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ECOLOGICAL, CARBON AND WATER FOOTPRINTS OF FOOD PRODUCTION AND CONSUMPTION IN THE MEDITERRANEAN REGION

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Abstract

The Johannesburg Plan of Implementation of the World Summit on Sustainable Development in 2002 calls upon taking action to change unsustainable consumption and production patterns. Consumption is a primary driving force of environmental degradation. Food systems and diets are major players in biodiversity erosion, natural resources and ecosystems degradation, climate change, etc. The aim of this work is to analyse the ecological, carbon and water footprints of the Mediterranean food consumption patterns. Standard impact data from different sources (*e.g.* Water Footprint Network; Barilla Centre; Mekonnen & Hoekstra, 2010; Ewing *et al.*, 2010) were used to calculate and discuss environmental impacts. In general, the ecological deficit in the Mediterranean increased in the period 1961-2007 since the ecological footprint (EF) per capita increased (+47.4%) while the biocapacity decreased (-36.4%). The EF of consumption is generally higher than the EF of production. Furthermore, the carbon footprint alone is generally higher than the biocapacity. Cropland EF is the higher in Mediterranean countries. Some differences in terms of environmental impacts were observed between North Africa, Middle East, the Balkans and the North Mediterranean. Northern Mediterranean countries have a higher water footprint of consumption (2279 m^3/year/capita) compared to the Balkans (1708), North Africa and Middle East (1656). Almost 65% of water in the Mediterranean is used in irrigation. Food consumption has significant impacts on the limited and scarce Mediterranean natural resources therefore the traditional Mediterranean diet should be safeguarded and promoted as a model of sustainable diets and consumption should become central in sustainable development policies.

Key words: Mediterranean; food consumption; footprint; environmental impacts.

Introduction

The World Commission on Environment and Development stated already in 1987 that "*Sustainable development requires changes in values and attitudes towards environment and development*...". Agenda 21 of the Earth Summit in 1992 called upon governments to adopt national strategies for sustainable development. The Johannesburg Plan of Implementation of the World Summit on Sustainable Development (WSSD) in 2002 calls upon all governments to take action to "*change unsustainable patterns of consumption and production*". The efficient and wise use of the earth's resources in order to secure the basic human requirements for existence, the highest quality of life and equitable social and economic development is an essential principle of sustainable and responsible consumption (UNEP, 2010).

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Environmental degradation - whose primary driving forces are population, consumption and technology - has reached in the Mediterranean proportions that require immediate action (UNEP, 2010). There are growing evidence on the impact of diet on health (Reddy *et al*., 2009). However, sustainability of food systems and food consumption is about more than health concerns as it regards also environmental impacts. According to one large European study, food and drink accounts for an estimated 20 to 30% of the environmental impact of all consumption (Carlsson-Kanyama *et al*., 2003). Food systems and 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. (Reddy *et al*., 2009). From this point of view, in the Mediterranean should be addressed many issues (biodiversity loss, soil erosion, water scarcity, etc.) directly or indirectly related to Mediterranean food consumption patterns.

The MD was inscribed, in November 2010, on the Representative List of the Intangible Cultural heritage of UNESCO. The nomination was supported by Italy, Spain, Greece and Morocco but the MD is a common and shared Mediterranean cultural heritage. The food pyramid that reflects Mediterranean dietary pattern has been associated with good health (Willet *et al*., 1995) but also respects the environment. Reclassifying foods on the basis of their negative effect on the environment produces an Environmental Pyramid. When the Environmental Pyramid is brought alongside the Food Pyramid, it creates a Food-Environmental Pyramid called the "Double Pyramid". It shows that those foods with higher recommended consumption levels are also those with lower environmental impact (Barilla Center, 2010).

This paper aims at analysing the ecological, carbon and water footprints of the Mediterranean food consumption patterns.

Material and methods

The paper is mainly based on a literature review. Standard impact data were used to calculate and discuss food consumption environmental impacts. In this paper, environmental impacts refer to the Ecological Footprint (EF), Carbon Footprint (CF) and Water Footprint (WF).

