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A Preliminary Assessment of the Environmental Sustainability of the Current Italian Dietary Pattern: Water Footprint Related to Food Consumption

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Abstract Sustainable diets concept has recently gained an increased momentum. The sustainability of food systems and diets is not simply related to health concerns as it also involves environmental impacts. The paper aims at analysing the environmental cost of non-adherence to the Mediterranean dietary pattern in Italy from a water footprint perspective. The water footprint of the current Italian food consumption pattern is compared with North American and Scandinavian ones as well as with the proposed food Mediterranean dietary pattern *i.e.* the Mediterranean diet (MD). The paper is mainly based on secondary data from different sources (*e.g.* FAOSTAT; Water Footprint Network). According to FAOSTAT, food supplies in Italy (3649 kcal/capita/day) and the USA (3766 kcal/capita/day) are slightly higher than in Finland (3217 kcal/capita/day). The share of plant-based energy in the diet in Italy (74.2%) and the USA (72.6%) is higher than in Finland (63.5%). The average water footprint of an Italian citizen (1848.29 m^3/capita/year) is 65.5% higher than a Finnish one (1116.69 m^3/capita/year) but 15.9% lower than that of a North American citizen (2198.66 m^3/capita/year). Meat and dairy products represent more than a half of the total water footprint of food supply. The water footprint of the current Italian dietary pattern is 69.9% higher than that of the proposed diet. That's to say that a 100% adherence of the Italian population to the proposed Mediterranean diet from 2006 to 2011, would have allowed an estimated saving of about 152,749 million m^3 of water; corresponding to total freshwater abstraction for about three and half years. Adherence of the Italian population to the Mediterranean dietary pattern can bring about not only significant health benefits but also reduces the food environmental footprint on natural resources especially water consumption.

Keywords: *Italian dietary pattern, Mediterranean diet, environmental sustainability, water footprint, sustainable diets*

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1. Introduction

There is growing evidence on the impact of diet on health, including increased risk of obesity, cardiovascular diseases and cancers, and also of its role as a social indicator [1,2]. However, the sustainability of the food system and food consumption patterns is about more than health concerns as it regards also environmental impact (*e.g.* [3,4]).

Food sector contribution to total greenhouse gas (CO_2, CH_4, N_2O) emissions ranges from 15 to 31%. According to studies carried out by the EU's Environmental Impact of Products (EIPRO), the production and consumption of food accounts for 22-31% of the EU countries' total greenhouse gas (GHG) emissions the so-called food's carbon footprint. The consumption of meat and dairy products is estimated to be responsible for approximately 14% of Europe's overall impact on global warming [5]. Overall agriculture is the largest single source of greenhouse gas emissions in the food chain [6].

The global freshwater resources are subject to increasing pressure in the form of consumptive water use and pollution [7,8]. The increase in water needed to meet the demand for food is a major concern given the growing water scarcity and environmental problems. Already 1.4 billion people live in places where water is physically scarce [9]. The Comprehensive Assessment of Water Management in Agriculture [9] estimated that water demands could double with present production practices by the year 2050. What kind of food is demanded and how much, determine to a large extent how water for agriculture is allocated and used [10].

Food supply directly translates into consumptive water use, that is, how much water is transpired and evaporated from the field during the production of a specific amount of food (*e.g.* [11]). Water requirements for plant and animal food products vary widely [12].

The water footprint (WF) concept is closely linked to the virtual water (VW) concept [13]. The water footprint and virtual water concepts provide the opportunity to link the use of water resources to the consumption of goods [14]. These concepts have been brought into water management science in order to show the importance of consumption patterns and global dimensions in good water governance [15,16].

According to Mekonnen and Hoekstra [17], the global water footprint was 9087 Gm^3/yr in the period 1996-2005 and agricultural production contributes 92% to this total footprint. The total volume of international virtual water flows related to trade in agricultural and industrial products was 2320 Gm^3/yr of which 76% is related to crop products trade (animal products trade contributes 12%). Moreover, the water footprint of the global average consumer was 1385 m^3/yr in the period 1996-2005, of which 92% is related to agricultural products consumption.

Diets are a significant factor in a number of critical sustainability issues such as climate change; public health; social inequality; biodiversity; energy, land and water use; etc. [2]. Sustainable diets are those with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems; culturally acceptable; accessible, economically fair and affordable; nutritionally adequate, safe and healthy, while optimizing natural and human resources [18].

The Mediterranean dietary traditions have been associated historically with good health [19,20,21]. Many other studies provided a strong evidence for a beneficial effect of higher conformity with the Mediterranean dietary pattern on risk of death from all causes, including cardiovascular diseases and cancers [22,23,24,25,26].

