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Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA-IO method

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ABSTRACT

Evaluations of the environmental sustainability of lifestyles and consumption practices have been taking centre stage in European research projects in recent years. Considerable work has been undertaken on the environmental assessment of food consumption patterns, and several analytical tools and methodologies have been proposed to quantify the environmental burden of production and consumption. Claims have been made in several international reports that the Mediterranean diet offers the best consumption pattern in terms of both the environment and health, but there has never been a specific assessment of the Mediterranean diet in comparison with other food consumption behaviours.

This paper explores the environmental burdens of the Mediterranean diet applied in the Italian context. The environmental performance of this diet is compared to the national average diet in Italy, as well as to two empirical scenarios of healthy and vegetarian food consumption patterns.

The environmental burdens of the different diets are assessed in terms of their energy consumption and their carbon footprint using a hybrid IOA-LCA method. This method considers the positive aspects of both bottom-up methodologies (e.g. life cycle assessment – LCA) and top-down methodologies (e.g. input–output analysis – IOA).

The results allow several comparisons to be made between the different diets. When compared with the national average diet, the Mediterranean diet reveals an improvement in environmental performance of 95.75 MJ (2.44%) and 27.46 kg CO_2 equivalent (6.81%) per family. The best overall environmental performance can be found with the vegetarian diet in which energy consumption is 3.14% lower and the carbon footprint 12.7% lower than the national average diet.

1. Introduction

Food consumption is considered one of the main contributors to a household's environmental burden. Indeed, according to a recent literature review (Hertwich, 2011) regarding the environmental impacts of consumption, the residential sector accounts for 35–53% of total energy use, mobility – including fuel use, vehicle purchase and public transportation 15–31%, food 11–19%, recreation 4–10%, clothing 3–5%, and health 1–5%. It should be noted that in this review the energy use for some food consumed in restaurants, hotels, on package tours or in educational and healthcare institutions has not been allocated to the food category but is listed under other, recreation, transportation or government consumption.

Taking greenhouse gas (GHG) emissions from household consumption into account, comprehensive research was undertaken in 2006 across Europe 25 (Tukker and Jansen, 2008). In this study, 31% of GHG emissions are from food, beverages, tobacco and narcotics, 2% from clothing and footwear, 24% from housing, furniture, equipment and utility use, 2% from health, 19% from transport, 2% from communication, 6% from education, 9% from restaurants and hotels and 5% from other goods and services.

1.1. The Mediterranean diet

Among general statistics regarding household impacts, the focus of this work is food consumption. To make a comprehensive

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analysis, a diet (beginning by the Mediterranean one) has been chosen as patterns of goods to analyse.

Several studies have been conducted into the origins and the meaning of the Mediterranean diet. In general terms it should not be referred to as a single dietary prescription, but rather as a variety of plant-based food patterns obtained from a heritage of exchanges over millennia among the peoples and cultures of the Mediterranean Basin (Mediterra, 2012). This diet is typical of, above all, people from Italy, Northern Africa, Spain and Greece (Bach-Faig et al., 2011; Dernini et al., 2013).

According to research conducted in the 1960s (Cresta et al., 1969), diets in the Mediterranean area were based more on cereals, vegetables, fruit and fish than on potatoes, meat and dairy foods, eggs and sweets. Given such a definition, it is evident that a true Mediterranean diet can only be produced in a region with a Mediterranean climate, although modern transportation and food preservation methods would permit such a diet to be consumed anywhere in the world throughout the year (Gussow, 1995).

The Mediterranean diet is considered to be more than a nutritional model: it includes all the different stages before the consumption of food, such as crop selection and growing, harvesting, fishing, processing and food preparation. All the activities tend towards the respect of lands and landscapes, ensuring conservation of traditional activities and crafts linked to fishing and farming in Mediterranean communities. For all these reasons, the Mediterranean diet was added to the Representative List of the Intangible Cultural Heritage of Humanity in 2010.

A pyramid representation (Mediterra, 2012) has been used since 1993 to spread the Mediterranean diet. The use of a pyramid is useful to show the frequency of consumption, differentiated usually on a daily or weekly basis. According to the various food habits, pyramids were defined for several Mediterranean countries (including Italy – Fig. 1).

In detail, as reported in technical documents (e.g. Dernini et al., 2012) it should be noted that:

- it is stated as fundamental to drink 1.5–2 L of water daily;
- main meals are based on three basic foods (cereals, fruit, and vegetables) in different proportions;
- vegetables, fruit and minimally refined cereals are located at the base of the diet pyramid because of their low energy content;
- fruit and vegetables of different colours contain different ranges of antioxidants and protective active principles, therefore they should all be included;
- olive oil is in the central position of the pyramid, because of its high nutritional quality and health benefits; oleic acid, found in olive oil, is also the major fatty acid which is present in adipose tissue and functions as an antioxidant (Berry et al., 2011).

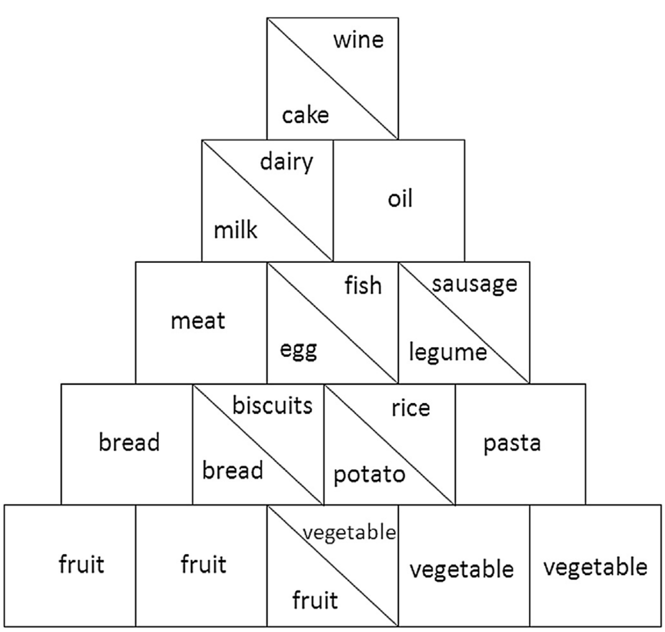

Fig. 1. General Mediterranean diet pyramid for Italy, adapted from the Italian Ministry of Health (Ministero della Salute, 2004).

The Food and Agriculture Organization of the United Nations (FAO) has identified the Mediterranean diet as one of the more environmentally friendly food consumption patterns (FAO, 2010; Burlingame and Dernini, 2011). Aspects of the diet's environmental sustainability have to be related to the lower consumption of animal products and higher consumption of vegetables, but also to the preference for very fresh (unprocessed) vegetable consumption in the Mediterranean (Gussow, 1995; Tukker and Jansen, 2006). Given the interest on the topic, the environmental impact, considered only for GHGs emissions and energy consumption, of the Mediterranean diet has been compared with other food consumption patterns just once (Tukker et al., 2011) at the European level, resulting in 1.01 tCO_2-eq capita^{-1} year^{-1}.

1.2. Environmental assessment methods for food consumption patterns

Several analytical tools and methodologies are available for quantifying the environmental burden of production and consumption. Environmental impact assessment methods are mainly divided into bottom-up methodologies (e.g. life cycle assessment – LCA) and top-down methodologies (e.g. input–output analysis – IOA), the former focusing on production processes and the latter on a community's macroeconomic dimensions.

