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### Water Footprint Comparison in Various Food Ingredients Used in Mediterranean and Western-Type Diets in the Island of Crete, Greece

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#### Abstract

Different dietary patterns have different impacts on human health and on environment. The old traditional Mediterranean (Med) diet, based mainly on vegetables, fruits, olive oil, cereals and legumes, is considered a healthy diet. However, it has been gradually replaced from unhealthy dietary patterns the so-called Western-type diets, based more on red meat, processed meat, sugary drinks and prefabricated meals. The harmful health impacts of Western-type diets have been mentioned. Based on existing studies the water footprint (WF) of Med diet and Western-type diets have been analyzed and the green, blue and grey

part of it has been examined. The low WF of Med diet compared to the WF of Western-type diets has been highlighted. Med diet has benefits on human health and on ecosystems while Western-type diets are unhealthy, have lower cost and are more consistent with modern lifestyles. It has been indicated that shift from Western dietary patterns to Med diet in the island of Crete, Greece causes a significant reduction on the WF. Our findings could be useful to policy makers and to public authorities who should promote Med diet which does not offer benefits only to human health but also to global ecosystems.

**Keywords:** Food Ingredients, Health, Mediterranean Diet, Obesity, Water Footprint, Western Diet

#### 1. Introduction

Large quantities of water are currently used in agriculture with rather inefficient irrigation technologies while the production of plant- and animal-related foodstuff utilize significant amounts of water resources [1,2,3,4,5,6]. Many people in Western wealthy societies have changed their traditional dietary patterns using diets adjusted to modern lifestyles [7,8,9,10]. Existing research has indicated that Western-type diets are related with many serious health problems which can be partly avoided with the shift to traditional Med diet [11,12,13]. Additional research has also indicated that Western-type diets are related with high WF compared to traditional Med diet.

*The aims of the current study are: a) to examine the environmental impacts, regarding water resources of Med diet and Western-type diets using published data, and b) to examine the benefits in water resources derived from the adoption of Med diet instead of Western-type diets focusing on the island of Crete, Greece.*

The text is structured as follows: After the literature survey the Med diet and the Western-type diet are stated followed by an analysis of water footprint. Next, the water footprint in various foodstuffs included in Med and in Western-type diets is described using the existing literature. After that, the reduction of the WF in the island of Crete, Greece is estimated due to shifting from Western-type diet to Med diet. The text ends with discussion of the findings, the conclusions drawn and the citation of the references used. The current study covers a gap regarding the WF benefits from sifting from the current dietary pattern of Western diet to Med diet in the island of Crete, Greece while is innovative since there are not many studies published in this field so far. It could be useful to local authorities, policy makers, food companies, medicinal doctors, farmers and water managing authorities in the island.

#### 2. Literature Survey

The green, blue and grey water footprint in several crops has been studied [1]. The authors stated that the global average WF per kg of crops varies in the range of 200 l/kg to 4,000 l/kg. They also mentioned that the water used in crops during the period 1996-2005 was 78% green, 12% blue and 10% grey. The WF of farm animals and animal products has been estimated [2]. The authors provided a comprehensive account of the global green, blue and grey WF of different sort of animals and animal

