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ORIGINAL ARTICLE

Evaluating the environmental impact of various dietary patterns combined with different food production systems

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Objective: Recent studies support the hypothesis that plant-based diets are environmentally better than meat-based diets. This study aims to further explore this topic and to compare different environmental impacts resulting from different dietary patterns (omnivorous, vegetarian, vegan) and methods of production (conventional farming and organic agriculture).
Design: Three weekly balanced diets, equivalent to one another for energetic and nutrient content, have been planned: an omnivorous one, a vegetarian one and a vegan one. For each one, the Life Cycle Assessment (LCA) method has been applied in order to calculate the environmental impact, expressed in 'points'.
Interventions: The software we selected to carry out the Inventory Analysis and the Impact Assessment is SimaPro5. The Assessment phase has been conducted using Ecoindicator 99, a damage-oriented method, which analyses the impact according to three large damage categories, each of them subsuming various impact categories.
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Introduction

The World Health Organization recently reported that malnutrition affects one in every three people worldwide, afflicting all age groups and populations, and plays a major role in half of the 10.4 million annual child deaths in the developing world; malnutrition continues also to be a cause and a consequence of disease and disability in the children who survive (World Health Organization, 1996, 2000).

This is the largest number and proportion of malnourished people ever recorded in human history. The food shortage and malnutrition problems are primarily related to rapid population growth in the world and to the declining per capita availability of land, water and energy resources (Pimentel and Pimentel, 1993, 1999; Pimentel *et al*., 1999).

On the other hand, advances in technology have also allowed dramatic output increases in modern agriculture. With these improvements, the environmental impact of food production and consumption has also increased (Pimentel and Pimentel, 2000; Rojstaczer *et al*., 2001).

The term 'Nutritional Ecology' was first used by Gussow in 1978 (Gussow, 1978). The term 'Ernährungsökologie' (nutrition ecology) was coined by Leitzmann in 1986 (Spitzmüller *et al*., 1993) and defined as an interdisciplinary scientific area of research that incorporates the entire food chain as well as its interactions with health, environment, society and economy.

Recently, some interesting studies have been published, tackling the problem of sustainable food production and computing the environmental impact of human consumption and its related processes (Beeton, 2003; Imhoff *et al*., 2004). In particular, recent studies show that plant-based diets are environmentally better than meat-based diets (Leitzmann, 2003; Pimentel and Pimentel, 2003; Reijnders

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and Soret, 2003). This study, which is focused on the Italian situation, aims to further explore this topic and to compare the environmental impacts deriving from:

- omnivorous diets, based on products derived from conventional farming and non-organic agriculture;
- omnivorous diets, based on products derived from organic farming and agriculture;
- vegetarian/vegan diets, based on products derived from conventional farming and non-organic agriculture;
- vegetarian/vegan diets, based on products derived from organic farming and agriculture.

By 'vegetarian' we mean a diet that includes any vegetable food and milk, dairy products, eggs and excludes any type of animal flesh (meat or fish), whereas 'vegan' defines a plant-only diet, which excludes any food of animal origin, such as milk, dairy products and eggs.

This research's claims to originality lie in the fact that for the first time a complete diet is assumed as the basis for calculations (a complete diet being defined as the total amount of food that one single person eats in 1 week), whereas previous studies have been limited to single foods or specific comparisons.

The complexity of environmental issues has made it necessary to develop methodologies aimed specifically at evaluating the environmental impact of a product or service in the most nearly objective way. Our research is based on the Life Cycle Assessment (LCA) method, an internationally standardized procedure (ISO 14040 norms; Environmental Management, 2000; Cowell *et al*., 2002; Matthews *et al*., 2002; Ekvall and Weidema, 2004; Rebitzer *et al*., 2004).

Methods

An LCA is an objective procedure for the evaluation of the energy and environmental impacts of a process or activity. It is effected through the identification of the energy and raw materials consumption and of the release of waste into the environment. The assessment includes the whole life cycle of the process or activity, from the extraction and processing of raw materials to the production, transportation, distribution, use, reuse, recycling and final disposal.

According to ISO 14040 regulations, an LCA must include the following phases:

- Goal and Scoping.
- Life Cycle Inventory.
- Life Cycle Impact Assessment, LCIA.
- Life Cycle Interpretation and Improvement.