The EF is a method to answer the following research question: How much of the regenerative capacity of the biosphere is occupied by human activities? (Schaefer *et al*., 2006). Biocapacity refers to the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies (GFN, 2011). According to Ewing *et al*. (2010a), EF= Population*Consumption per person* Resource and waste intensity. The calculation methodology of the EF on a national scale was fully explained by Ewing *et al*. (2010a, 2010b). The EF measures appropriated biocapacity, expressed in global average bioproductive hectares, across six major land use types (*i.e.* cropland, grazing land, fishing grounds, forest land, carbon footprint, and built-up land). In order to keep track of both the direct and indirect biocapacity needed to support consumption patterns, the EF methodology uses a consumer-based approach; for each land use type, the EF of consumption (EFC) is thus calculated as: EFC=EFP+EFI-EFE ; where EFP is the EF of production; EFI and EFE are the ecological footprints embodied in imported and exported commodity flows.

The CF is a measure of the exclusive total amount of CO_2 emission directly and indirectly caused by an activity or accumulated over the life stages of a product (Wiedmann & Minx, 2008).

The 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 (Mekonnen & Hoekstra, 2011). The water footprint of a product is similar to what has been called alternatively the 'virtual-water content' of the product or the product's embedded, embodied, exogenous or shadow water (Hoekstra & Chapagain, 2008). 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. 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. The methodology of the global standard for water footprint assessment was developed by the Water Footprint Network. The entire estimate included a breakdown of water footprints, virtual water flows and water savings into their green, blue and grey components (Hoekstra *et al.*, 2011).
Differences in terms of environmental impacts between North Africa (Algeria, Libya, Morocco, Tunisia), Middle East (Egypt, Jordan, Lebanon, Palestine, Syria, Turkey), Balkans (Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia), the North Mediterranean (Cyprus, France, Greece, Italy, Malta, Portugal, Slovenia, Spain), Central & Northern Europe (Austria, Belarus, Belgium, Denmark, Estonia, Finland, Germany, Iceland, Ireland, United Kingdom) and North America (Canada, United States of America) have been analysed.

Results and discussion

The Mediterranean EF of consumption are always higher than the EF of production, except for Serbia. The CF alone is generally higher than the biocapacity, except for Morocco, Tunisia, Albania, Turkey, Bosnia, Croatia and France. In general, the northern Mediterranean countries have a higher EF with respect to North Africa and Middle East ones (Figure 1).