products in different production systems in several countries. Their estimations indicated that the green WF accounts at around 80-90% of the total WF. The WF of poultry, pork and beef has been estimated [3]. The authors examined three main factors affecting their WF including: a) feed conversion efficiency, b) feed composition, and c) feed origin. They mentioned that beef had larger WF than pork which in turn had larger WF than poultry. The water consumption in crop's production has been analyzed [4]. The authors stated that blue water is important in water resources research while the use of green water in food production has not been studied extensively. They analyzed the water consumption in various crops mentioning that more than 80% of the water used was green water. The use of hidden water resources behind meat and dairy has been explored [5]. The author stated that the consumption of animal products contributes to more than one quarter of the water footprint of humanity while feed production is the major factor behind the water footprint of animal products. He also mentioned that in industrialized countries, moving towards a vegetarian diet can reduce the food-related water footprint of people by 36%. The water consumption in fruit and vegetables processing plants has been calculated [6]. The authors stated that substantial amount of water is consumed during processing of fruits and vegetables. They mentioned that the use of water saving methods can reduce the water consumption during processing up to 50%-70%. The implications of Western diets on health have been examined [7]. The authors stated that western diets have adverse effects on metabolism, cardiovascular health, cancer, inflammation and antioxidant status. The implications of Western diet on brain function and behavior have been studied [8]. The authors stated that Western diet often leads to obesity and overweight while it has been linked to cognitive impairment and emotional disorders. They mentioned that dietary patterns alter the composition of gut microbiota and influence brain function. The health impacts of Western diet have been analyzed [9]. The authors stated that the mismatch between the ancient physiology of *homo sapiens* and the Western diet and life style underlies many "diseases of civilization". They mentioned that a holistic approach in dietary patterns is required to prevent the so called "diseases of civilization". The impacts of high fat western diets on human health have been reviewed [10]. The authors stated that this type of diets is unhealthy resulting in dysbiosis and fat-driven inflammation. The relation between Med diet and survival rate in a Greek population has been investigated [11]. The authors conducted an investigation, for 44 months, involving 22,043 people with different nutritional patterns. They stated that their findings indicated that adherence to traditional Med diet was associated with a significant reduction in total mortality. The health improvement in young people following the implementation of a multidisciplinary intervention program has been explored [12]. The authors stated that the realization of the program had positive cardiometabolic and psychosocial health impacts on patients. The impacts of Med diet on global challenges have been analyzed [13]. The author stated that Med diet helps in treating obesity and malnutrition while it contributes positively in climate change mitigation and in the achievement of the 17 Sustainable Development Goals of UN. The role of water in transforming food systems has been studied [14]. The authors stated that United Nations (UN) are trying to transform food systems towards

sustainability. They mentioned that water is essential in food systems while climate change affects the water availability and their function to food systems. The food-energy-water nexus in United Kingdom's (UK) vegetable sector has been studied [15]. The authors stated that nearly 11 million tones vegetables are consumed annually in UK while almost 40% of them are imported from water-stressed countries. wastewater consumption in vegetables' production has been estimated [16]. The authors stated that water use in vegetables' The water and production should be controlled due to limited water availability. They also mentioned that water consumption in vegetables' processing plants varies in the range of 1.5 l/kg to 5.0 l/kg. The land and water usage in beef production systems has been evaluated [17]. The authors using published data compared the use of land and water in four beef production systems. They stated the beef production can be achieved with low land and water consumption without harming valuable natural resources. The use of water in fruit trees and vines has been examined [18]. The authors stated that due to water scarcity orchards and vineyards are subjected to periodic droughts. They mentioned that in most countries' health-related concerns have increased the consumption of fruits and vegetables. The factors affecting the water footprint of crops focusing on Gaza strip, Palestine have been analyzed [19]. The authors examined the use of blue and green water in nine basic crops cultivated in Gaza strip. The yield and water productivity of eight vegetables with limited irrigation have been evaluated [20]. The authors stated that due to declining water resources worldwide water restrictions are inevitable. They mentioned that sharp decrease in irrigation has adverse impacts on vegetable yields. The changes in blue and green water consumption in 46 agricultural crops located near the equator have been estimated [21]. The authors estimated the total water consumption at 6,668 km<sup>3</sup> including 5,588 km<sup>3</sup> green water and 1,080 km<sup>3</sup> blue water. The WF of beef and dairy cattle production in Karditsa, Greece has been estimated [22]. The authors estimated the WF for beef production for intense production systems at 90,535 l/kg (88% gray, 9% green and 3% blue), while for semi-intense production systems at 82,027 l/kg (84% gray, 12% green and 4% blue). For dairy cows the total WF was estimated at 2,750 l/kg milk (81% gray, 14% green and 5% blue). The WF related with diet focused on Italy has been analyzed [23]. The authors used the Med diet as a benchmark stating that by adopting slight changes in the consumption of certain categories of foods it is possible to reduce the WF of diets. They estimated that the WF of the real Italian diet is at 3,076.76 l/person day, compared to 1,570.07 l/person day for the Italian Med diet. The water consumption and the wastewater production in a slaughterhouse have been calculated [24]. The authors estimated that the water consumption was at 1,114 l/animal while the wastewater production was between 916 l/animal to 1,089 l/animal. The water use of selected indigenous grain legumes in South Africa has been estimated [25]. The authors stated that the lowest WF of three legumes studied was in the range of 1,000 l/kg to 1,333 l/kg. The water efficiency in grain legumes has been examined [26]. The authors stated that securing enough water resources for crops' production is becoming more difficult due to climate change. They mentioned that improvement of crops' yields with less water requires the development of water efficient crops' varieties and adoption of integrated management practices. Several