Goal and scoping

Three weekly well-balanced diets, equivalent to one another for energetic and nutrient content, have been planned by a registered dietitian: one omnivorous, one vegetarian and one vegan.

Detailed nutrient and energetic intakes are reported in Table 1.

Table 1 Nutrients and energetic distribution following the omnivorous, vegetarian and vegan menu

Omnivorous	*Day 1*		*Day 2*		*Day 3*		*Day 4*		*Day 5*		*Day 6*		*Day 7*		*Daily average*	
	2037 kcal		2092 kcal		2182 kcal		2196 kcal		2057 kcal		2090 kcal		2078 kcal		2105 kcal	
	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g
Protein	16	77	15	76	12	64	14	72	13	64	15	75	15	75	15	72
Lipid	27	59	29	66	34	80	33	78	31	67	29	65	29	64	30	68
Carbohydrate	57	295	56	295	54	297	53	296	56	295	56	296	56	295	55	296
Dietary fibre	100		100		100		100		100		100		100		100	28
Vegetarian																
	2136 kcal		2214 kcal		2201 kcal		2215 kcal		2076 kcal		2060 kcal		2201 kcal		2158 kcal	
	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g
Protein	15	76	14	74	13	66	14	74	13	66	14	69	13	69	14	71
Lipid	30	70	25	59	34	82	33	80	31	68	28	62	26	62	30	69
Carbohydrate	55	296	61	347	53	297	53	296	56	295	58	302	61	302	56	305
Fibre	100		100		100		100		100		100		100		100	32
Vegan																
	2306 kcal		2382 kcal		2229 kcal		2370 kcal		2306 kcal		2229 kcal		2265 kcal		2298 kcal	
	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g
Protein	15	83	14	81	14	75	14	78	15	83	14	75	13	70	14	78
Lipid	31	77	26	66	29	69	26	67	31	77	29	69	27	66	28	70
Carbohydrate	54	317	60	368	57	323	60	364	54	317	57	323	60	345	57	337
Fibre	100		100		100		100		100		100		100		100	36

These three different diet plans, combined with two different methods of food production and cattle rearing, together make up six different 'dietary patterns'.

In addition, average Italian food consumption has been used as a reference (Eurostat, 2000; Euromeat, 2001; FAO, 2001), and a seventh dietary pattern, the 'actual' or 'normal' Italian one, has been added to the above-mentioned ones. The seven dietary patterns will be referred to through the following abbreviations:

- OMNIV-INT omnivorous diet based on food from conventional farming.
- OMNIV-BIO omnivorous diet based on food from organic farming.
- VEGET-INT vegetarian diet based on food from conventional farming.
- VEGET-BIO vegetarian diet based on food from organic farming.
- VEGAN-INT vegan diet based on food from conventional agriculture.
- VEGAN-BIO vegan diet based on food from organic agriculture.
- NORM-INT 'normal' Italian diet, equivalent to the average Italian weekly diet, with food from conventional farming.

Taking an average person as an example, the seven diet plans will be examined in order to assess their complete environmental impacts, taking into account:

- damages to human health (substances which have a negative impact on respiration, organic and inorganic compounds, carcinogenesis, climate change and ozone, ionizing radiations);
- damages to ecosystems quality (ecotoxicity, acidification and eutrophization);
- damages to resources (use of primary resources and of fuel).

Life Cycle Inventory

In this phase, which is the central and most demanding core of any LCA, the necessary data are collected and a model representing the whole life cycle of the products, processes and activities is prepared.

In some case, it has been necessary to subsume individual foods into overall categories in order to have a simpler explanation and the possibility to compare our results with extant databases or previous literature which, sometimes, present simplified data for 'fruits', 'vegetables' and 'cheese'.

In this case, we gave a weight to each food category depending on the percentage of Italian consumption.

The software we selected to carry out the Inventory Analysis and the Impact Assessment is SimaPro5 (Goedkoop and Oele, 2001).

The sources for the data collection process were textbooks and scientific papers describing specific case studies (Aghina and Maletto, 1979; Watanabe, 1989; Conso, 1992; Barnard, 1994; CORINAIR, 1996; Moriconi, 1997; Cederberg, 1998; Frees, 1998; Høgass Eide and Ohlsson, 1998; ANPA, 2000; Fukuoka, 2001; Baldoni and Giardini, 2002, 2002a, 2002b; Høgass Eide, 2002; Beeton, 2003; Leitzmann, 2003; Pimentel and Pimentel 2003; Reijnders and Soret, 2003; Imhoff *et al*., 2004).