The Mediterranean dietary pattern doesn't offer only considerable health benefits but also respects the environment [4,27,28,29,30]. The new Mediterranean diet (MD) pyramid is an innovative new and up-to-date tool for a healthy lifestyle for Mediterranean people, which pays due attention to other issues dealing with production, processing, distribution and consumption of foods, such as seasonality, eco-friendliness, biodiversity and consumption of traditional and local products [31].

Dietary changes such as increasing consumption of vegetables and reducing animal products reduces the environmental footprint and thus the use of natural resources. The adherence of a given population to the MD by getting the food proportions and composition defined in the new Mediterranean Diet pyramid not only influences human health but also the environment [32].

The paper ultimate aim is to assess the environmental cost of non-adherence to the Mediterranean diet in Italy. The main objective of the study is to demonstrate that a greater adherence to Mediterranean diet involves positive implications in terms of a more efficient and sustainable use of natural resources - especially water - through a comparison of the water footprint of the current Italian food consumption pattern with North American and Scandinavian ones as well as with the proposed food Mediterranean dietary pattern *i.e.* Mediterranean diet.

2. Materials and Methods

The methodology used in this paper is similar to that used by Sáez Almendros *et al.* [32] in their analysis of the environmental footprint of the Spanish dietary pattern. The dietary composition of the MD was obtained from the MD pyramid exemplified in the Italian context by the diet proposed by the Italian Institute of Food Science of the La Sapienza University-Rome [33].

The current Italian diet was estimated from two independent data sources: the Italian Food Consumption Survey 2005-2006 carried out by the Italian National Institute of Research for Food and Nutrition [34] and the FAO Food Balance Sheets 2006 [35]. Data regarding the western dietary patterns (WD), exemplified by the U.S.A. and Finland food patterns, were also obtained from the FAO Food balance sheets [35].

Regarding definitions of the WF, the Water Footprint Network's Global Water Footprint Standard is used [36].

The water footprint (WF) is the demand of freshwater resources required to produce goods and services and it represents a measure of human's appropriation of freshwater resources: freshwater appropriation is measured in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time [17]. The water footprint includes the use of blue water (ground and surface water), green water (rain water or moisture stored in soil strata), and grey water [36]. The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards [36].

The water footprint of consumption (WFcons) of a country is defined as the total volume of freshwater that is used to produce the goods consumed by its inhabitants. It is the sum of direct and indirect water use of domestic and foreign water resources through domestic consumption [37].

Water footprints of crops and derived crop products as well as farm animals and animal products - expressed as the average water footprint per ton of commodity per country, weighted based on origin (in m^3/ton) - were obtained from the reports of Mekonnen and Hoekstra [38,39].

3. Results and Discussion

3.1. Comparison of Water Footprints of Food Supply in Italy, the United States and Finland

3.1.1. Characterisation of Food Supplies in Italy, Finland and the USA

The FAOSTAT data [35] show that dairy products are the most consumed food group in Italy, Finland and the USA. However, while cereals represent the second most consumed food group in Italy and Finland, meat products are ranked second in the case of the USA. Vegetables represent the third consumed food group in Italy and USA and alcoholic beverages in the case of Finland (Figure 1).

According to FAOSTAT [35], total food supplies in Italy and the USA are quite similar and slightly higher than in Finland. Moreover, the share of plant-based energy in the diet is also similar in Italy and the USA and about 10% higher than in Finland. Animal fat supply is lower in Italy and the USA than in Finland (Table 1).

According to Vanham *et al.* [14], for a healthy diet in the EU28 (EU27 and Croatia), the intake of some product groups should be reduced (sugar, crop oils, meat and animal fats) and that of other product groups increased (vegetables and fruit).