In order to assess GHG emissions and energy consumption at product level both methods are used. Companies that use 'bottom-up' approaches account for all the environmental externalities associated with specific goods and resources used during the production process through a process-based LCA all through the production system and, sometimes, the supply chain as well. A number of authors (Wilting, 1996; Lenzen, 2001; Kok et al., 2003; Huppes et al., 2008) highlights that this approach suffers from 'truncation error' and, when applied to household consumption, leads to a serious underestimation of the total impact. The truncation arises from the inevitable omission of steps and processes in order to make the task manageable. The omission of steps and processes inevitably triggers the infeasibility of an analysis that covers the entire life cycle. LCA considers the system as a finite number of steps: the analysis on these steps often allows an adequate estimation (Baumann and Tillman, 2004). However, it will be difficult to consider a 'total economy scenario' using this method.

On the other hand, there are 'top-down' assessments using input–output analysis (IOA) which are able to allocate emissions to different sectors taking the country's total economy into consideration. This approach therefore has the benefit of not underestimating global figures. It also allows the possibility to have ready and available data against the difficulty of collecting a large amount of information; meanwhile it is necessary to consider its limits, among them the possibility to incur old data and the fact that the calculations are only made for economic sectors and not for certain products (Suh and Huppes, 2005; Omar et al., 2014). This means that IOA produces cruder estimates than LCA, but its calculations are more comprehensive. Furthermore, IOA indicates an emission factor based on monetary units consumed in a certain sector. This is considered very useful, but a problem, called 'aggregation error', may arise. The coefficients used in the IOA defined for each industry are usually calculated from the comprehensive group of production processes, which are related to each other but they are not completely equal. Each individual process is no longer individually discernible; as a result, unlike the bottom-up approach, IOA does not include specificity properties of each particular sector (Wiedmann, 2009).

Recently, a revised environmentally-extended input–output database (E3IOT model) was proposed by a European panel of experts (Huppes et al., 2008). This model aims to evaluate emissions from the entire supply chain of products in order to assess the environmental impact of final consumption. This method is potentially very useful because it avoids having to extrapolate the environmental impact of very specific products to whole product groupings (which carries a high risk of not being representative). However it does require highly disaggregated input–output tables for which environmental information is not readily available for the EU-25 and considerable effort is required to create them (Huppes et al., 2008).

Therefore, a number of hybrid models that combine LCA and IOA have been developed to describe consumption systems from a systemic point of view, in an attempt to benefit from both the completeness of EIOA and LCA's potential for specificity (Hertwich, 2011). Furthermore such hybrid analysis allows synthetic results from emissions provided by the EIOA approach and impact estimations provided by the LCA approach.

Within the GERME (Green Economy Scenarios in the Mediterranean Economy) research project, a hybrid LCA-IOA method was used on the basis of work by Wilting (1996) to calculate the energy requirements and GHG emissions of food consumption in Italian households. Although not all the scientific literature considers GHG emissions and energy consumption as the most relevant indicators of the environmental impact (Galli et al., 2012; Laurent et al., 2010), the analysis in this work is based on these two aspects, due to the fact that in specific cases, as in the evaluation of household consumptions (Kok et al., 2006), they could be used as the right proxy of the environmental impact. As applied in some previous works (e.g. Carlsson-Kanyama, 1998; Garnett, 2011; Berners-Lee et al., 2012), energy consumption and GHG emissions have been considered as references for a general assessment of the environmental impacts of the diet. It is well known that considering other impact categories (such as nutrient enrichment potentials) results may be different: in fact energy consumption and GHG emissions can't be considered representatives of all the environmental impacts.

2. Methods

2.1. The hybrid method

The hybrid method is mainly based on the life cycle of products from specific product categories, in which some stages of the cycle are accounted through standard LCA and others via IOA (Fig. 2). This approach started to find applications in the early 1990s and was improved by the works carried out at the Carneige Mellon University (e.g. Lave et al., 2005). Details on the use of strengths and weaknesses of the method are described in depth by Suh and Huppes (2005).

In each stage of the product lifecycle, a specific quantity of energy is consumed and emissions produced. In this method energy is accounted for as cumulative energy (Wilting, 1996; Kok et al., 2003) defined as the sum of the direct and indirect quantity of primary energy embodied in products and services.

However, as some stages of the lifecycle cannot be accounted for in physical units, all parts of the lifecycle are given a cost and an economic balance approach for each product (e.g. Williams, 2004) is performed.

The starting point for allocating economic value to a product in its lifecycle is the consumer price. This price is the sum of the costs of each process in the lifecycle of the product studied (producer price) together with commercial margins and taxes (1):

$$\text{(I)Consumer price} = \text{(II)producer price} + \text{(III)commercial margins} + \text{(IV)taxes} \tag{1}$$

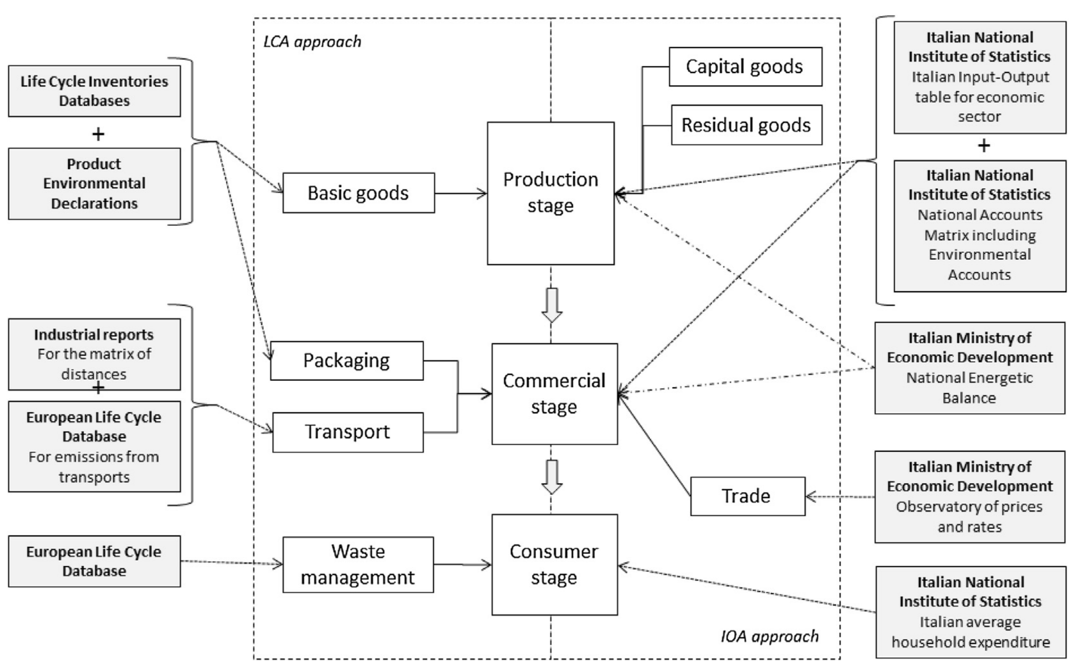

Fig. 2. Graphical representation of the hybrid LCA-IOA model.

where: (I) consumer price is the average cost at which any food category is bought in Italian markets according to Italy's Ministry of Economic Development (Osservatorio prezzi e tariffe, reference year 2010), (II) producer price is the economic value that has to be found in order to perform formula (2), (III) commercial margins per commercial sector calculated from the national input–output matrix (ISTAT – *Database: Tavole delle risorse e degli impieghi*), (IV) taxes were taken from Italy's Ministry of Economic Development (Osservatorio prezzi e tariffe, reference year 2010).