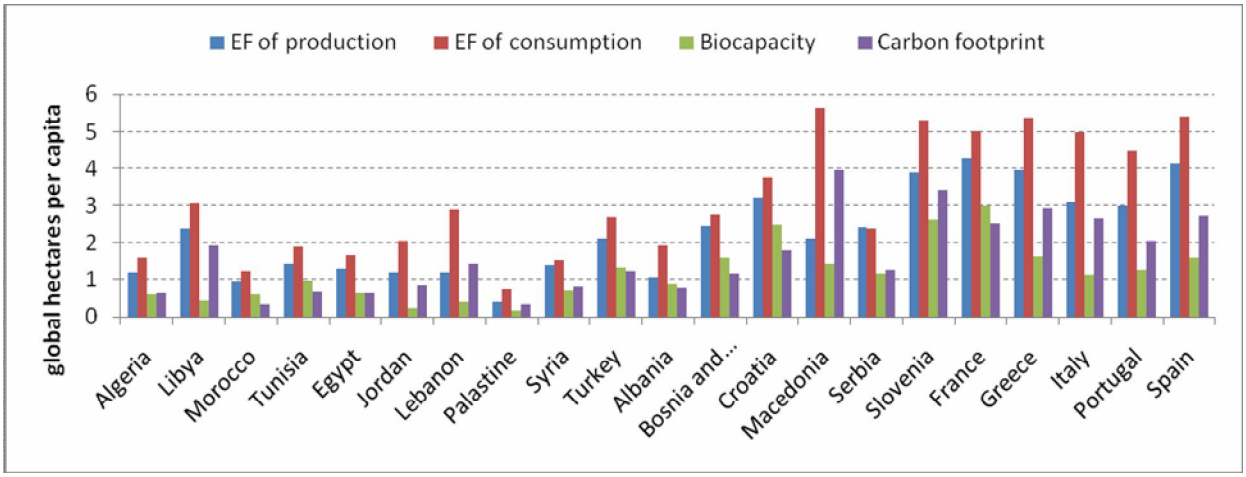

Figure 1. A comparative analysis of EF of production, EF of consumption, Biocapacity, and Carbon footprint in the Mediterranean region (Source: adapted from Ewing *et al.*, 2010a).

Referring to the EF of production, the period needed to regenerate the resources used in the year 2007 in the Mediterranean ranges between 5 years and 5 months in Libya and 1 year and 3 months in Albania. Considering the EF of consumption, the period needed to regenerate the resources consumed ranges between 8 years and 6 months in Jordan and 1 year and 6 months in Croatia. The Mediterranean countries have a net demand on the planet: on average, 2 years and 3 months are needed to regenerate the resources used for production, while 3 years and 4 months are needed to regenerate the resources effectively consumed. Ecological footprints of

production and consumption as well as carbon footprint of North American countries are higher that those recorded in Mediterranean countries even northern ones (Table 1). The EF per capita in the Mediterranean increased in the period 1961-2007 except in Morocco, Jordan and Albania, while the biocapacity decreased. Thus the ecological deficit increased. On average, the EF has increased by 47.4% while the biocapacity decreased by 36.4%.

Table 1. The Mediterranean region in the world: a comparative analysis in terms of EF of production, EF of consumption, Biocapacity, and Carbon footprint in global hectares per capita (Source: adapted from Ewing *et al.*, 2010a).

Geographical areas	EF of production	EF of consumption	Biocapacity	Carbon footprint
North Africa	1.483	1.940	0.655	0.890
Middle East	1.263	1.928	0.573	0.877
North Mediterranean	3.053	4.276	1.708	2.297
Central and northern Europe	4.310	4.680	2.890	2.540
North America	8.390	7.900	4.930	5.420

The cropland EF is the highest in Mediterranean countries (table 2). The average EF in Balkans and North Mediterranean countries is at least 1.5 times the EF of the North Africa and Middle-East.

Table 2. The Mediterranean in the world: a comparative analysis in terms of EF (in global hectares per capita) by land use type (Source: adapted from Ewing *et al.*, 2010a).

Geographical areas	Cropland	Grazing land	Forest land	Fishing grounds	Built-up land
North Africa	0.663	0.183	0.140	0.035	0.025
Middle East	0.657	0.128	0.160	0.038	0.072
North Mediterranean	1.001	0.212	0.408	0.243	0.115
Central and northern Europe	1.060	0.190	0.550	0.220	0.120
North America	1.060	0.150	1.090	0.110	0.070

Overall agriculture is the largest single source of greenhouse gas emissions in the food chain (Carlsson-Kanyama, 1998) with meat and meat products being the largest contributor. The classification of the impact of individual foods is sufficiently clear. Red meat is the food with greatest impact, while fruit and vegetables have a decidedly limited impacts (Barilla Center, 2010). In general, lower is the animal food consumption lower is the environmental impact. The livestock sector is one of the important drivers of deforestation, land degradation, pollution, climate change, erosion and sedimentation of coastal areas, facilitation of alien species invasion, among others (Steinfeld *et al.* , 2006). According to FAO (2009), dietary energy in the Mediterranean ranges from 2,176 in Palestine to 3,694 cal/day/person in Greece. In general, dietary energy is higher in northern Mediterranean countries. The share of plant-based energy in the diet - cereals, vegetable oils (including olive oil), roots and tubers, fruits and pulses - in the Mediterranean is generally higher than 50%; ranging from 80.7% in Egypt to 46.6% in Cyprus. In general, that share is higher than in northern and central Europe and North American (*e.g.* USA). In general, it is higher in eastern and southern Mediterranean countries with respect to northern ones while intermediate values are recorded in the Balkans. The largest share of plant-based energy is derived from cereals (from 21.5% in Spain to 63.7% in Egypt).