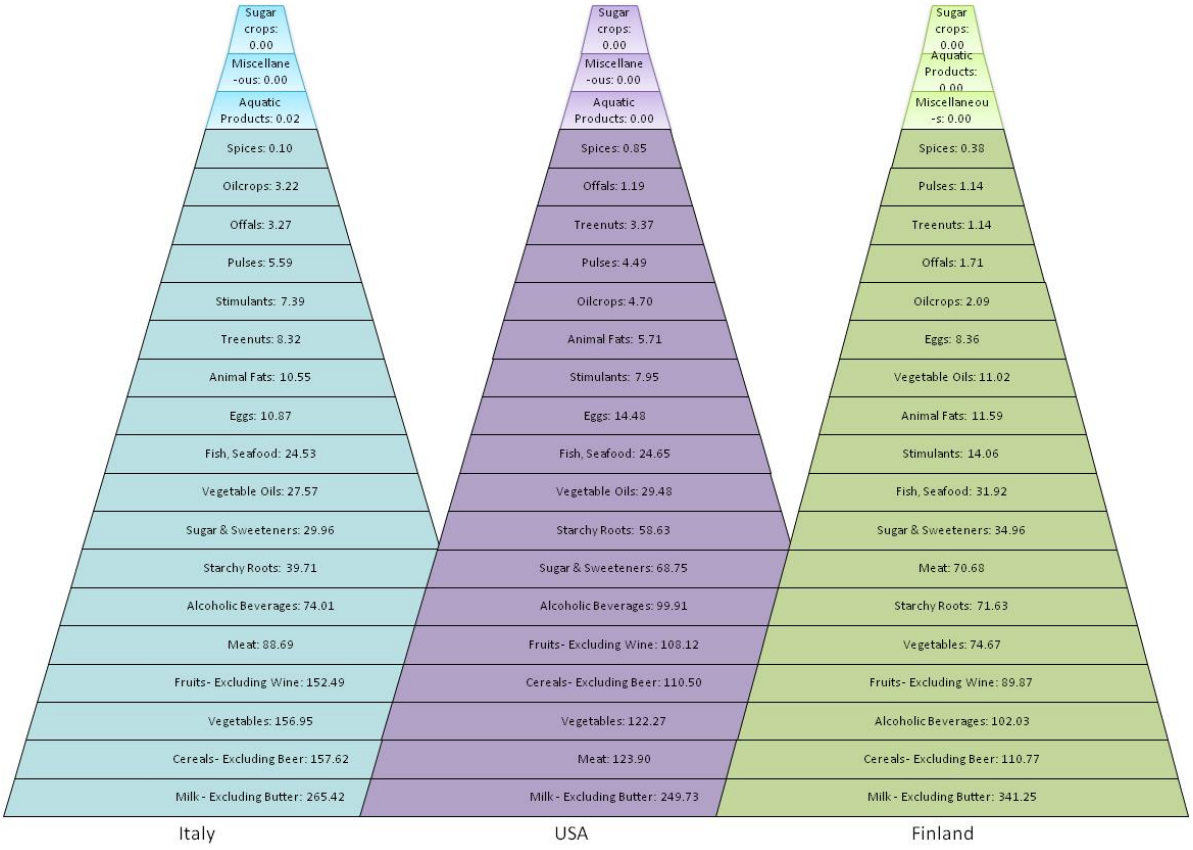


Figure 1. Food supply pyramids in Italy, the USA and Finland during 2006 (kg/year/capita) [35]

Table 1. Total, vegetal and animal foods and fat and protein supply in Italy, USA and Finland during 2006 [35]

Country	Item	Year	Total Population - Both sexes (1000)	Food supply (kcal/capita/day)	Vegetal and animal Food supply (% of total food supply)	Protein supply quantity (g/capita/day)	Fat supply quantity (g/capita/day)
Italy	Grand Total	2006	58982	3649	-	111.60	158.80
	Vegetal Products			2708	74.2	51.10	88.00
	Animal Products			941	25.8	60.50	70.80
United States of America	Grand Total	2006	305697	3766	-	113.70	160.20
	Vegetal Products			2734	72.6	40.00	89.50
	Animal Products			1032	27.4	73.70	70.80
Finland	Grand Total	2006	5263	3217	-	106.20	129.00
	Vegetal Products			2042	63.5	42.00	29.00
	Animal Products			1176	36.6	64.20	90.00

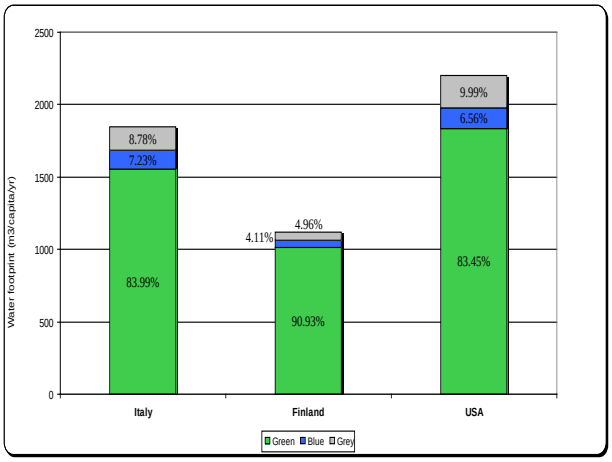
3.2. Water Footprint of Food Supplies in Italy, Finland and the USA

3.2.1. Total Water Footprint of Food Supply

The average water footprint of an Italian citizen (1848.29 m^3/capita/year) is 65.5% higher than a Finnish one (1116.69 m^3/capita/year) but, at the same time, 15.9% lower than that of a North American one (2198.66 m^3/capita/year).

Vanham *et al.* [14] and Vanham and Bidoglio [37] found that the total current EU28 (EU27 and Croatia) water footprint of consumption is 4815 litres per capita per day (lcd) (1757.47 m^3/capita/year). Of the latter 60% is internal and 40% is external to Europe. The WF of agricultural products contributes by far the largest fraction of the total WF, *i.e.* 89% of the water footprint of consumption [37].