strategies regarding water use in grain legumes have been explored [27]. The authors stated that the yields of grain legumes are constrained by water availability while it is crucial to understand traits influencing water's uptake. They mentioned that global comparisons reveal that water use in different grain legumes is very similar. The carbon assimilation and the efficiency in water use of six food legumes in Malkerns, Eswatini have been estimated [28]. The authors stated that legumes with high photosynthetic rates exhibit high efficiency in water use and vice-versa. The nutrition outcome per unit of water consumed of selected grain legumes has been studied [29]. The authors stated that groundnuts and dry beans had the highest nutritional water productivity. The Med diet and its health benefits have been explored [30]. Med diet is characterized by high intake of vegetables, legumes, fruits, nuts, grains, fish, fish food, virgin olive oil and moderate intake of red wine. The authors stated that existing research indicates that adherence to Med diet results in many health benefits. The Med diet has been studied [31]. The authors tried to develop a definition for Med diet as well as its nutritional status reviewing several existing studies. They stated that Med diet contains around 9,300 kJ, 37% as total fat, 18% as monosaturated, 9% as saturated and 33 gr of fibers per day. The microbiome connections and the cardiovascular health of Med diet have been studied [32]. The authors stated that Med diet helps in preventing various deceases while it is not clear whether its benefits are due to individual components or as a whole. They mentioned that Med diet has positive impacts on intestinal microbiota. Several water-resilient cereal crops have been examined [33]. The authors stated that the wild ancestors can be stress-resilient compared to present species. They mentioned that development of water-stress resilient crop species is necessary to cope with the current climate change and the lower water availability. The use of water in winter cereals' production has been studied [34]. The authors estimated the water use in several cereals including: a) wheat at 1.5-2.0 l/kg, b) winter barley at 0.8-1.4 l/kg, and c) winter oat at 0.5-0.8 l/kg. The WF in cereals in Tunisia has been evaluated [35]. The authors stated that globally the WF of cereals is in the range of 1,080 l/kg to 1,220 l/kg. They also stated that in dry years the importance of blue WF in cereal crops is increased. The performance of summer cereals under limited water inputs has been analyzed [36]. The authors evaluated three cereals including maize, millet and sorghum stating that sorghum was the most water-efficient crop. The wastewater and grey water footprint of olive oil production in Northwest Argentina have been estimated [37]. The authors studied two olive mills stating that the total WF in those olive mills was at 8.69 and 45.5 liters of water per liter of olive oil. The WF in olive oil production in Spain has been evaluated [38]. The authors stated that the average green WF was in the range of 8,253 l/l to 13,468 l/l in rainfed olive groves, 1,428 l/l to 3,002 l/l blue WF and 712 l/l to 1,509 l/l grey WF. They mentioned that the share of different components in total WF was 83% green water, 7% blue water and 10% grey water. The WF of raw milk production on a dairy farm has been estimated [39]. The authors stated that the average WF was at 1,112.3 l of water per l of milk. The WF of a dairy milk processing industry in India has been calculated [40]. The authors stated that the total WF, accounting for both direct and indirect water consumption, was at 9 l per l of milk processed. The blue WF of milk production in Germany has been evaluated [41].

The authors estimated the blue WF at around 3.9 l per l of milk produced. The parallel improvement of psychosocial and cardiometabolic health of obese young people following an intervention program have been studied [42]. The authors stated that following for one year a multidisciplinary personal intervention program the health of the patients was improved. The global impacts of western diets and their effect on metabolism and health have been explored [43]. The authors highlighted the undesired and harmful impacts of western diets on metabolism, inflammation, antioxidant status, cardiovascular and mental health as well as cancer. The cost of Med and Western-type diet in Spain has been compared [44]. The authors stated that Med diet is more expensive than Western diet. This economic barrier might affect consumers to choose the Western diet instead of the healthy Med dietary pattern. The cost of Med diet has been analyzed [45]. The authors stated that Mediterranean societies choose the Western dietary pattern instead of the traditional Med diet. They mentioned that possible causes of this change might be the increasing prices in some food items of Med diet. Therefore, the higher cost might be the decisive factor that consumers choose the Western dietary pattern instead of the traditional healthy Med diet.