Once the producer price is known, it is used to complete the financial balance of the product using the following equation (2):

$$\text{(II)Producer price} = \text{(V)basic goods} + \text{(VI)packaging} + \text{(VII)direct energy} + \text{(VIII)added value} + \text{(IX)depreciation} + \text{(X)residual goods} \quad (2)$$

where: (V) basic goods is the sum of the costs of each good used in the production of the final product, (VI) packaging is the sum of the costs of each packaging material used in the preparation of the product for the commercial phase, (VII) direct energy is the cost of the energy material consumed during production as a percentage of the producer price related to the production sector, (VIII) added value for each sector is obtained from the national input–output matrix (ISTAT – *Database: Tavole delle risorse e degli impieghi*) and expressed as the net value from labour, (IX) depreciation per sector is obtained from the National Institute of Statistics (ISTAT – *Database: Conti economici nazionali*); (X) residual goods is the difference between all other costs and the manufacturer price. It is then possible to associate an environmental burden in terms of MJ/€ and kgCO_2-eq/€ with each component of the product's final price.

The functional unit on which input and output are calculated is that of the average Italian family in 2010, which includes 2.4 components (ISTAT, 2011a). Main results are presented according to this unit because family is considered as the base unit of consumption (Stiglitz et al., 2009; Padovan et al., 2012) as purchases are mainly decided at this level and not on the individual one, mediating among needs, wants and wills inside household (Heimer and Stinchcombe, 1980). Thus we can argue that household behaviour, and not individuals, is more fruitful to investigate in order to understand the social organization of environmental consumption and the inequality patterns that it gives rise to. Nevertheless, in order to compare results of other studies, environmental impact in terms of energy consumed and GHG emissions per capita per year are also given.

2.2. Data references for environmental externalities

As a result of the economic balance each component of the producer price is defined and associated to specific energy consumption and GHG emission values. Therefore, the environmental impact of each component (excluding added value) is taken into account as follows:

- (V) basic goods and (VI) packaging are accounted by using the LCA approach as regards energy and emission per unit of material. Several LCA data sources have been consulted in order to identify the reference process or case study which is closer to the average Italian product per food category and packaging material. This meta-analysis, fully described in an intermediate report of the GERME project, includes results from 68 environmental product declarations (International EPD Consortium), 24 case studies from scientific literature and publicly available life cycle inventories (LCI) data sources, such as ELCD (ELCD version 2.0).
- (VII) direct energy use is calculated as the MJ consumed multiplied by the cost of direct energy in the product at the average national energy cost. Data on energy consumption per energy vector and on energy intensity per sector are acquired from the National Energy Balance (BEN, 2010).
- (IX) depreciation cost represents the component of the producer price due to capital goods. It is calculated by multiplying the cost of depreciation by the energy intensity (or emission intensity) of a dummy sector called depreciation, which has been inserted for such a purpose into the input–output matrix (ISTAT – *Database: Tavole delle risorse e degli impieghi*), according to the method described by Wilting (1996).
- (X) residual goods are calculated by multiplying the price component from residual goods by the energy intensity (or emission intensity) of residual goods from the relative sector, using the national input–output matrix (ISTAT – *Database: Tavole delle risorse e degli impieghi*) in accordance with the formula (3) described by Wilting (1996):

$$e_j^r = \frac{\sum_i e_i X_{ij}}{\sum_i X_{ij}} \quad (3)$$

where: e_j^r is the energy intensity of residual goods of sector J; e_i is the energy intensity of sector I and X_{iJ} is the intermediate delivery from sector I to sector J.

Furthermore, environmental impacts from other components of the life cycle of foods, besides production, were assessed; in particular:

transport is calculated by multiplying each product's tkm by the emission factors specific for the means of transport. Data on emission factors relate to transport of foods and goods are obtained from ELCD (ELCD version 2.0).
- *trade* is calculated by multiplying the economic contribution of the commercial margins (ISTAT – *Database: Tavole delle risorse e degli impieghi*) by the energy intensity or emission intensity of the commercial sector. Data on energy consumption per energy vector and on energy intensity per sector are acquired from the National Energy Balance (BEN, 2010).
- *waste* (here, only material is considered, food waste has not been evaluated) is calculated by multiplying the quantity of waste material (from production, storage and transportation) by the emissions of energy consumption of the relative management strategy. Data on energy consumed and GHG emissions is obtained from ELCD (ELCD version 2.0)

2.3. Main advantages of the method

Compared to the application of a standard LCAs to food consumption patterns (e.g. Davis et al., 2010), the quantification of the impacts with the hybrid method is not "production oriented" but "consumption oriented". As most of the applications of LCA methodologies to diets apply system boundaries from cradle to storage (this evaluation is different if a complete LCA, from cradle to grave, is considered). (Meyer and Christen, 2013), sometimes including waste management (Munoz et al., 2010), impacts from non-physical processes, such as services, are not considered. In particular, the hybrid method solves some issues by taking capital goods and foreign trade into account. As is well known, the Leontief model, used primarily in environmental applications, only considers the intersectorial transaction of actual production activities in a given year. Transactions relating to the safeguarding and enhancement of fixed equipment (or stocks of raw and semifinished materials) are combined into a single item of final demand called investment. This means that they are not endogenous to production, but elements to be determined independently. This causes a problem because investment is needed in part to create new production capacity, but also to replace worn-out fixed assets during annual production. Thus the question is one of how the role of investment should be considered in an analytical framework, such as the evaluation of the carbon footprint of the population's consumption. A number of methods have been proposed. Some studies simply ignore this issue, while others propose full inclusion of investments.

Nevertheless the most appropriate method is one that involves segregating an amount equal to depreciation from the sector of final demand and internalising it in the matrix of cross-sectorial exchanges. This kind of solution is therefore adopted by the hybrid model which introduces a fictitious sector called depreciation. This sector takes into account the redistribution of externalities embedded in the use of annual capital equipment based on the share of depreciation specific to each sector of the economy.

With the issue of foreign trade, the hybrid model has the advantage of clearly distinguishing between competitive and non-competitive imports, depending on whether goods and services are produced at country level or not. Imports of the former are included in the matrix of intermediate exchanges on the assumption that the country's production structure is similar to that of the pilot country. These assumptions are not unreasonable in the context of Italy which imports mainly from other western countries.

2.4. Construction of the food database for the LCA part of the analysis

A specific investigation concerning food products was undertaken to obtain data on the various aspects involved in the assessment of environmental impacts, especially in terms of energy consumption and emissions.

Construction of the database for the hybrid model requires an investigation of each item, taking into account:

- environmental aspects resulting from the application of methodologies encompassing the entire product life cycle
- average percentage composition of different types of packaging used
- distances covered by products to reach the place of consumption
- waste management.

All potential data on emissions from companies and research institutes was considered, but it would be impossible to set an average panel of data in this way.