In all the three countries the highest water footprint is the green one (83.9, 90.9 and 83.4% in Italy, Finland and the USA, respectively), followed by the grey then the blue one. That is also an indicator of the relevance of agricultural products since there is no green water footprint in the cases of industrial products and domestic water use. However, the shares of the three components of the water footprint changes from a country to another. The highest green water footprint share is recorded in Finland while that of grey water footprint was recorded in the USA. The highest share of the blue water component in the total water footprint is recorded in Italy (Figure 2).



Figurre 2. Green, blue and grey water footprint of food supply in Italy, Finland and the USA; 2006

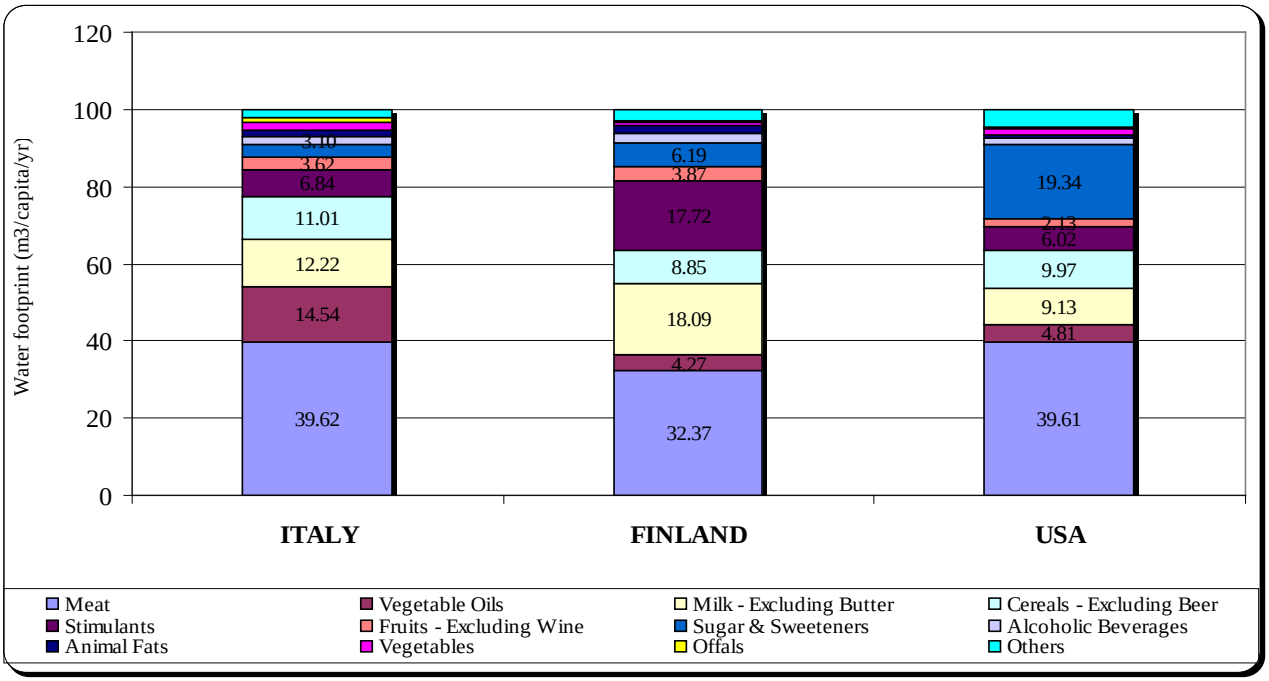


Figure 3. Food product groups contribution to the total water footprint of food supply in Italy, Finland and the USA; 2006

3.2.2. Food Product Groups Contribution to the Total Water Footprint of Food Supply

The meat products group contribution to the total water footprint is the highest in all the three countries. In fact, in Italy, Finland as well as the USA more or less a third of the total water footprint is due to meat products consumption. The contribution of vegetable oils to the water footprint is relevant in Italy but not the case of Finland and the USA. Dairy products are also another important contributor to water use. When considering both meat and dairy products they represent in all the three countries more than a half of the total water footprint of food supply. The contribution of stimulants (*i.e.* coffee, cacao, tea) is particularly relevant in the case of Finland. The same thing is true for sugar and sweeteners in the USA (Figure 3).

Despite the fact that data acquired for some foods vary quite significantly, the classification of the impact of individual foods is nonetheless sufficiently clear: red meat is the food with greatest impact, while fruit and vegetables have a decidedly limited impacts [4,28,29,30,40]. In general, lower is the animal consumption (especially beef meat) lower is the environmental impact. Meat production has high environmental impacts [41,42,43].