Life Cycle Impact Assessment

The LCIA is the phase where the transition from data collection and analysis to the study of environmental impacts is effected.

Here the impact of each single process on the overall damage is quantified.

The elements necessary to an assessment of impact are:

- the selection of impact categories (environmental effects) and of the environmental indicators that represent them;
- the attribution of the results of inventory analysis to the selected impact categories (classification) according to the effects they have or may have on the environment.

This is effected by attributing a 'weight' to each substance. This weight, which is an adimensional value, is attributed according to the more or less intense effect each substance has on the environment.

The assessment phase has been conducted using Ecoindicator 99, a damage-oriented method that analyses the impact according to three large damage categories, each of them subsuming various impact categories (Goedkoop and Spriensma, 2000).

We used the 'Eco-Indicator 99 W' method, obtained from a modification of the standard method 'Eco-Indicator 99', proposed by the Simapro software. The purpose of this modification was to include among the resources, the resource 'water', which has been included in the Minerals impact category, and thus automatically in the Resources damage category. Because in Simapro the impact of each mineral is evaluated as the amount of energy necessary for future extractions, the unit of measure used to evaluate the impact of water was the amount of energy, expressed in MJ, necessary to extract 1 kg of material (Mattoni, 2000).

Ecoindicator 99 has been chosen because it is well suited for Europe: damages are normalized with reference to the damage caused by a European citizen in a year. Damage assessment within each of the three categories is then combined into a 'single score', allowing to assign 'scores' to each scenario.

The relative weight of the three categories in defining the index is established according to three different models, which represent three 'cultural approaches' to the question of environmental issues:

- *Individual perspective* – I: This perspective only considers substances, which have demonstrable short-term adverse effects (100 years at the most); it further assumes that the adoption of technological measures and economic development can solve all environmental problems. As a consequence, the Individual perspective does not consider at all the consumption of fossil fuels; this makes it impossible to use this perspective as a comparison in the Resources Assessment.

- *Hierarchical perspective* – H: This perspective considers all substances for which a consensus has been reached on medium-term adverse effects, even if the effects have not been demonstrated; it further assumes that environmental problems can be solved through political choices.
- *Egalitarian perspective* – E: This perspective considers all substances that may have long-term adverse effects, even if no consensus has been reached about these effects; it is a very conservative perspective, based on the assumption that environmental problems are difficult to solve and may result in catastrophes.

The LCA has been carried out three times, one for each standard perspective.

Life Cycle Interpretation and Improvement

This is the phase in which the results of the Inventory and/or of the Impact Analysis are elaborated according to the objective and purpose of the study so as to make it possible to formulate conclusions and recommendations.

It is the final phase of an LCA and its purpose is to propose the changes, which are necessary to reduce the environmental impact.

Results

The results of the analysis are expressed in points (Pt), the unit of measure which the software uses to assign a numeric value to environmental impact. The higher the 'score' in Pt, the higher the damage done to the environment.

The results for the seven patterns, according to the three kinds of the above-mentioned perspectives, are reported in Tables 2–4.

As an example, Table 5 reports the impact for various single food within the OMNIV-INT menu, using the Hierarchical perspective.

The comparison between the average environmental impact of the seven dietary patterns, obtained through the three different perspectives, is shown in Figure 1.

Discussion

Some results were predictable and have been largely confirmed in our study:

(1) Within the same method of production, the 'normal' unbalanced diet turns out to have the greatest impact on the environment.
(2) Within the same method of production, a greater consumption of animal products translates to a greater impact on the environment.