LCA studies carried out in Italy, such as studies on wine (Ardente et al., 2006), rice (Blengini and Busto, 2009), fruit (Cerutti et al., 2013a, 2013b) and oil (Salomone and Ioppolo, 2012) were used as case studies, considering the modest scientific research hitherto available in Italy on the environmental evaluation of food products using this methodology.

Environmental Product Declarations (EPD) were also considered, as derived from LCA studies on the products of large producers such as Pasta Barilla which is also a national market leader. Each EPD reported environmental indicators calculated for comparison between products of the same category. Other EPDs used are for biscuits, crackers, milk, wine, oil, beer and water.

The question of whether an LCA study on a specific case is sufficiently representative of other realities is a matter for debate, combined with the possibility of using an Italian LCA database which would contain average data, although such a database does not yet exist (Vesce et al., 2012).

Prior analysis of the retail sector in Italy was needed to evaluate trade in food products. Food products are distributed mainly by hypermarkets, supermarkets and superstores, cash-and-carry and hard discount stores. The area is highly diversified due to the classification of "fresh products" or those with a "medium" or "long" best-before date.

Lack of data on average product distance to market, even from professional associations, has been a significant factor. Data was therefore obtained by:

- selecting the market leader for each product category
- selecting towns by geographic distribution
- calculating distances from the market leader to towns and the average distance covered in Italy.

Moreover, aggregate data on distances covered by food products according to Italy's Ministry of Infrastructure and Transport, the Statistics Office and the National Statistics System (2009–2010) illustrate energy consumption versus distance, related to the type of transport used for delivery.

As regards average packaging research, the approach included:

- research on the local situation (consultation with CONAI, the national packaging consortium, and consortia representing major packaging materials operators) and in Europe (the European shopping basket)
- an analysis of packaging data extrapolated from the Environmental Product Declaration
- an assessment of data received from the professional associations of major distributors
- direct evaluations in hypermarkets.

The sources investigated did not provide sufficient information in order to establish which packaging was used and in what percentage for each packing material (such as plastic, cardboard and glass),and the waste recyclers only provided aggregate data.

The data collated was mainly the result of visits to hypermarkets owned by major local retailers (Coop Italia, Conad and Auchan) for the purpose of assessing the material mix used for the different products.

The main share of food product waste comes from packaging, with a minor contribution from organic waste. Data from the Urban Waste Report 2012 (ISPRA, 2012) illustrates the situation of waste recycling or disposal of different materials in Italy. This information was used to delineate an equivalent scenario for each material, considering the same percentage for recycling and disposal respectively. Organic waste from food spoilage, even if it could be a relatively highly percentage, do not constitute a source of emission as itself because, according to the Italian waste management system, organic waste are used again in agriculture after composting.

From the study and investigation undertaken, it was possible to compose the database of food products, necessary for the hybrid model, including direct emissions from transport, packaging and waste management.

2.5. Construction of scenarios for environmental comparisons of diets

The creation of different diet scenarios is extremely useful in order to test their environmental impact and begins with the simple consideration that a different quality and quantity of food consumption could lead to different results in terms of health and environmental externalities. Individuating consolidated scenarios

(Bravo et al., 2013) could be the focus of initial investigations and evaluations starting from other researchers' conclusions on consumption patterns and health, before exploring them in more detail in order to identify other possibilities in environmental terms (Roma et al., 2010; Tukker et al., 2011; Berners-Lee et al., 2012).

These considerations could confirm a specific line of research which studies the environmental impact of single products both in production and during consumption phases. With reference to the production phase, it should be considered that agriculture and livestock have a great impact on environment; subsequent transformation phases of raw material have less of an impact in terms of energy and material consumption (Jungbluth et al., 2000). Considering different product categories, plenty of different research projects and studies (DEFRA, 2006; Tukker and Jansen, 2008) reveal how meat has a major impact on the environment but also that it is important to make a distinction between different kinds of animals in the same "meat category" (De Vries and De Boer, 2010). Other research concentrates on minor environmental impacts from greater vegetable consumption (Carlsson-Kanyama, 1998; Sonesson et al., 2009; Marlow et al., 2009).

In the study, three scenarios, the Mediterranean diet, the healthy diet and the vegetarian diet, have been built to compare different dietary habits, all of them that ensure the necessary intake of energy, mixing different groups of foods, calculating right substitutions among portions. These scenarios have been compared with National average data about food consumption.

The National average diet represents the situation of food consumption in Italy using what is known as the basket of Italian products derived from the National Statistics Institute. This scenario defined as the reference scenario clearly identifies the environmental impact related to actual Italian food habits.

The Mediterranean diet has been chosen as an example which is recognised for its characteristics. These are also due to the specific Italian environment and climate (Kushi et al., 1995a, 1995b; Duchin, 2005). This kind of diet, which is widespread in countries around the Mediterranean Sea due to the resources available, was deemed an exemplary diet in studies conducted in the 1950s and improved in subsequent years (Keys, 1995). This scenario has been determined in accordance with the "Modern Diet Mediterranean Food Pyramid" defined by INRAN, the National Institute of Research on Food and Nutrition.

Food is subdivided in accordance with defined portions and suggested consumption frequency; the pyramid is based on "main meals", almost all vegetables and fruit, vegetables, pasta, rice and other vegetables; meat consumption, especially red meat, is located at the apex of pyramid between weekly meals.

These considerations have been added to by a model developed using correct considerations from a nutritional perspective (Moresi and Valentini, 2010).

The healthy diet and the vegetarian diets have been built following the guidelines defined by the Italian Nutrition Society (SINU) and the daily recommended intake of nutrients (LARN), which are classified by the following main classes: "milk and derivates", "meat", "fish", "eggs", "legumes", "cereals and tubers", "vegetable and fruits" and "fat and seasoning". The appropriate way in which to alternate food groups according to specific portions allows daily energy requirements to be fulfilled, set according to SINU's indication, for an average person who undertakes moderate physical activity. The food portions for a standard person have then been multiplied by the number of components of the average Italian family in 2010, which is 2.4 (ISTAT, 2011a), in order to obtain quantity and typologies of food consumed per month at the household level. In addition, according to what has been stated on fruit and vegetable consumption (Baroni et al., 2007; Joyce et al., 2012) the vegetarian scenario has also been individuated in which meat portions have been substituted with different vegetables meals with a high protein content. The change in the mix of portions has been made evaluating the necessity to assure the right intake of calories and the same nutritional value of the other scenarios.

Main changes in monthly portions per capita in each food consumption pattern is summarized in Table 1. In addition to food in the highlighted categories, all consumption patterns comprehend water and beverages, in the same volume of the national average, with a maximum value of sugar drinks and alcohol allowed in SINU standards for the healthy diet, and quantities of wine described by INRAN for the Mediterranean diet. More than meals, the average food basket is composed by a set of other food categories, such as sugar, coffee and dressings. As these products are not consumed in portions, but as ingredients to other foods, they were considered in the same quantity of the National average, applied limits, if needed, for restricted aliments according to the consumption pattern (e.g. sugar or fats in the healthy diet).

3. Results

The Mediterranean diet pattern applied in Italy for an average family would require expenditure of € 441.77 per month which corresponds almost entirely to the same budget for the national average food consumption (€ 440.12 per month) but with a different proportion of each product class (Fig. 3). The healthy diet is the most expensive food pattern (€ 464.86 per month) and the vegetarian diet the cheapest (€ 413.79 per month) because of the absence of the meat and fish component in the economic balance. Although the conditions for a potential rebound effect are present (Hertwich, 2008) the amounts involved in the consumption shift are limited and not sufficient to produce significant effect.

