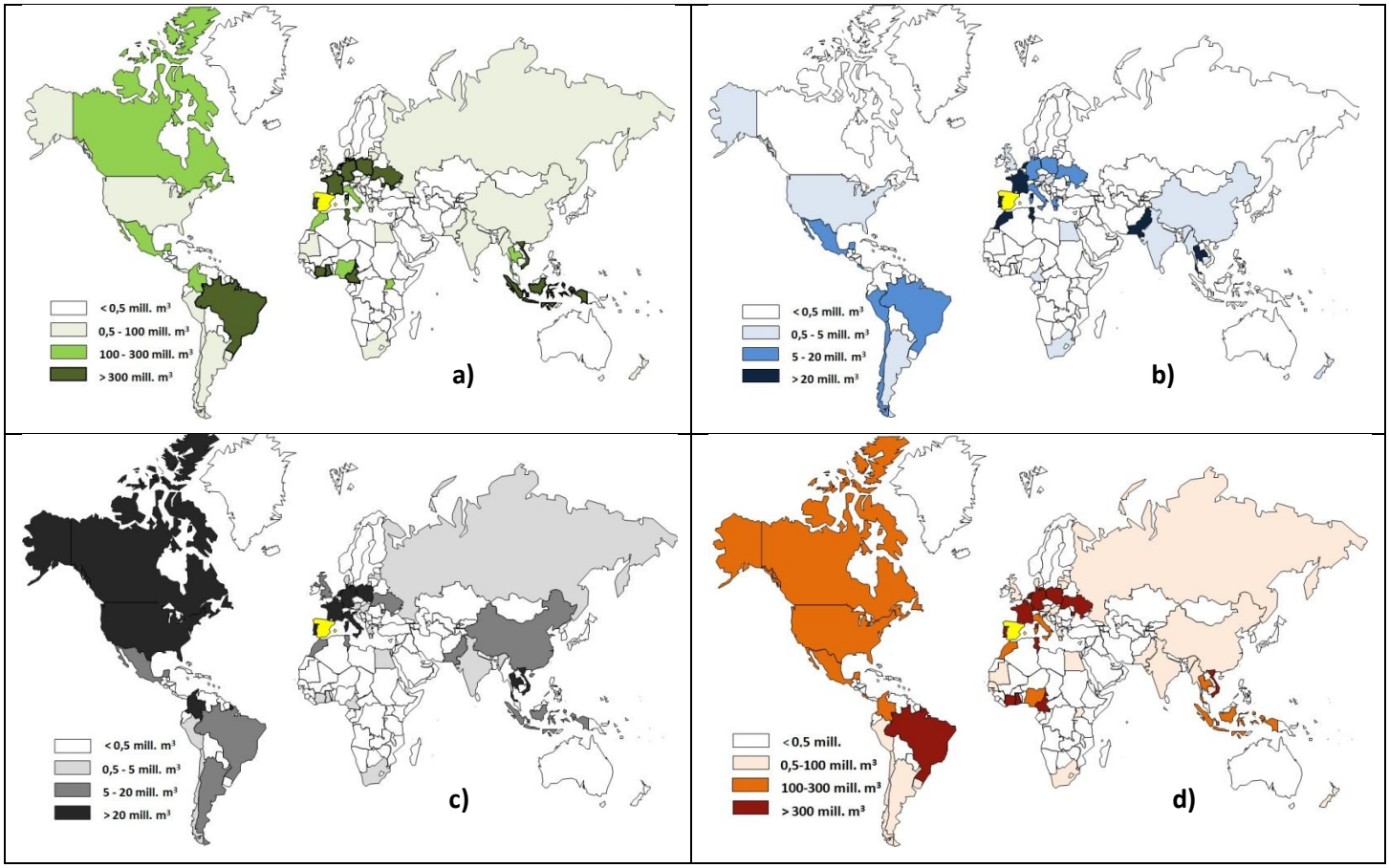
On the other hand, in the USDAr diet semi-skimmed milk is the product that accrues the largest share of the WF (16%, equivalent to 1085 litres per person day) in Spain. While in the US the product that claims the largest WFdiet is beef meat (14%, 789 litres per person and day). Most of the products that influence the most for green, blue, and grey (and thus in WFdiet) for both dietary options and countries originate from only three products groups: a) meat, fish and animal fats; b) dairy products and c) oils and vegetable fats. Moreover, products from the group of legumes and nuts account for the major part of the grey WF for both diets in US.

3.2. Food consumption and waste in Spanish households

In the second study about water implications of food consumption and waste in Spanish households during one year, results show firstly that Spanish household food consumption differ from a recommended and traditional Mediterranean diet pyramid, where fruits and vegetables have a leading role. Moreover, our calculations show that livestock products are as consumed as the groups of vegetables and fruits together. As other studies highlighted (Bonaccio et al. 2012; Serra-Majem et al. 2004), although Mediterranean diet still exists, actual Spanish consumption patterns are changing to a more meat and sugar products based diet.

Within households during one year, the total imported virtual water represents the 41% of total water consumed, which highlights the importance of the up growing global food trade and its volume of water associated. Western Europe is the region of the world where more water is imported from, and Tunisia (because of olive´s oil importation and high WFs values, especially the green one), Portugal and France the most important countries. This results (for blue, green, grey and total virtual water values) can be seen in Figure 2.

Figure 2. Annual imported water (million cubic meters; 1 mill. m^3 = 1 hm^3) with respect to Spanish household food consumption (Oct. 2014 -Sept. 2015) broken down by a) green, b) blue, c) grey and d) total virtual water.