In the Mediterranean, water resources are limited and unevenly distributed. Irrigation accounts for almost 65% of anthropogenic abstraction in the Mediterranean. It may even

exceed 80% in the southern and eastern Mediterranean countries. Total water use efficiency ranges between 50 and 85% (Thivet & Blinda, 2007). What kind of food is demanded and how much, determine to a large extent how water for agriculture is allocated and used (Lundqvist *et al*., 2008). Food supply directly translates into consumptive water use. Water requirements for plant and animal products vary widely: approximately 0.5 m^3 of water is needed to produce 1,000 kcal of plant-based food, while some 4 m^3 are required for animal-based food (Falkenmark & Rockström, 2004). The global water footprint was 9087 Gm^3/yr in the period 1996-2005 and agricultural production contributes 92% to this total footprint. Moreover, the water footprint of the global average consumer was 1385 m^3/yr in the same period (Mekonnen & Hoekstra, 2011).

There is a high variation of the WF of consumption between Mediterranean countries, especially in terms of internal and external WF of consumption. In fact, the External WF of consumption varies between 7.3% in Palestine and 85.8% in Jordan (Figure 2). Countries of the north Mediterranean had the highest water footprint of consumption per year and per capita (2279 m^3) compared to North Africa (1892 m^3), Balkans (1708 m^3) and Middle East (1656 m^3).

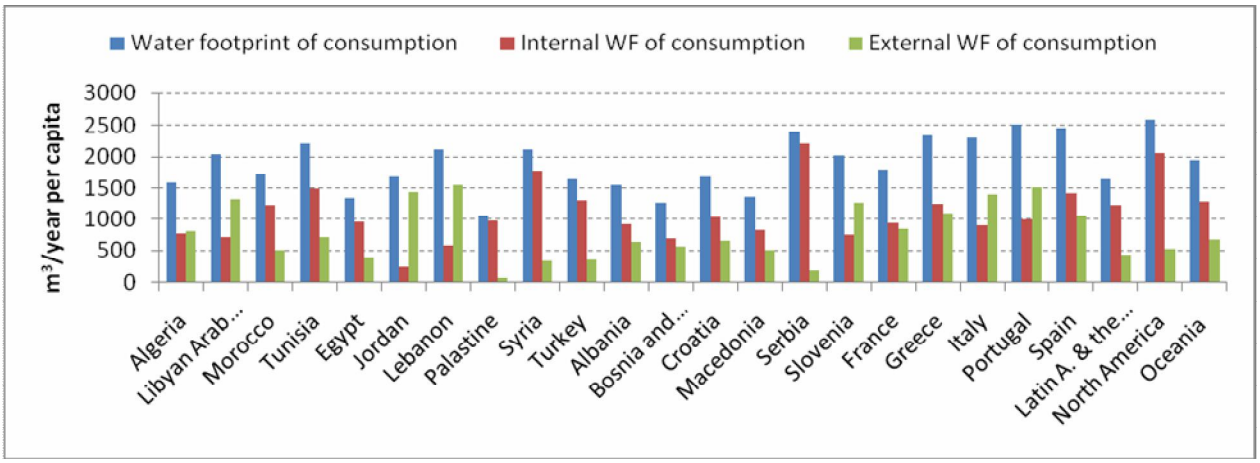

Figure 2. Water footprint of consumption (Source: adapted from Mekonnen & Hoekstra, 2011).

Most of the WF of consumption is due to agricultural products consumption. The average value is about 91% of the total WF of consumption: 96% in North Africa, 93% in Middle East, 82% in Balkans, and 91% in northern Mediterranean (Figure 3).