The energy consumption contained within the consumption patterns studied does not vary significantly. The Mediterranean diet consumes 3817.41 MJ per month, which is 2.44% lower than the national average and 4.36% lower than the healthy diet. Nevertheless the vegetarian diet is the food consumption pattern with the lowest energy consumption (3790.13 MJ/month), which is 0.71% less than the Mediterranean diet and 3.24% less than the national average. A breakdown of energy consumption for each product class is shown in Fig. 4.

The same proportion of results has given the carbon footprint of the consumption patterns studied (Fig. 5). The consumption pattern with the highest greenhouse gas emissions is the national average at 402.91 kg CO_2 eq/month, followed by the healthy diet which is 2.28% less than the national average, and then the Mediterranean diet with 6.81% less CO_2 eq/month. The best performance is achieved by the vegetarian diet with a consistent emission 14.55% below the national average and 6.74% below the Mediterranean diet.

Considering the contribution of each product class to energy consumption (Fig. 4), a major role is played by the fruit and vegetable category in all the diets, with a predominant role in the vegetarian pattern (44.73% of energy consumption) and a

Table 1
Monthly portions per capita according to the studied food consumption patterns.

	National average	Healthy diet	Vegetarian diet	Mediterranean diet
Bread, pasta and flour products	173	124	134	120
Potatoes, vegetables and fruits	125	156	186	158
Meat and meat products	140	32	0	14
Dairy products	46	72	72	75
Fish	9	8	0	8

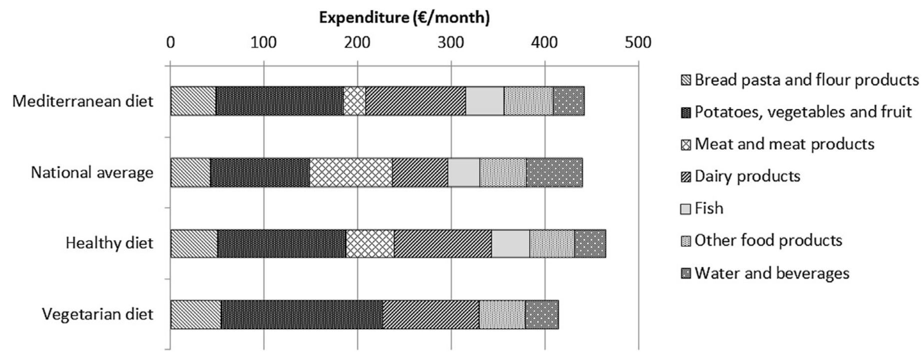

Fig. 3. Breakdown of expenditure comparison for main food product categories.

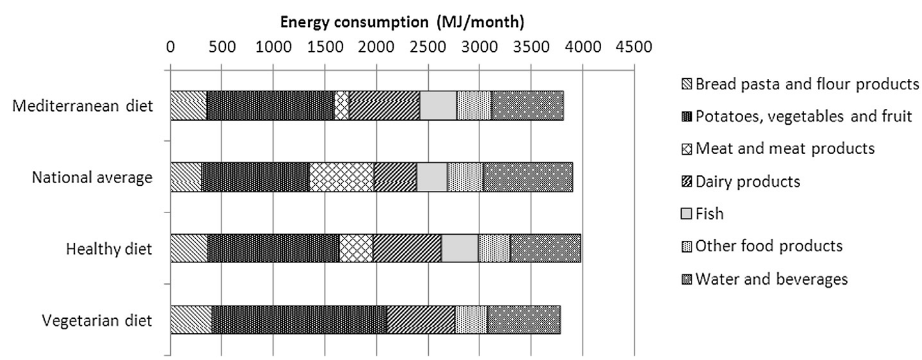

Fig. 4. Breakdown of energy consumption results for main food product categories.

contribution in the national average diet with a percentage of 32.24% of energy consumption (the smallest one, considering all the diets). Excluding the vegetarian diet, the meat impacts (for energy consumption and for carbon footprint) are proportional to the amount of meat consumed in each diet. The contribution of animal foods, expressed as the sum of meat and fish products, is highest in the national average diet (29.93% of energy consumption) and lowest in the Mediterranean diet (13.56% of energy consumption). In the national average, animal food weight produces 33.13% of emissions in comparison to 19.44% of emissions from vegetable and fruit products. In the Mediterranean diet, the opposite situation can be found: animal food weight accounts for 14.33% of emissions and vegetable products for 25.94% of emissions (Fig. 5).

Another important aspect is that the model used links GHG emissions with the cost of products, but different food categories have different prices. As a consequence, emissions and energy per cost of product represent an interesting indicator for carbon and energy intensities of each product category. These results are presented in Figs. 6 and 7. In terms of energy intensity, 90% of the products have an energy consumption ranging from five to ten MJ per € of the final price. High variability can be found in the potatoes, vegetable and fruit category due mainly to the energy consumption in the different conservation strategies (from fresh to frozen products) and the high quantity of packaging per unit of product.

Considering the emission intensity of each product category, 90% of the products show an emission range between 0.35 and 1.55 kg CO_2-eq per € of the final price of the product. As expected, the meat product category shows a high variability in emission intensity because of the great difference in emissions from animals, ranging from poultry to cows.

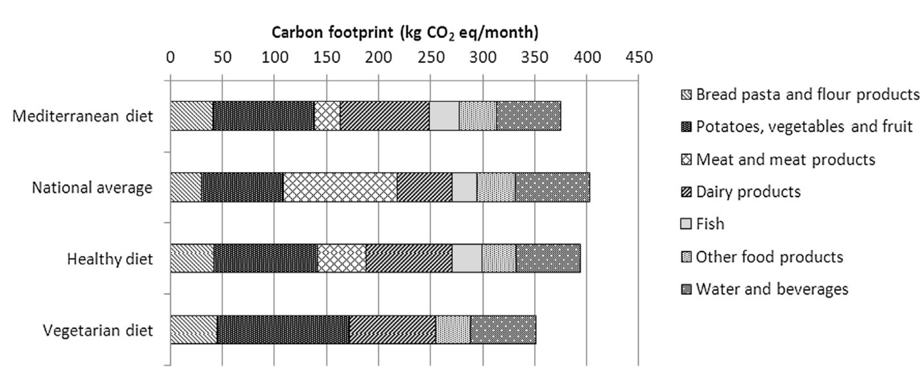

Fig. 5. Breakdown of carbon footprint results for main food product categories.

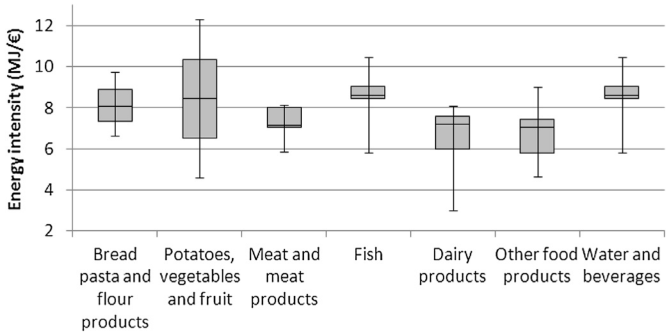

Fig. 6. Distribution of energy intensity within each class of product expressed as MJ/€.