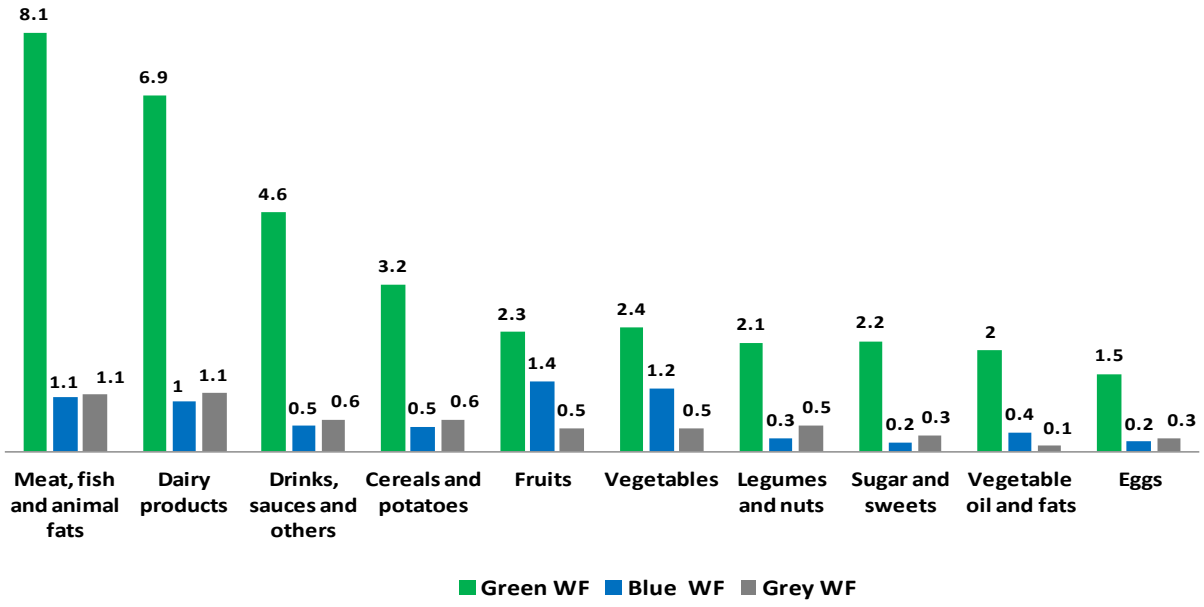
Fuente: Blas et al., 2018

The total annual WF of Spanish households, taking into account imported food products (and therefore imported water), was, on average, 1205 m^3 per person, equivalent to 3302 litres per

person and day. In absolute terms, the WF of Spanish household food consumption was 52,933 hm^3. Of the total WF per person over a one-year period, the green fraction accounted for around 77% (932 m^3/person and year), the blue for 12% (146 m^3/person and year) and the grey for 11% (127 m^3/person and year). The products which account the most to the water footprint of Spanish household's food consumption are the ones of livestock origin; meat, animal fats and dairy products. These results are consistent with the individual product analysis.

Regarding food waste, With respect to food waste, the amount of annual food waste is 26 kg/person and year on average. This is equivalent, on an annual basis, to an average food waste per household of 65.3 kg and a total food waste of nearly 1.14 million tons nationwide. The most wasted product group in Spanish households was fruit (7.3 kg/person and year) and vegetables (4.7 kg/person and year), accounting for 28% and 18% of total annual household waste, respectively. Figure 3 shows the results for Spanish household food waste WFs by food group for a one-year period. The total WF was 47.7 m^3 per person and year (4% of the total food consumption WF). This is equivalent, on an annual basis, to an average water waste due to uneaten food of 131 litres per person and day and a total of 2095 hm^3 across the whole country. The total green WF of food waste was 35.4 m^3 per person and year (i.e., 1555 hm^3 nationwide, 74%), while the blue WF (6.7 m^3/ person and year, 14%, 292 hm^3 nationwide) and grey WF (5.6 m^3/ person and year, 12%, 248 hm^3 nationwide) accounted for the remainder. As far as the analysis by food group is concerned, the meat, fish and animal fats and dairy products groups again had the largest share of the total waste WF.

Figure 1. Annual (green, blue and grey) water footprint (m^3/person) for different food groups within Spanish household food waste (Oct. 2014 - Sept. 2015).



Fuente: (Blas et al., 2018)

4. Conclusions

Few studies have evaluated the water used to cultivate those products embodied in recommended and daily menus (using traditional and national-local recipes), nor real food consumption and waste in households during one year. As this study has shown, changing

consumption patterns towards recommended diets based on vegetables, fruits and fish consumption would deliver significant water savings, in some cases larger than those associated to increasing efficient production or reducing food waste. The WF of food waste in Spanish households during one year has been calculated as the 4% of the total WF of the food consumed. There is a big difficultness of comparing the quantitative data with other studies, due to the different methodology and definitions applied in their measurements. Still, low wasted food data can be explained because of good consumer´s behaviour, or large food loss in other parts of the food chain. This study demonstrates how important diets and consumption patterns are for consumers and the environment, also, this paper highlights the benefits linked to embracing the Mediterranean diet not just because of its health potential benefits, but also because it is a less water intensive diet. The importance of saving freshwater by reducing food waste or consuming those diets with less water needs, will be crucial in the next decades to affront water scarcity problems in all around the globe. A shift back towards a Mediterranean diet will deliver greater water savings.

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