### 3. The Mediterranean diet

The Med Diet is widely recognized as one of the healthiest dietary patterns in the world. It is inspired by the traditional eating habits of people living in countries around the Med Sea, such as Greece, Italy, and Spain. This diet focuses on fresh, natural foods and balanced eating habits that support long-term health and well-being. One of the most important ingredients of the Med diet is olive oil, which is the main source of fat. Olive oil is rich in healthy monounsaturated fats and antioxidants that help reduce inflammation and support heart health. Instead of using butter or processed oils, Med cooking relies heavily on olive oil for cooking, dressing salads, and flavoring dishes. Another key component of this diet is the high consumption of plant-based foods. These include fruits, vegetables, legumes, nuts, and whole grains. Foods such as lentils, chickpeas, and tomatoes are commonly used in Med meals. These ingredients provide important nutrients, including fiber, vitamins, and minerals that help maintain a healthy body. Seafood is also an important part of the Med diet. Fish such as salmon, sardines, and tuna are eaten regularly because they are rich in omega-3 fatty acids. These healthy fats are known to support brain function and reduce the risk of heart disease. In contrast, red meat is eaten less frequently and usually in smaller portions. Another characteristic of the Med diet is the moderate consumption of dairy products, mainly in the form of yogurt and cheese. These foods provide calcium and protein that are essential for strong bones and overall health. Meals are often accompanied by herbs, garlic, and spices, which enhance flavor without the need for excessive salt. The health benefits of the Med diet are well supported by scientific research. Studies show that following this diet can lower the risk of heart disease, improve cholesterol levels, and help maintain a healthy weight. It may also reduce the risk of chronic illnesses such as Type 2 Diabetes and Alzheimer's disease. Therefore, the Med diet promotes a balanced and nutritious way of eating that focuses on fresh ingredients and healthy fats. By emphasizing fruits, vegetables, fish, whole grains, and olive oil, it supports both physical health and long-term well-

being. For these reasons, it is often recommended by nutrition experts as a sustainable and healthy lifestyle choice. The main ingredients of Med Diet are presented in Table 1 while the global average water footprint of several crops in Table 2.

**Table 1:** Main ingredients of Mediterranean diet

|    |                                       |
|----|---------------------------------------|
| 1  | Vegetables                            |
| 2  | Legumes                               |
| 3  | Fruits                                |
| 4  | Nuts                                  |
| 5  | Grains                                |
| 6  | Fish and seafood                      |
| 7  | Olive oil                             |
| 8  | Moderate intake of poultry and eggs   |
| 9  | Moderate intake of low-fat dairy food |
| 10 | Moderate intake of red wine           |

Source: [30, 31]

**Table 2:** Global average water footprint of several crops

| Type of crop | Total water footprint (l/kg) |
|--------------|------------------------------|
| Sugar crops  | 200                          |
| Vegetables   | 300                          |
| Roots        | 400                          |
| Fruits       | 1,000                        |
| Cereals      | 1,600                        |
| Oil crops    | 2,400                        |
| pulses       | 4,000                        |

Source: [1]

#### 4. The Western-type diet

The Western diet refers to the eating patterns commonly found in industrialized countries, especially in places such as United States, Canada, and parts of Western Europe. This dietary pattern has become increasingly widespread due to globalization, urban lifestyles, and the popularity of fast food and processed products. Although convenient and often inexpensive, the Western diet is often associated with several negative health effects. One of the main characteristics of the Western diet is the high consumption of processed and fast foods. Meals often include foods such as hamburger, French fries, and pizza. These foods are typically high in calories, saturated fats, and salt. In addition, sugary products like soft drink, donut, and ice cream are commonly consumed as snacks or desserts. Because of their high sugar and fat content, these foods can contribute to weight gain when eaten regularly. Another key component of the Western diet is the high intake of red and processed meats. Foods such as bacon, sausage, and hot dog are frequently included in meals. While these foods can provide protein, they are also rich in saturated fats and preservatives, which may negatively affect health when consumed in large amounts. Refined grains are also common in Western eating habits. Products made from refined flour, such as white bread and pasta, are widely consumed. Unlike whole grains, refined grains have lost much of their fiber and nutrients during processing. As a result, they may contribute to rapid increases in blood sugar levels. The health effects of the Western diet have been widely studied. A diet high in processed foods, sugars, and unhealthy fats is associated with an increased risk of chronic diseases. These include obesity, type 2 diabetes, and cardiovascular disease. In addition, excessive salt intake may raise blood pressure and increase the risk of heart problems. Therefore, the Western diet is characterized by