4. Discussion

This study assess energy consumption and GHG emissions at the household level, according to the national statistics regarding household diets, but, in order to compare these results with previous studies, figures regarding impact per capital annually have to be calculated (Table 2). Considering 2.4 the average number of components of Italian families in 2010 (ISTAT, 2011a) results range from 1.75 tCO_2-eq capita^{-1} year^{-1}of the vegetarian diet to 2.01 tCO_2-eq capita^{-1} year^{-1}of the national average diet. Our result with regards to the Mediterranean diet in Italy (1.87 tCO_2-eq capita^{-1} year^{-1}) is significantly higher than the calculation made at the European level by Tukker et al. (2011), which is 1.01 tCO_2-eq capita^{-1} year^{-1}, but it has to be considered that in the latter case a standard environmental extended IOA (without the LCA component) has been applied therefore some impacts from the life cycle of the product may be not accounted for. Closer results have been obtained in previous studies, e.g. Santacana et al. (2008) calculated that the carbon footprint of the average Spanish diet in 2000 emitted 1.65 tCO_2-eq capita^{-1} year^{-1} using a standard IOA. Higher figure of 2.10 tCO_2-eq capita^{-1} year^{-1} has been obtained by Munoz et al. (2010) for Spain as well, but using a standard LCA approach. Meyer and Christen, 2013 obtained an average of 2.05 tCO_2-eq capita^{-1} year^{-1} for Germany in the year 2006. The results are all consistent given the accepted level of uncertainty that exists in EIO-LCA and the differences in the data source for impacts.

The similar results in comparison with previous studies can be obtained considering the energy consumption. Diets accounted in the study range from 18.95 GJ capita^{-1} year^{-1} of the vegetarian diet to 19.95 GJ capita^{-1} year^{-1} of the healthy diet. Carlsson-Kanyama et al. (2003) calculated 6.9–21 GJ capita^{-1} year^{-1} in various Swedish food consumption patterns and Munoz et al. (2012) accounted the energy consumption of the average Spanish diet for 20 GJ capita^{-1} year^{-1}.

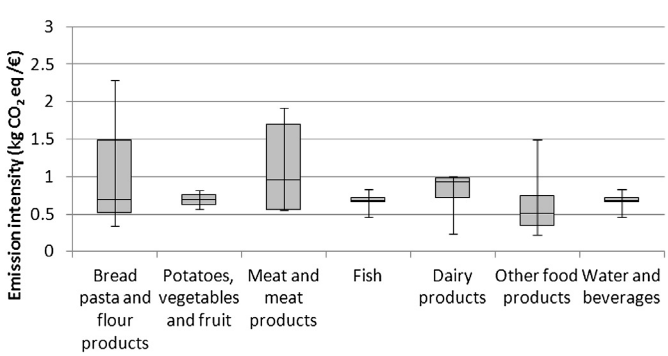

Fig. 7. Distribution of emission intensity within each class of product expressed as kg CO_2 equivalent/€.

Table 2
Comparison of obtained results with previous studies about GHGs emissions.

		Annual tCO_2-eq/capita	Annual GJ/capita
Cerutti et al. (present study)	Mediterranean diet	1.87	19.5
Tukker et al., 2011	European diet	1.01	–
Munoz et al., 2010	Average Spanish diet	2.10	20
Meier et al., 2013	Germany diet scenarios	2.05	13.5–22
Carlsson-Kanyama et al., 2003	Several Swedish food consumption patterns	–	6.9–21

The results of this study give a clear characterisation of the Mediterranean diet in the Italian context considering energy consumption and carbon footprint. A shift to a Mediterranean diet would lead an average family to cut 95.78 MJ/month and 27.46 kg CO_2 eq/month without any significant difference in monthly food expenditure. This shift, accounted for approximately 7% of impact reduction, is higher than that obtained by Tukker et al. (2011) at the European level, in which the reduction is estimated at about 1% because of the inclusion of the full life cycle of foods in the present study. On the contrary the shift to a vegetarian diet at the Italian level is estimated to lead to 78% of impact reduction by Baroni et al. (2007), but also take into account several common LCA impact categories, such as nutrient enrichment potentials and carcinogenic potential, in which animal products play a more important role.

Annually the impact reduction can be assumed to be 1149.41 MJ and 329.62 kg CO_2 eq, which corresponds to the energy consumption of 121cycles of an A-class washing machine (European Energy Data, 2012) and the emissions from travelling in an average European car for about 1700 km (DEFRA, 2012) respectively. Furthermore, although the shift to the Mediterranean diet would reduce the GHG emissions per family by 6%, considering that there are 25,175,793 families in Italy (ISTAT, 2011b), this could lead to a total annual reduction potential of 2.89E + 10 MJ and 8.30E + 09 kg CO_2 eq. This latter amount is particularly interesting because it represents 24.40% of Italy's annual CO_2 reduction target to achieve the Kyoto objectives (EEA, 2010).

Considering the comparison with other consumption patterns, the Mediterranean diet shows an intermediate environmental performance between the healthy and the vegetarian diets. As expected, a key role in the determination of environmental impacts is played by animal products and their substitution with horticultural products. Results confirm the high environmental impact reduction potential of a vegetarian diet highlighted in previous work (Garnett, 2011; Gonzalez et al., 2011) with an annual reduction potential calculation of 1476.82 MJ (approximately 156 cycles of an A-class washing machine) and 614.18 kg CO_2 eq (approximately 3175 km in an average European car) for an average Italian family.

Interesting results may be highlighted from the study of energy and emission intensity of product classes. As the hybrid method does not just consider the impact of production, the results concerning intensities reflect the impact of the entire supply chain of reference products on a national average. Energy and emission intensities do indeed also consider the impacts generated by the retail sector on a national basis using the input–output approach, thus they offer a more complete comparison of intensity evaluated on a product lifecycle base. This means that there is an absence of significant differences in the retail phases between classes, such as the difference in the distribution system highlighted by Gonzalez et al. (2011) which may be 100 times more between cereals and meat in terms of CO_2 intensities. Furthermore, it has to be remembered that results in energy and emission efficiency reflect only two of the environmental impacts of the product category. E.g. fish products have a low carbon intensity result, nevertheless, sea resources are already overexploited in many areas and fish from aquaculture systems have about the same impact as meat in nutrient enrichment potentials and other impact categories not directly related to GHG emissions.

Finally, the use of hybrid approach achieves a description of the environmental impact of consumption items and therefore a good assessment of national scenarios. Nevertheless, the limitations in the use of the hybrid approach are (Suh, Huppes, 2005; Omar et al., 2014): (I) the scale of the assessment, which cannot be lower than the level at which the Leontief matrix is calculated (e.g. in the study a national input–output table has been adopted, thus the model cannot be used at any sub-national level, such as regions or provinces); (II) the detail of the sectors considered in the Leontief matrix, e.g. in the Italian input–output table there is just one agricultural sector that comprises vegetable and animal products, thus the impact from residual goods used in the production processes are the same for both open crops and livestock systems.

5. Conclusions

Although it is claimed that the Mediterranean diet is one of the more sustainable food consumption patterns, specific modern environmental impact assessment methods in the Italian context have never been applied before. The hybrid method was chosen because it includes the environmental impact of the whole supply chain of products, from production to the disposal of packaging, and not just on the production phase or that of transportation. Considering residual impacts using a top-down approach (therefore evaluating environmental pressures in the framework of total economy) means that the impacts in the supply chain are not underestimated and consequently detailed analysis is conducted within a systemic framework which is necessary for investigation in complex systems such as the food sector.