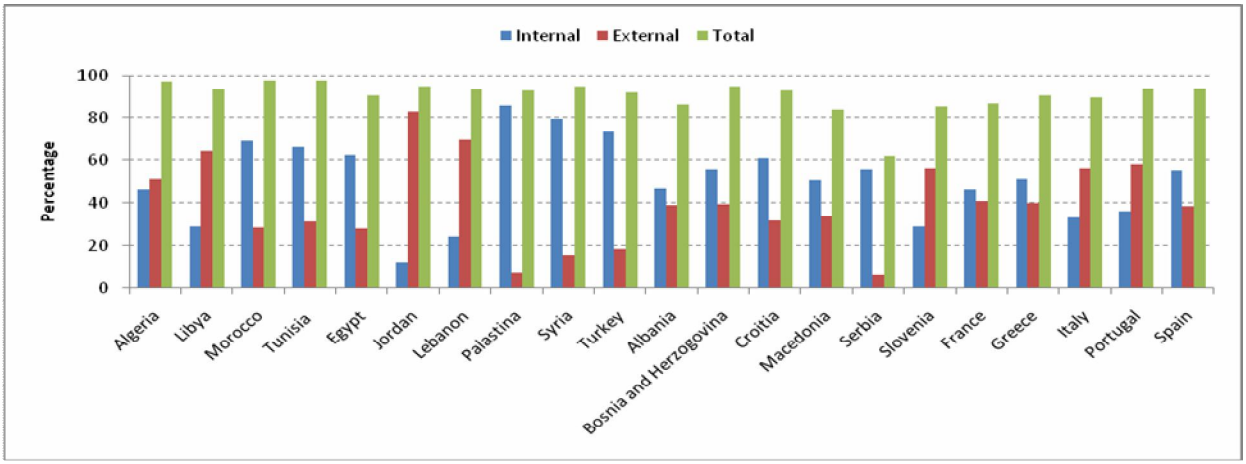

Figure 3. WF of agricultural products consumption (Source: adapted from Mekonnen & Hoekstra, 2011).

Evaluation of the net virtual water flow between the years 1995 and 2005 in Mediterranean countries, carried out by Mekonnen & Hoekstra (2011), showed that only Tunisia, Syria and Serbia present a negative total net virtual water flow. The other Mediterranean countries showed a water saving ranging between 340 in Macedonia and 62157 Mm^3 in Italy. In the Mediterranean region, there was a total water saving of 177168 Mm^3 (including blue, green and grey virtual waters).

Conclusions

The traditional MD offers not only considerable health benefits but it has also lower environmental impacts than Northern Europe and American diets. In fact, by using less meat and animal products, Mediterranean diets reduce environmental impacts of livestock sector on biodiversity and natural resources. In fact, "meat-based diets", as northern ones, have higher environmental impacts (*e.g* water footprint, ecological footprint, carbon footprint) than "plant-based diets", such as Mediterranean ones. Therefore, adopting the Mediterranean dietary pattern means reconciling personal well-being (personal ecology) with the environment (ecological context). The traditional MD could be considered as a model of sustainable diets so actions and measures aiming at MD safeguarding and sustainability should be promoted. Nevertheless, population increase, especially in southern and eastern Mediterranean countries, will increase pressure on the limited and scarce Mediterranean natural resources in particular water. In fact, almost 65% of water in the Mediterranean is used in irrigation. This puts under question also the sustainability of a diet that is based, also, on irrigated crops such as vegetables and fruit. In general, the EF per capita in the Mediterranean in the period 1961-2007 increased (+47.4%) while the biocapacity decreased (-36.4%) causing an increase of the ecological deficit. Furthermore, the carbon footprint is generally higher than the biocapacity. It is necessary to carry out further studies on environmental impacts and sustainability of Mediterranean food consumption patterns taking into consideration foods origins, and production, processing, and distribution systems as well as foods and drinks wastage and waste management.

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