high consumption of processed foods, red meats, refined grains, and sugary products. While it offers convenience and variety, its nutritional quality is often lower than other dietary patterns. For this reason, health experts often recommend reducing processed foods and increasing the intake of fresh fruits, vegetables, and whole grains in order to support better long-term health. The main ingredients of Western diets are presented in Table 3 while the water footprint of several animal products in Table 4. The main diseases related with Western type diets are presented in Table 5.

**Table 3:** Main ingredients of Western-type diets

|   |                         |
|---|-------------------------|
| 1 | Red meat                |
| 2 | Processed meat          |
| 3 | Fried food              |
| 4 | Prefabricated meals     |
| 5 | Candies                 |
| 6 | Refined cereals         |
| 7 | High-fat dairy products |
| 8 | High-sugar beverages    |

Source: [7, 43]

**Table 4:** The water footprint of several animal products

| Animal and animal product | Total water footprint (l/kg) |
|---------------------------|------------------------------|
| Beef                      | 15,415                       |
| Sheep                     | 10,411                       |
| Goat                      | 5,521                        |
| Pig                       | 5,988                        |
| Chicken                   | 4,325                        |
| Egg                       | 3,265                        |
| Milk                      | 1,021                        |
| Butter                    | 5,553                        |
| Cheese                    | 5,060                        |

Source: [2]

**Table 5:** Main diseases related with Western-type diets

|   |                        |
|---|------------------------|
| 1 | Obesity                |
| 2 | Type 2 diabetes        |
| 3 | Cardiovascular disease |
| 4 | Several cancers        |
| 5 | Hyperlipidemia         |
| 6 | Oxidative stress       |
| 7 | Systemic inflammation  |
| 8 | Metabolic disorders    |
| 9 | Mental disorders       |

Source: Several authors

#### 5. The concept of water footprint

The concept of the water footprint has become an important tool for assessing sustainability and understanding how human activities affect global water resources. Introduced in the early 2000s, the water footprint measures the total amount of freshwater used to produce goods and services. This concept helps researchers, governments, and companies evaluate how efficiently water is used and how consumption patterns influence environmental sustainability. The water footprint considers the direct and indirect use of water. Direct water use refers to the water people use in their daily lives for drinking, cooking, and cleaning. Indirect water use, often called “virtual water or embedded water” refers to the water required to produce food, clothing, and other products. For example, agricultural products such as beef, rice, and cotton require large amounts of water during their production processes. By calculating

these values, the water footprint reveals how consumption choices can affect water resources. A key advantage of the water footprint is that it divides water use into three categories: blue, green, and grey water. Blue water refers to surface and groundwater used in irrigation, industry, and households. Green water represents rainwater stored in soil that is used by plants, especially in agriculture. Grey water indicates the amount of water required to dilute pollutants to safe levels. Together, these categories provide a comprehensive picture of how water is used and polluted during production processes. The water footprint is widely used in sustainability assessments because it helps identify areas where water resources are under pressure. In regions with limited freshwater availability, such as Middle East, Med basin and North Africa, understanding water use is essential for managing resources effectively. By analyzing the water footprint of agricultural products, industries, or even entire countries, policymakers can design strategies to reduce water waste and promote more sustainable production. Furthermore, the concept is supported and promoted by organizations such as the Water Footprint Network, which develops methods and tools for measuring and reducing water use. Many companies now analyze their water footprint to improve efficiency, reduce environmental impacts, and meet sustainability goals. However, the water footprint approach also has limitations. Critics argue that it may oversimplify complex water systems and may not always account for local environmental conditions or water availability. Despite these limitations, it remains a valuable indicator for highlighting the hidden water use behind everyday products. Therefore, the water footprint is a useful framework for assessing sustainability and raising awareness about global water consumption. By examining how much water is used to produce goods and services, it encourages more responsible consumption and supports better water management strategies for a sustainable future. The categories of water footprint are presented in Table 6.