The obtained results show that the top ten contributor products to the total water footprint of food supply change from a country to another. In the case of Italy, the top ten

products are, in descending order: bovine meat, milk, olive oil, wheat, pigmeat, coffee, sugar, poultry meat, wine, and cocoa beans.

According to Vanham *et al.* [14] especially the consumption of animal products accounts for high WF amounts. Therefore, the reduction in meat intake contributes most to the WF reduction. Each of the specific WF components (green, blue and grey) shows a reduction similar to the observed reduction in the total water footprint of consumption (WFcons). The reduction in meat intake has the largest impact on the WF reduction, due to the relatively high WF of meat products. But also the reduction in oil and sugar intake has an important impact. According to them, there is even more potential for reducing the WFcons, namely by reducing the consumption of stimulants (especially coffee and cocoa).

Due to the numerous negative impacts of an intensive livestock production system on the planet's resources and ecosystems as well as the growing demands of non-western countries for animal products, moving to a more resource-efficient (and healthier) vegetable-rich diet is a necessity [37].

3.2.3. Relationship between Water Footprint and Dietary Energy

Since meat in particular and animal-based products in general have high environment impacts and vegetal-based diets bring about considerable health benefits, it is generally admitted a convergence between health and environmental impacts.

The relationships between the water footprints of the most important food groups and their contributions to dietary energy in Italy are presented in the following figure (Figure 4). Regarding meat products, their contribution to the total water footprint is almost 40% while they represent just about 10% of the dietary energy. Meanwhile, cereals represent just about 11% of the total water footprint of an Italian citizen while they provide about a third of the dietary energy. That means that in the Italian context, the consumption of cereals allows to have a low water footprint of consumption while meeting the energy intake requirements. Nevertheless, these conclusions cannot be generalised as the water footprints of the different food products change from a country to another.

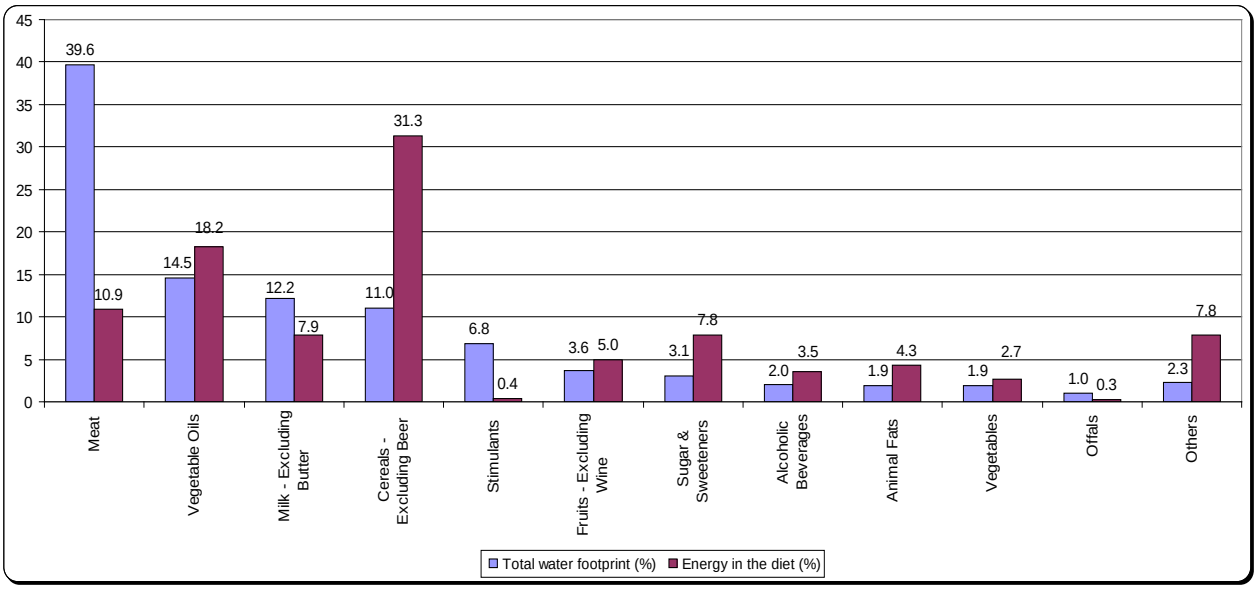


Figure 4. Contribution of different food groups to the total water footprint and dietary energy supply in Italy, 2006

3.3. Environmental Cost of Non-adherence to the Proposed Mediterranean Dietary Pattern in Italy

3.3.1. Food Pyramids of the Proposed and Current Diets in Italy

Comparison of the food consumption pyramids based on the proposed diet and data from the food consumption survey in Italy [34], shows that adult Italians consume much less fruit and vegetables than the recommended intakes and much more meat. The real and effective consumption of milk is similar to the proposed one (Figure 5).