Table 2 Results categorized by target of environmental impact obtained through the hierarchical perspective (H) in points

Impact category	*Norm – INT*	*Omniv –BIO*	*Omniv – INT*	*Vegan – BIO*	*Vegan – INT*	*Veget – BIO*	*Veget – INT*
Total	5.75000	1.36000	2.34000	0.59900	0.85400	1.03000	1.56000
Carcinogens	0.03140	0.00279	0.01460	0.00067	0.00661	0.00258	0.01050
Respiratory organics	0.00280	0.00095	0.00145	0.00023	0.00033	0.00087	0.00128
Respiratory inorganics	0.94200	0.22800	0.45600	0.04860	0.13700	0.18600	0.35300
Climate change	0.17400	0.02940	0.05960	0.00610	0.01810	0.02340	0.04530
Ozone layer	0.00034	0.00011	0.00018	0.00003	0.00005	0.00010	0.00016
Ecotoxicity	0.01780	0.00143	0.00824	0.00035	0.00381	0.00132	0.00587
Acidification/eutrophication	0.21400	0.03830	0.09430	0.00661	0.03230	0.02530	0.06420
Land use	0.31400	0.18100	0.12100	0.05240	0.05800	0.12000	0.06960
Minerals	2.86000	0.56900	0.95900	0.40900	0.40900	0.38300	0.48900
Fossil fuels	1.20000	0.31100	0.62200	0.07500	0.18900	0.28700	0.51800

Table 3 Results categorized by target of environmental impact obtained through the Egalitarian perspective (E) in points

Impact category	*Norm – INT*	*Omniv – BIO*	*Omniv – INT*	*Vegan – BIO*	*Vegan – INT*	*Veget – BIO*	*Veget – INT*
Total	5.12000	1.27000	2.02000	0.56600	0.76800	0.92200	1.29000
Carcinogens	0.02340	0.00208	0.01090	0.00050	0.00492	0.00192	0.00782
Respiratory organics	0.00209	0.00071	0.00108	0.00017	0.00025	0.00065	0.00096
Respiratory inorganics	0.70500	0.17100	0.34100	0.03650	0.10300	0.14000	0.26400
Climate change	0.13000	0.02190	0.04440	0.00455	0.01350	0.01740	0.03380
Ozone layer	0.00026	0.00008	0.00014	0.00002	0.00004	0.00007	0.00012
Ecotoxicity	0.02970	0.00238	0.01370	0.00058	0.00634	0.00220	0.00979
Acidification/eutrophication	0.35700	0.06380	0.15700	0.01100	0.05380	0.04220	0.10700
Land use	0.52300	0.30200	0.20200	0.08730	0.09670	0.20000	0.11600
Minerals	2.69000	0.53600	0.90300	0.38500	0.38500	0.36100	0.46100
Fossil fuels	0.66100	0.17000	0.34300	0.04100	0.10500	0.15700	0.28500

Table 4 Results categorized by target of environmental impact obtained through the Individual perspective (I) in point

Impact category	*Norm – INT*	*Omniv – BIO*	*Omniv – INT*	*Vegan – BIO*	*Vegan – INT*	*Veget – BIO*	*Veget – INT*
Total	109.00000	21.70000	36.60000	15.40000	15.60000	14.60000	18.70000
Carcinogens	0.02280	0.00250	0.01070	0.00061	0.00465	0.00232	0.00789
Respiratory organics	0.00666	0.00226	0.00345	0.00054	0.00079	0.00206	0.00304
Respiratory inorganics	0.70300	0.06460	0.28400	0.00578	0.12100	0.02210	0.16700
Climate change	0.43300	0.07210	0.14600	0.01490	0.04420	0.05690	0.11100
Radiation	x	x	x	x	x	x	x
Ozone layer	0.00071	0.00022	0.00038	0.00005	0.00010	0.00021	0.00033
ecotoxicity	0.00241	0.00021	0.00112	0.00005	0.00051	0.00019	0.00080
Acidification/ eutrophication	0.20300	0.03630	0.08950	0.00627	0.03060	0.02400	0.06090
Land use	0.29800	0.17200	0.11500	0.04970	0.05500	0.11400	0.06600
Minerals	107.00000	21.30000	35.90000	15.30000	15.30000	14.30000	18.30000

Table 5 Results by target of environmental impact and single food in the OMNIV-INT diet in descending order of magnitude through the Hierarchical perspective (H) in point