**Table 6:** Categories of water resources

| S. No | Type of water       | Explanation   |
|-------|---------------------|---|
| 1     | Green               | Green water represents rainwater stored in soil that is used by plants, especially in agriculture |
| 2     | Blue                | Blue water refers to surface and groundwater used in irrigation, industry and households          |
| 3     | Grey                | Grey water indicates the amount of water required to dilute pollutants to safe levels             |
| 4     | Total               | The sum of green, blue and grey water   |
| 5     | Virtual or embedded | The total volume of fresh water used to produce foodstuff during the entire supply chain          |

Source: Own estimations

**6. The water footprint of various foodstuffs included in Mediterranean diet**

The Med diet, widely recognized for its health and environmental benefits, is based on staple ingredients such as olive oil, fruits, vegetables, cereals, legumes, and moderate amounts of fish, poultry and dairy. However, behind these foods lies an often-overlooked environmental dimension: their water footprint. Green water is the dominant component in most Med crops, particularly olives, wheat, and many fruits and vegetables. For example, olive trees, a cornerstone of the Med diet, rely heavily on rainfall

in traditional farming systems. Similarly, cereals such as wheat and barley are largely rain-fed, especially in Med climates. Because green water does not require irrigation infrastructure, it is generally considered the least environmentally disruptive form of water use, provided land management is sustainable. Blue water becomes particularly important in regions where rainfall is insufficient or irregular. Crops such as vegetables, citrus fruits, and almonds often require supplemental irrigation, especially in drier Med areas. Blue water use can place significant pressure on rivers, lakes, and aquifers, especially when extraction exceeds natural replenishment rates. For instance, intensive irrigation for fruit and vegetable production can lead to water scarcity, particularly in southern Med regions where water resources are already limited. Grey water includes runoff containing fertilizers, pesticides, and other agricultural chemicals. In Med agriculture, grey water is associated with both crop cultivation and livestock production. For example, the use of nitrogen-based fertilizers in cereal and vegetable farming contributes to water pollution, increasing the grey water footprint. Similarly, dairy products—though consumed in moderate amounts in the Med diet—have a relatively high grey water footprint due to feed production and waste management. When examining the main ingredients of the Med diet, plant-based foods generally have a lower total water footprint compared to animal-based products, especially when considering blue and grey water components. Legumes, such as lentils and chickpeas, are particularly efficient, often relying mostly on green water while also improving soil fertility, thereby reducing the need for synthetic fertilizers and lowering grey water impacts. In contrast, dairy and fish can have more complex water footprints. While fish may have a relatively low direct freshwater use, aquaculture systems can contribute to grey water pollution if not properly managed. Overall, the Med diet aligns well with sustainable water use principles, primarily due to its emphasis on rain-fed crops and limited reliance on water-intensive animal products. However, increasing demand, climate change, and shifts toward more irrigated agriculture could alter this balance. Understanding the distinctions between green, blue, and grey water is essential for improving agricultural practices and ensuring that the Med diet remains both healthy and environmentally sustainable in the long term. The water footprint of two diets in industrialized countries is different. The shift from western diet to Med diet can substantially decrease the water footprint. The water footprint of two different diets in industrialized countries is presented in Table 7.

**Table 7:** The water footprint of two different diets in industrialized countries

|                    | Meat-based diet          | Meat-based diet         | Vegetable-based diet     | Vegetable-based diet    |
|--------------------|--------------------------|-------------------------|--------------------------|-------------------------|
|                    | Energy intake (Kcal/day) | Water footprint (l/day) | Energy intake (Kcal/day) | Water footprint (l/day) |
| Animal origin      | 950                      | 2,375                   | 300                      | 750                     |
| Vegetable's origin | 2,450                    | 1,225                   | 3,100                    | 1,550                   |
| Total              | 3,400                    | 3,600                   | 3,400                    | 2,300                   |

Source: [5]