Complete data regarding food consumption regarding the groups of food products as reported in the food consumption survey carried out by the National Institute of Research for Food and Nutrition (INRAN) in 2005-06 are shown in the following table (Table 2).

Table 2. Consumption of food product groups in Italy according to the food consumption survey 2005-2006 (kg/capita/year)

Food group products	Food consumption (Kg/capita/year)
Water & soft drinks	316.82
Cereals and bakery products	95.63
Vegetables	81.03
Fruits	76.29
Milk, derivatives & substitutes	67.89
Meat	41.25
Pulses, fresh and preserved	4.02
Alcoholic beverages & substitutes	39.06
Potatoes	18.25
Oils and fats	15.33
Confectionery (sweet) & substitutes	12.41
Eggs	7.67
Others	56.58

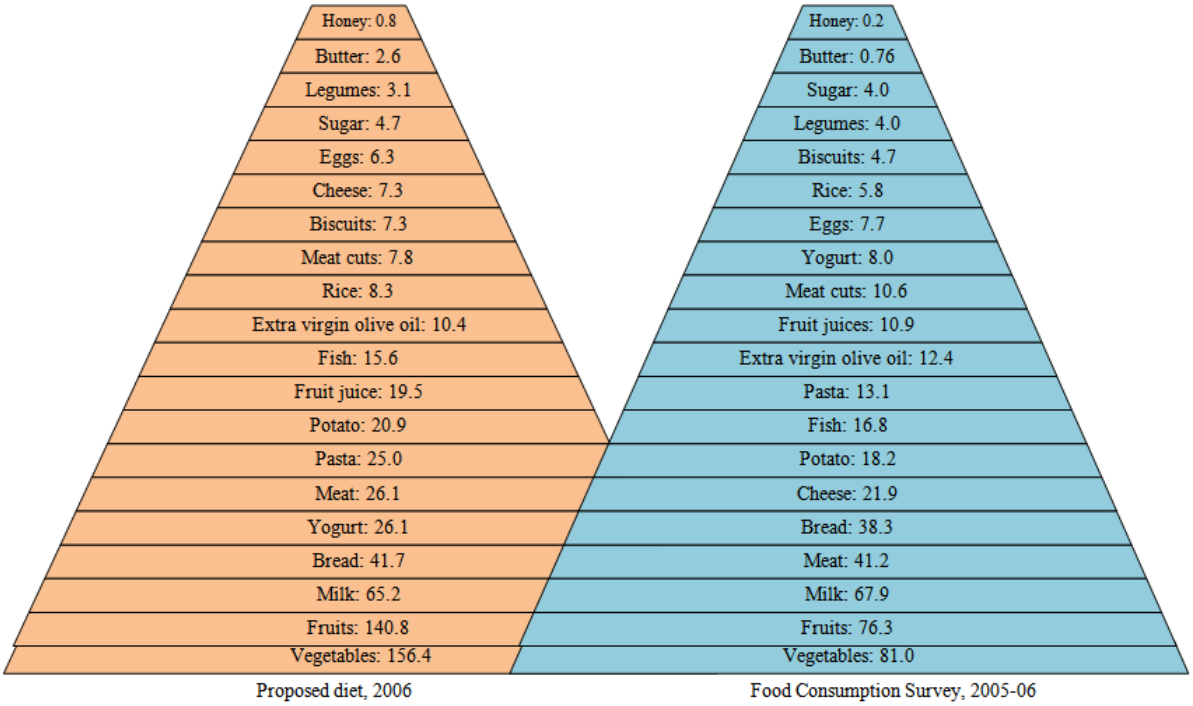


Figure 5. Food pyramids for adults in the Italian context (kg/capita/year): proposed diet by the Italian Institute of Food Science of La Sapienza University (left) and the food consumption survey of the National Institute of Research for Food and Nutrition (INRAN) (right)

3.4. Water Footprint of the Current and Proposed Food Consumption Patterns in Italy

3.4.1. Water Footprint of the Proposed Diet

The total water of the diet proposed by the Italian Institute of Food Science of La Sapienza University is 964.29 m^3/capita/year: 79.10% green; 11.46% blue, and 9.44% grey.