Impact category	*Total*	*Carcinogens*	*Respiratory organics*	*Respiratory inorganics*	*Climate change*	*Ozone layer*	*Ecotoxicity*	*Acidification/ eutrophication*	*Land use*	*Minerals*	*Fossil fuels*
Total	2.34000	0.01460	0.00145	0.45600	0.05960	0.00018	0.00824	0.09430	0.12100	0.95900	0.62200
Beef	0.39700	0.00195	0.00013	0.06970	0.00979	0.00002	0.00112	0.02070	0.02360	0.21000	0.06010
Sole fish	0.32300	0.00175	0.00010	0.03780	0.00497	0.00001	0.00101	0.00870	0.02110	0.19500	0.05240
Fresh cheese	0.23800	0.00121	0.00027	0.06250	0.00791	0.00003	0.00065	0.00950	0.00604	0.05450	0.09480
Aged cheese	0.19000	0.00097	0.00022	0.05000	0.00633	0.00003	0.00052	0.00760	0.00484	0.04360	0.07590
Milk	0.17600	0.00090	0.00020	0.04630	0.00586	0.00002	0.00048	0.00704	0.00448	0.04040	0.07030
Yoghurt	0.17100	0.00088	0.00019	0.04510	0.00571	0.00002	0.00047	0.00686	0.00437	0.03940	0.06850
Vegetables	0.15500	0.00193	0.00007	0.03570	0.00474	0.00001	0.00112	0.00900	0.01850	0.03610	0.04810
Tuna fish	0.12900	0.00070	0.00004	0.01510	0.00199	0.00001	0.00040	0.00348	0.00843	0.07780	0.02100
Poultry	0.09840	0.00055	0.00002	0.01050	0.00139	<0.00001	0.00032	0.00258	0.00693	0.06180	0.01430
Grana cheese	0.08310	0.00042	0.00009	0.02190	0.00277	0.00001	0.00023	0.00333	0.00212	0.01910	0.03320
Rice	0.06750	0.00025	0.00001	0.00459	0.00061	<0.00001	0.00014	0.00116	0.00152	0.05310	0.00618
Whole bread	0.06110	0.00035	0.00001	0.00650	0.00086	<0.00001	0.00020	0.00164	0.00513	0.03760	0.00876
White bread	0.05600	0.00032	0.00001	0.00595	0.00079	<0.00001	0.00019	0.00150	0.00470	0.03450	0.00803
Pasta	0.03790	0.00022	0.00001	0.00404	0.00054	<0.00001	0.00013	0.00102	0.00319	0.02340	0.00544
Fruit	0.03590	0.00055	0.00002	0.01020	0.00135	<0.00001	0.00032	0.00257	0.00121	0.00590	0.01370
Crisp bread	0.01220	0.00007	<0.00001	0.00130	0.00017	<0.00001	0.00004	0.00033	0.00103	0.00752	0.00175
Jam	0.00314	0.00005	<0.00001	0.00089	0.00012	<0.00001	0.00003	0.00023	0.00011	0.00052	0.00120
Sugar	0.00187	0.00002	<0.00001	0.00045	0.00006	<0.00001	0.00001	0.00011	0.00035	0.00026	0.00060

(3) Within the same dietary pattern, chemical–conventional production methods have a greater environmental impact than organic methods.

As a consequence, independently from the perspective selected, the 'normal' diet based on products from chemical–conventional agriculture and conventional farming (NORM-INT) turns out to have the greatest environmental impact, whereas the vegan diet based on organic products (VEGAN-BIO) turns out to have the smallest environmental impact.

These results were predictable as a consequence of the results already obtained and/or discussed by other authors, in different countries and different situations, that will be cited or discussed during the analysis of the different impact typologies.

The objective of our study was to identify the so-called 'critical points' of environmental impact, to single out the smallest changes in eating patterns leading to the greatest benefits for the environment, rather than analyse extreme situations.