### 7. The water footprint in various foodstuffs included in Western-type diets

The Western diet—characterized by high consumption of red and processed meats, refined cereals, high-fat dairy products, sugary beverages, and ultra-processed foods—has a substantial environmental impact, particularly in terms of its water footprint. A large portion of green water is indirectly embedded in animal products, especially red meat. Livestock consume feed crops such as maize and soy, which are often rain-fed. As a result, a significant share of the water footprint of beef and dairy originates from green water. However, despite being “natural,” this large consumption reflects inefficiencies in converting plant-based calories into animal-based foods. In Western food systems, blue water plays a crucial role in the production of feed crops, processed foods, and beverages. Irrigated agriculture for animal feed, sugar crops, and refined grains places pressure on freshwater resources. Additionally, food processing industries—such as meatpacking, dairy processing, and beverage manufacturing—consume significant quantities of blue water. Sugary beverages, for instance, may appear water-light at first glance, but their production (including sugar cultivation and bottling processes) relies heavily on irrigation and industrial water use. Grey water component is particularly significant in the Western diet. Intensive livestock farming produces manure, antibiotics, and other waste that can contaminate water bodies. Similarly, the heavy use of fertilizers and pesticides in feed crop production contributes to nutrient runoff, increasing the grey water footprint. Processed and ultra-

processed foods also contribute indirectly through industrial effluents generated during manufacturing. Thus, the Western diet is associated not only with high water consumption but also with considerable water pollution. Among the main foodstuffs, red meat stands out as the most water-intensive, with a large total WF dominated by green water but also substantial grey water due to pollution from feed production and livestock waste. Processed meats further increase the grey and blue components because of additional industrial processing steps. High-fat dairy products, such as cheese and butter, also have high water footprints, reflecting both feed requirements and processing demands. Fried foods and prefabricated (ready-made) meals accumulate water use across multiple ingredients and industrial stages, often increasing both blue and grey water footprints. Refined cereals and sugary products, including candies and beverages, may have lower total water footprints per kilogram compared to meat, but their reliance on irrigation and agrochemicals can raise their blue and grey water shares. Moreover, their high level of processing adds an additional layer of water use not present in whole foods. Overall, the Western diet exerts considerable pressure on global freshwater resources. Its heavy reliance on animal products and processed foods leads to high total water footprints and disproportionately large grey water impacts. Shifting toward less resource-intensive foods and reducing ultra-processed consumption could significantly improve water sustainability. The global-average water footprint of crops and animal products is presented in Table 8.

**Table 8:** The global-average water footprint of crops and animal products

|    | Food item           | Green water footprint (l/kg) | Green water footprint (%) | Blue water footprint (l/kg) | Blue water footprint (%) | Grey water footprint (l/kg) | Grey water footprint (%) | Total water footprint (l/kg) | Total water footprint (l/kcal) |
|----|---------------------|------------------------------|---------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|------------------------------|--------------------------------|
| 1  | Sugar crops         | 130                          | 65.99                     | 52                          | 26.40                    | 15                          | 7.61                     | 197                          | 0.69                           |
| 2  | Vegetables          | 194                          | 60.25                     | 43                          | 13.35                    | 85                          | 26.40                    | 322                          | 1.34                           |
| 3  | Starchy roots       | 327                          | 84.50                     | 16                          | 4.13                     | 43                          | 11.11                    | 387                          | 0.47                           |
| 4  | Fruits              | 726                          | 75.47                     | 147                         | 15.28                    | 89                          | 9.25                     | 962                          | 2.09                           |
| 5  | Cereals             | 1,232                        | 74.94                     | 228                         | 13.87                    | 184                         | 11.19                    | 1,644                        | 0.51                           |
| 6  | Oil crops           | 2,023                        | 85.58                     | 220                         | 9.31                     | 121                         | 5.12                     | 2,364                        | 0.81                           |
| 7  | Pulses              | 3,180                        | 78.42                     | 141                         | 3.48                     | 734                         | 18.10                    | 4,055                        | 1.19                           |
| 8  | Nuts                | 7,016                        | 77.41                     | 1,367                       | 15.08                    | 680                         | 7.50                     | 9,063                        | 3.63                           |
| 9  | Milk                | 863                          | 84.61                     | 86                          | 8.43                     | 72                          | 7.06                     | 1,020                        | 1.82                           |
| 10 | Eggs                | 2,592                        | 79.39                     | 244                         | 7.47                     | 429                         | 13.14                    | 3,265                        | 2.29                           |
| 11 | Chicken meat        | 3,545                        | 81.97                     | 313                         | 7.24                     | 467                         | 10.80                    | 4,325                        | 3.00                           |
| 12 | Butter              | 4,695                        | 84.55                     | 465                         | 8.37                     | 393                         | 6.56                     | 5,553                        | 0.72                           |
| 13 | Pig meat            | 4,907                        | 81.95                     | 459                         | 7.67                     | 622                         | 10.39                    | 5,988                        | 2.15                           |
| 14 | Sheep and goat meat | 8,253                        | 94.18                     | 457                         | 5.22                     | 53                          | 0.60                     | 8,763                        | 4.25                           |
| 15 | Beef meat           | 14,414                       | 93.51                     | 550                         | 3.57                     | 451                         | 2.93                     | 15,415                       | 10.19                          |