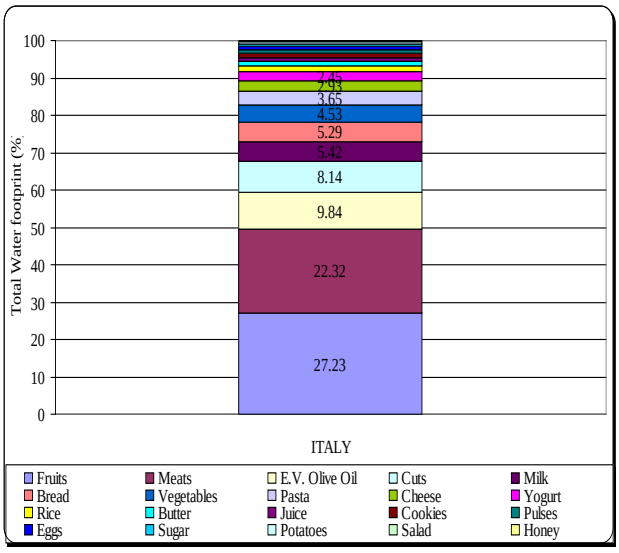


Figure 6. Contribution of different food products to the total water footprint of the proposed diet in Italy

The most relevant contributors to the total water footprint of the proposed diet are fruit and meat. These two food product groups represent almost a half of the total water footprint of the proposed Italian diet. Extra-virgin olive oil, meat cuts, milk and bread represent more than 5% of the total water footprint each. These seven previously mentioned food products represent circa 80% of the proposed diet water footprint (Figure 6).

3.4.2. Water Footprint of the Current Food Consumption Pattern

Contribution of different food product groups to water footprint changes depending on the component that is taken into consideration *i.e.* green, blue or grey (Figure 7). Cereals and bakery products are the most important contributor to the total water footprint. In fact, they contribute more than two fifths to the water footprint of the current Italian food consumption pattern. When cereals and bakery products are combined with pulses they represent more than a half of the total water footprint. Vegetables and fruits - that are the most consumed food groups - contribute less than a fifth to the total water footprint.

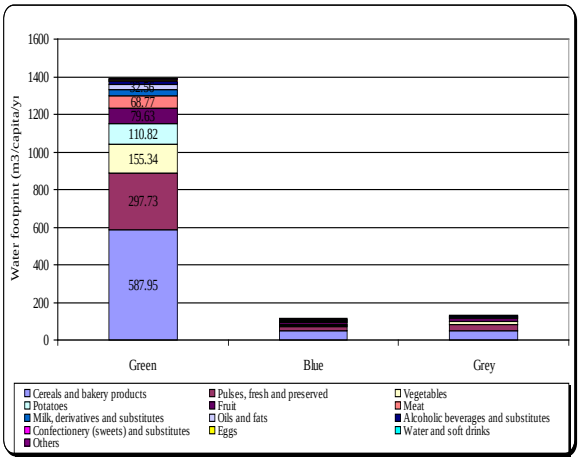


Figure 7. Contribution of different food product groups to the green, blue and grey water footprints of the current food consumption pattern in Italy

3.5. Comparison of the Water Footprints of the Proposed Diet and the Current Food Consumption Pattern in Italy

The water footprint of the current Italian food consumption pattern (1638.30 m^3/capita/year) is 69.9% (*i.e.* 674 m^3/capita/year) higher than that of the proposed diet (964.29 m^3/capita/year) (Figure 8).

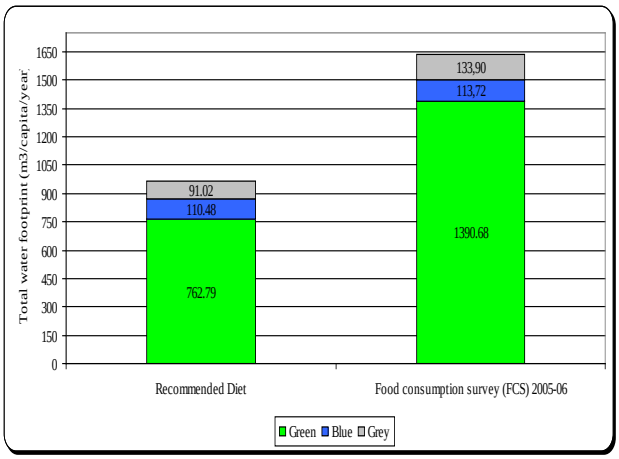


Figure 8. Comparison of the green, blue and grey water footprints of the proposed diet and the current food consumption pattern in Italy

That means that a 100% adherence to the proposed Mediterranean diet for the last 6 years (from 2006 to the end of 2011) would have allowed saving a bit more than 152,749 million m^3 of water (Table 3).

Table 3. Water saving supposing a 100% adherence of the Italian population to the proposed Mediterranean diet during the last 6 years (from 2006 to the end of 2011) in million cubic meters - Mm^3

Years	2006	2007	2008	2009	2010	2011	Total water saving (Mm^3)
Italian adult population (18-64 years) (ISTAT data*)	37,250,394	37,523,477	37,760,955	37,906,233	38,095,091	38,095,091	-
Water saving by the Italian population (Mm^3/year)	25,106.8	25,290.8	25,450.9	25,548.8	25,676.1	25,676.1	152,749.5

- Work hypothesis: It is assumed that the food consumption pattern has not changed meanwhile so that the same annual amount of water is saved per person.