It is confirmed that the environmental performance of the Mediterranean diet is better than the national average diet, mainly due to it featuring fewer animal products. The estimated environmental impact reduction potential if all Italian families were to adjust their consumption pattern to the Mediterranean diet is very high and can be compared to a quarter of the CO_2 which needs to be reduced in order to achieve Italy's annual Kyoto target.

The vegetarian consumption pattern is more environmentally efficient than the Mediterranean diet. Nevertheless, it is unlikely to assess whether the consumption of beef will be completely replaced by vegetable consumption, for social, cultural and psychological reasons (Goodland, 1997; Vinnari, 2008).

As a consequence, the Mediterranean diet could represent the best compromise between the need to reduce the environmental impact of food consumption and maintain the cultural meaning of food consumption behaviour. This balance is one of the key aspects that should be borne in mind when developing policies for emission reduction or research projects for maintaining the heritage of the Mediterranean diet.

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References

Ardente, F., Beccalli, G., Cellura, M., Marvuglia, A., 2006. POEMS: a case study of an Italian wine-producing firm. Environ. Manag. 38 (3), 350–364.
Bach-Faig, A., Berry, E., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Medina, F.X., Battino, M., Belahsen, R., Miranda, G., Serra-Majen, L., 2011. Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutr. 14 (12A), 2274–2284.
Baroni, L., Cenci, L., Tettamanti, M., Berati, M., 2007. Evaluating the environmental impact of various dietary patterns combined with different food production systems. Eur. J. Clin. Nutr. 61, 279–286.
Baumann, H., Tillman, A.M., 2004. The Hitch Hikers Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application. Studentlitteratur, Göteborg (Sweden).
BEN, 2010. Bilancio Energetico Nazionale. National Energy Balance. Ministero dello Sviluppo Economico. http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp (accessed 30.10.12.).
Berners-Lee, M., Hoolohan, C., Cammack, H., Herwitt, C.N., 2012. The relative greenhouse gas impacts of realistic dietary choices. Energy Policy 43, 184–190.
Berry, E.M., Arnoni, Y., Aviram, M., 2011. The Middle Eastern and biblical origins of the Mediterranean diet. Public Health Nutr. 14 (12A), 2288–2295.
Blengini, G.A., Busto, M., 2009. The life cycle of rice: LCA of alternative agri-food chain management systems in Vercelli (Italy). J. Environ. Manage. 90, 1512–1522.
Bravo, G., Vallino, E., Cerutti, A.K., Pairotti, M.B., 2013. Alternative scenarios of green consumption in Italy: an empirically grounded model. Environ. Model. Softw. 47, 225–234.
Burlingame, B., Dernini, S., 2011. Sustainable diets: the Mediterranean diet as an example. Public Health Nutr. 14, 2285–2287.
Carlosson-Kanyama, A., Pipping Ekstrom, M., Shanahan, H., 2003. Food and life cycle energy inputs: consequences of diets and ways to increase efficiency. Ecol. Econ. 44, 293–307.
Carlsson-Kanyama, A., 1998. Climate change and dietary choice – how can emissions of greenhouse gases from food consumption be reduced? Food policy 23 (3/4), 277–293.
Cerutti, A.K., Beccaro, G.L., Bagliani, M., Donno, D., Bounous, G., 2013a. Multifunctional Ecological Footprint Analysis for assessing eco-efficiency: a case study of fruit production systems in Northern Italy. J. Clean. Prod. 40, 108–117.
Cerutti, A.K., Bruun, S., Donno, D., Beccaro, G., Bounous, G., 2013b. Environmental sustainability of traditional foods: the case of ancient apple cultivars in Northern Italy assessed by multifunctional LCA. J. Clean. Prod. 52, 245–252.
Cresta, M., Ledermann, S., Garnier, A., 1969. Étude des consommations alimentaires des populations de onze régions de la Communauté européenne en vue de la détermination des niveaux de contamination radioactive. rapport. Centre d'étude nucléaire de Fontenay-aux- Roses, France.
Davis, J., Sonesson, U., Baumgartner, D.U., Nemecek, T., 2010. Environmental impact of four meals with different protein sources: case studies in Spain and Sweden. Food Res. Int. 43, 1874–1884.
De Vries, M., De Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: a review of life cycle assessments. Livest. Sci. 128, 1–11.
DEFRA, 2006. Environmental Impacts of Food Production and Consumption. Final report to the Department for Environment. Food and Rural Affairs.
DEFRA, 2012. Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting.
Dernini, S., Berry, E.M., Bach-Faig, A., Belahsen, R., Doukkali, C., Donini, L.M., Lairon, D., Serra-Majem, L., Cannella, C., 2012. A Dietary Model Constructed by Scientists. Mediterra, pp. 71–88 (Chapter 3).
Dernini, S., Meybeck, A., Burlingame, B., Gitz, V., Lacirignola, C., Debs, P., Capone, R., Bilali, El, 2013. Developing a methodological approach for assessing the sustainability of diets: the Mediterranean diet as a case study. New. Medit. 3, 28–36.
Duchin, F., 2005. Sustainable consumption on food, A framework for analyzing scenarios about changes in diets. J. Indust. Ecol. 9 (1, 2), 99–114.
ELCD database v. 2.0, European Commission–Joint Research Centre, LCA-tools, Services and Data http://elcd.jrc.ec.europa.eu/ELCD3/ (accessed 30.10.12.).
European Energy Data, 2012. Report on Energy Efficiency for Appliance Labelling. EuroPatentpean Energy Portal. http://www.energy.eu (accessed 30.10.12.).
European Environment Agency, 2010. Tracking Progress towards Kyoto and 2020 Targets in Europe. EEA Report No 7/2010.
FAO, 2010. International Symposium on Biodiversity and Sustainable Diets. FAO, Rome.
Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., Giljum, S., 2012. Inegrating Ecological, Carbon and Water footprint into a "Footprint Family" of indicators: definition and role in tracking human pressure on the planet". Ecol. Indic. 16, 100–112.
Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy 36, s23–s32.
Gonzalez, A.D., Frostell, B., Carlsson-Kanyama, A., 2011. Protein efficiency per unit energy and per unit greenhouse gas emissions: potential contribution of diet choices to climate mitigation. Food policy 36, 562–570.
Goodland, R., 1997. Environmental sustainability in agriculture: diet matters. Ecol. Econ. 23, 189–200.
Gussow, J.D., 1995. Mediterranean diets: are they environmentally responsible? Am. J. Clin. Nutrition 61 (Suppl. 6), 1383S–1389S.

Heimer, C.A., Stinchcombe, A.L., 1980. Love and irrationality: it's got to be rational to love you because it makes me so happy. Soc. Sci. Inf. 19, 697–754.

Hertwich, E.G., 2008. Consumption and the rebound effect an industrial ecology perspective. J. Industrial Ecol. 9, 85–98.

Hertwich, E.G., 2011. The life cycle environmental impacts of consumption. Econ. Syst. Res. 23 (1), 27–47.

Huppes, G., de Koning, A., Guinée, J., Heijungs, R., van Oers, L., Kleijn, R., Tukker, A., 2008. Environmental Impacts of Diet Changes in the EU. European Commission, Annex to EUR 23783.