Source: [5]

## 8. Reduction of the water footprint in the island of Crete, Greece due to shifting from Western-type diets to Med diet

The water savings of the population in the island of Crete, Greece assuming a shift from Western dietary patterns to Med diet have been calculated under the following assumptions.

- Population in Crete 624,410 inhabitants (census 2021),
- Average daily reduction in the WF 1,300 l/person due to change in the dietary pattern (table 7),
- Average share of blue and grey water in the total WF 20%.

The calculated daily blue and grey water saving is 162,347 m<sup>3</sup> or 260 l per inhabitant in the island. The daily green WF benefits are 649,388 m<sup>3</sup> or 1,040 l per inhabitant in the island. However, the majority of beef, pork, poultry, pulses, cereals, fruits and other foodstuff are not produced in Crete and are imported in the island. Therefore, a lot of water saving due to the abovementioned dietary changes in the diet patterns in Crete is virtual water embedded in the imported foodstuffs consumed by local residents.

## 9. Discussion

The benefits in water resources derived from the adoption of Med diet instead of Western-type diets focusing in the island of Crete, Greece have been examined. The green, blue and grey water resources related with plant-based and animal-based food production have been analyzed. The existing research indicates that significant water benefits can be derived from a shift in dietary patterns. Although the Western dietary pattern is cheaper and suitable for the dominant lifestyle in Western societies adoption of Med diet results in several health benefits as well as in environmental benefits. Med diet is based on ingredients which have lower water FP than the ingredients dominant in Western type diets. The lower WF of Med diet is important in regions with limited water resources in the current era of climate change. The water-related externalities of Western-type diets should be taken into account in developing appropriate policies promoting the healthy Med diet. The strengths of Med diet, compared to Western diets, are related with better human health and environmental benefits while its weaknesses with higher cost and inconsistency with modern lifestyle. Our estimations regarding the WF of various food ingredients are based on published data. Preliminary estimations regarding the reduction of the water footprint in the island of Crete, Greece due to shifting from Western-type diets to Med diet are also based on published data [5] and should be considered as indicative. Future work should be based on more accurate estimations conducting a multi-criteria analysis regarding the benefits of adopting the traditional Med diet, instead of the unhealthy Western dietary pattern, in the island of Crete.

## 10. Conclusions

The environmental impacts, regarding water resources of Med diet and Western type diets have been examined using published data. Additionally, the water benefits derived from shifting from Western-type diets to Med diets in the island of Crete, Greece have been evaluated.

The main findings can be summarized as follows:

- Green water dominates in plant-based foods (cereals, olive oil, legumes), reflecting reliance on rainfall,
- Blue water is relatively low overall but becomes

important in irrigated crops (fruits, nuts, vegetables),

- Grey water is higher in animal products (eggs, chicken, milk) due to pollution from feed production and waste,
- Olive oil and nuts have high total WF per kg because they are energy-dense products requiring large raw inputs, even though most of their water is green (rain-fed),
- Western-type diets are cheaper than Med diet,
- Med diet has many health benefits compared to Western-type diets. Western dietary patterns have adverse impacts on human health burdening the health system in Western societies,
- The total WF of Med diet is lower than the total WF of Western-type diets,
- The calculated daily blue and grey water saving, due to shifting from Med to Western-type diet in Crete, Greece, is 162,347 m<sup>3</sup> or 260 l per inhabitant in the island, and
- Shift from Western-type diets to Med diet results in significant total water saving.

The health and environmental impacts of Med diet should be highlighted promoting the shift from unhealthy Western dietary patterns to healthy Med diet. Taking into account the environmental and health externalities of Western-type diets some short of financial and nonfinancial public support for the promotion of Med diet should be considered in the near future.

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