* Population at January 1st was considered that of the previous year. Data referring to January 1st 2011 were considered for 2010 and 2011.

This water saving represents almost 294 times the blue domestic water consumption in Italy in 2005 [17]. In other words the estimated water saving generated thanks to the adherence of the adult Italian population to the proposed Mediterranean diet is enough to cover domestic water consumption in Italy for almost 294 years.

Taking into consideration that the average total abstraction of freshwater in Italy is around 42 km^3/year [44], this water saving represents total water abstraction (including household, industry, agriculture and energy water demands) for more than three and half years.

Vanham *et al.* [14] showed that different EU28 diets – a healthy (DGE), vegetarian (VEG) and combined (COM) diet – as compared to the current average diet (REF) would result in a substantial reduction of the EU28 WFcons for agricultural products. Of the diets analysed, the VEG diet would result in the lowest WFcons. The reduction in meat intake has the largest impact on the WF reduction, due to the high WF per caloric value of meat products.

With traditional water use statistics, awareness campaigns and policy have always focused on increasing water efficiency in domestic and industrial water use. However, much more water can be saved in agricultural production processes, by reducing food waste and by a change in diet [37].

4. Conclusion

Total food supplies in Italy and the USA are quite similar and a bit higher than in Finland. The share of plant-based energy in the diet is also similar in Italy (74.2%) and the USA and about 10% higher than in Finland. Dairy products are the most consumed food group. Comparison of the proposed diet and the current Italian food consumption pattern shows that Italians consume much less fruit and vegetables and much more meat than the proposed intakes [34].

The average water footprint of an Italian citizen is 65.52% higher than a Finnish one but 15.94% lower than that of a North American one. The green component is the most relevant one followed by the grey then the blue ones. Meat and dairy products represent in all the three countries more than a half of the total water footprint of food supply. The top contributors to the total water footprint of food supply in Italy are bovine meat, milk, olive oil, wheat and pigmeat. In Italy, meat products contribution to the total water footprint is almost 40% while they represent just about 10% of the dietary energy. Meanwhile, cereals represent just about 11% of the total water footprint of an Italian citizen while they provide about a third of the dietary energy.

More than a half of the total water footprint of the current food consumption pattern (1638.30 m^3/capita/year) is due to the consumption of cereals and pulses. Vegetables and fruits contribute less than a fifth.

The water footprint of the current Italian diet is 69.9% higher than that of the proposed diet. Adherence of the whole Italian adult population to the proposed diet from 2006 to 2011, would have allowed saving an amount of water that can allow covering total abstraction of freshwater (household, industry, agriculture and energy water demand) in the country for more than three years.

Data availability and calculation limits were the main constraints faced in the course of this work. In fact, one of the problems faced was related to the availability of and/or accessibility to footprints of food products or food product groups. There were also some difficulties regarding the management and processing of data and some simplification was necessary.

This work is intended as a preliminary attempt to get a scientifically-based insight into the environmental sustainability of the current Italian food consumption pattern and the environmental implications of the low adherence of the Italian population to the typical Mediterranean food consumption pattern exemplified by the Mediterranean diet pyramid. Further multidisciplinary research activities and studies are necessary to make a

more precise assessment and to overcome the difficulties faced. Weaknesses regarding precision of the assessment are to a large extent due to that related to the secondary data used and some working hypotheses adopted to make data processing feasible and simpler.

It should be underlined that water footprint values associated with individual foods are absolute. This means that the relationship between water footprint values and nutritional ones of food products was not taken into account, but it would be very useful in view of the integration of different types of indicators (environmental, nutritional, economic and social) for assessing the relative impacts and the overall sustainability of the Italian diet.

It is also important to find a way to make the assessment of the environmental sustainability of the Italian food consumption pattern taking into consideration at the same time all the environmental footprints (*e.g.* water footprint, ecological footprint, carbon footprint, nitrogen footprint). The production of waste is another factor that should be considered for a more accurate assessment of the sustainability of a diet.

As the definition of sustainable diets [18] is quite complex - due to the implications of several factors, not only environmental aspects - it is necessary to follow a multi-step process, analyzing single indicators and trying to identify the links in order not to leave out initially hidden relationships and tradeoffs, and to estimate the weight of the different factors.

Statement of Competing Interests

The authors have no competing interests.

List of Abbreviations

CH_4	Methane;
CO_2	Carbon dioxide;
EIPRO	EU's Environmental Impact of Products;
GHG	Greenhouse gas;
N_2O	Nitrous oxide;
MD	Mediterranean diet;
WD	Western dietary pattern;
WF	Water footprint;
VW	Virtual Water

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