International EPD Consortium. The International Environmental Product Declaration System. http://www.environdec.com/ (accessed 30.10.12.).

ISPRA, 2012. Istituto Superiore per la Protezione e la Ricerca Ambientale. Rapporto Rifiuti Urbani Rapporto n.163/2012.

ISTAT, 2011a. Istituto nazionale di statisticaBilancio Demografico Nazionale. http://www3.istat.it/salastampa/comunicati/in_calendario/bildem/20110524_00/testointegrale20110524.pdf. Accessed 03.2012.

ISTAT, 2011b. Istituto nazionale di statistica. Rapporto Italiano in cifre 2010. http://www.istat.it/it/files/2011/06/italiaincifre2010.pdf (accessed 30.10.12.).

Italian Ministry of Economic Development, 2010. Database dell'Osservatorio Prezzi e Tariffe. http://osservaprezzi.sviluppoeconomico.gov.it/.

Italian Ministry of Infrastructures and Transports, 2009–2010. Statistics Office and National Statistics System, Conto nazionale delle infrastrutture e dei trasporti. anni.

Joyce, A., Dixon, S., Comfort, J., Hallet, J., 2012. Reducing the environmental impact of dietary choice: perspectives from a behavioral and social change approach. J. Environ. Public Health. http://dx.doi.org/10.1155/2012/978672.

Jungbluth, N., Tietje, O., Scholz, W., 2000. Food purchase: impacts from the consumers' point of view investigated with a modular LCA. J. Life Cycle Assess. 5, 134–142.

Keys, A., 1995. Mediterranean diet and public health: personal reflections. Am. J. Clin. Nutr., 1321S–1323S.

Kok, R., Falkena, H.J., Benders, R.M.J., Moll, H.C., Noorman, K.J., 2003. Household Metabolism in European Countries and Cities (IVEM Report).

Kok, R., Benders, R.M.J., Moll, H.C., 2006. Measuring the environmental load of household consumption using some methods based on input-output analysis: a comparison of methods and discussion of results. Energy Policy 34, 2744–2761.

Kushi, L., Lenar, E.B., Willet, W., 1995a. Health implications of Mediterranean diets in light of contemporary knowledge 1. Plant foods and dairy products. Am. J. Clin. Nutr. 61, 1407S–1415S.

Kushi, L., Lenar, E.B., Willet, W., 1995b. Health implications of Mediterranean diets in light of contemporary knowledge 2. Meat, wine, fats and oils. Am. J. Clin. Nutr. 61, 1416S–1427S.

Laurent, A., Olsen, S.I., Hauschild, M.Z., 2010. Carbon footprint as environmental performance indicator for the manufacturing industry. Manuf. Technol. 59, 37–40.

Lave, L., Cobas Flore, E., Hendrickson, C., McMichael, F., 2005. Using input-output analysi to estimate economy wide discharges. Environ. Sci. Technol. 29 (9), 420–426.

Lenzen, M., 2001. Errors in conventional and input-output based life-cycle inventories. J. Indust. Ecol. 4, 127–148.

Marlow, H., Hayes, W., Soret, S., Carter, R., Schwab, E., Sabaté, J., 2009. Diet and the environment: does what you eat matter? Am. J. Clin. Nutr., 1699S–1703S.

Mediterra, 2012. The Mediterranean Diet for Sustainable Regional Development/International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM). Presses de Sciences Po, Paris.

Meyer, T., Christen, O., 2013. Environmental impacts of dietary recommendations and dietary styles: Germany as an example. Environ. Sci. Technol. 47, 877–888.

Ministero della Salute, 2004. Elaborazione del tipo di dieta verso cui indirizzare il cittadino consigliando le opportune variazioni. D.M. 1 September 2003, Rome.

Moresi, M., Valentini, R., 2010. Dieta mediterranea e impatto ambientale. Ind. aliment. 49 (501), 9–20.

Munoz, I., Mila i Canals, L., Fernandez-Alba, A., 2010. Life cycle assessment of the average Spanish diet including human excretion. Int. J. Life Cycle Assess. 15, 794–805.

Omar, W.M.S.W., Doh, J.-H., Panuwatwanich, K., Miller, D., 2014. Assessment of the mebodied carbon in precast concrete wall panles using a hybrid life cycle assessment approach in Malesysa. Sustain. Cities Soc. 10, 101–111.

Padovan, D., Martini, F., Cerutti, A.K., 2012. Household Metabolism and social practices. A model for assessing and changing household consumption. Cult. della Sostenibilita 10, 7–35.

Roma, R., De Boni, A., De Blasi, G., 2010. Environmental impact of different dietary habits of modern consumers, LCAFood2010. In: VII International Conference on Life Cycle Assessment in the Agri Food Sector, Bari, 22–24 September.

Salomone, R., Ioppolo, G., 2012. Environmental impacts of olive oil production: a Life Cycle Assessment case study in the province of Messina (Sicily). J. Clean. Prod. 28, 88–100.

Santacana, M., Pon, J., Pon, D., Arto, I., Casanovas, S., 2008. Greenhouse gas emission from a consumption perspective in a global economy - opportunities for the Mediterranean region. Sustainable consumption and production in the Mediterranean regional activity centre for cleaner production. Annu. Tech. Publ. 7, 101–112.

Sonesson, U., Davis, J., Ziegler, F., 2009. Food Production and Emissions of Green House Gases – an Overview of the Climate Impact of Different Product Groups. SIK report of the Swedish Institute of Food and Biotechnology, (Accessed 01, October 2012), at. http://www.se2009.eu/polopoly_fs/1.23297!menu/standard/file/foodproduction.pdf.

Stiglitz, J.E., Sen, A., Fitoussi, J.P., September 2009. Report by the Commission on the Measurement of Economic Performance and Social Progress. Commission of the Government of France, Paris. http://www.stiglitz-sen-fitoussi.fr/ (accessed 30.10.12.).

Suh, S., Huppes, G., 2005. Methods for Life Cycle Inventory of a product. J. Clean. Prod. 13, 687–697.

Tukker, A., Jansen, B., 2008. Environmental impacts of products: a detailed review of Studies. J. Indust. Ecol. 10, 159–182.

Tukker, A., Goldbohm, A., De Konigin, A., Verheijden, M., Kleijn, R., Wolf, O., Perez-Dominguez, I., Rueda-Cantuche, J., 2011. Environmental impacts of changes to healthier diets in Europe. Ecol. Econ. 70, 1776–1788.

Vesce, E., Pairotti, M.B., Giordana, F., 2012. The need to make Life Cycle Analysis unbiased and representative outside the original context: set-up of two case studies. In: Proceeding of the 18th IGWT Symposium "Technology and Innovation for a Sustainable Future: a Commodity Science Perspective in press.

Vinnari, M., 2008. The future of meat consumption – expert views from Finland. Technol. Forecast. Soc. Change 75, 893–904.

Wiedmann, T., 2009. Carbon footprint and Input–Output analysis – an introduction. Econ. Syst. Res. 21, 175–186.

Williams, E., 2004. Energy intensity of computer manufacturing: hybrid assessment combining process and economic input-output methods. Environ. Sci. Technol. 38, 6166–6174.

Wilting, H.C., 1996. An Energy Perspective on Economic Activities. PhD. Thesis. Center for Energy and Environmental Studies, University of Groningen.