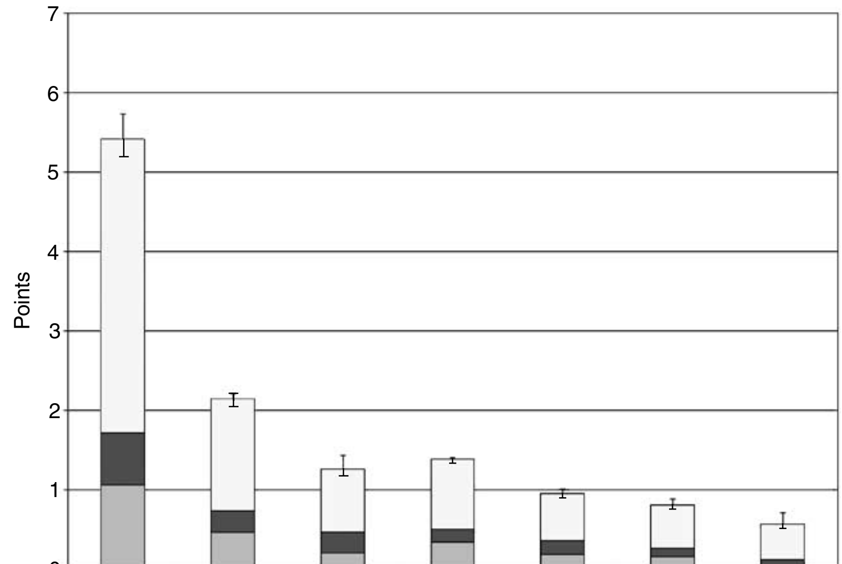
This choice derives from two preliminary remarks:

(1) people generally and openly display extreme reluctance to change their eating habits;
(2) a change in the eating habits and in the dietary trends of developing countries may play an important role in the arrest and reversal of some major current environmental problems.

If the impact of single foods is analysed, we see that:

1. (1) Beef is the single food with the greatest impact on the environment; this is true for all the perspectives.
2. The other high impacting foods are cheese, fish and milk; this also is true, with little differences, for all the perspectives.

If we analyse the different impact typologies of omnivorous diets in order of increasing importance, the following



	NORM - INT	OMNIV - INT	OMNIV - BIO	VEGET - INT	VEGET - BIO	VEGAN - INT	VEGAN - BIO
Resources	3.7	1.415	0.798	0.878	0.594	0.544	0.455
Ecosystems quality	0.65	0.268	0.265	0.167	0.177	0.112	0.0714
Human health	1.06	0.458	0.2	0.335	0.18	0.15	0.0397

Figure 1 Average environmental impact: comparison among the various dietary patterns, expressed as the average of the results obtained through the three different perspectives.

results are confirmed across different analytic perspectives and production methods:

(1) Three to four per cent of the overall impact is due to eutrophication processes: This kind of impact, which is normally the consequence of chemical–conventional agriculture, also plays a role in organic production methods: the impact of animal waste, that is, liquid manure from livestock cleanliness, on the ecosystem is comparable to the impact of pesticides and chemical fertilizers (World Watch Institute, 2004).

In Italy, farm animals produce about 19 million tons per year of waste that, owing to their poor organic content and high pollutant content, cannot be used as fertilizers. At present, they are spread over the ground, leading to severe nitrogen pollution problems, which in turn lead to pollution of water springs, waterways and eutrophication of seas (Moriconi, 2001).

(2) Five to thirteen per cent of the impact is due to land use: According to EU Commission data, Europe can grow enough vegetable proteins to feed all its inhabitants, but not all its farm animals. Only 20% of the proteins that are fed to animals originates in Europe. The missing amount is imported from other countries, including developing ones, playing an important role in the further impoverishment of these countries and in the exploitation of their environmental resources (FAO, 2001). The increase in the use of land for animal husbandry purposes is linked to deforestation and to the modification of the management of rainforests (Denslow and Padoch, 1988).

Every year 17 million hectares of rainforests are destroyed, and the trend is increasing: the Institute for Space Research of the Brazilian government has documented a 40% growth of deforestation from 2002 to 2003. Even though not all the land is used for rearing cattle, most of it is: in the Amazon 88% of the land cleared from rainforests has been used for grazing; in Costa Rica and Panama the amount is about 70% (WWF, 1997), whereas the influence of wood production in the deforestation process is relatively lower (Kaimowitz *et al*., 2003).

In semi-arid areas like Africa, land is increasingly used for extensive farming of products, which are not used to feed the local human population but are exported to developed countries as cattle feed, or for cattle grazing. This use of land is an important factor responsible for the desertification process. The UN estimate that at present 70% of drylands and about 25% of the total land area of the world is undergoing desertification (UN, 2004).

(3) Fifteen to eighteen per cent of the impact is due to damage to respiration from inorganic chemical compounds, whereas 20–26% is due to consumption of fossil fuels: Both these processes are due to production and transport of foodstuffs; they represent energy management and its related pollution. Their combined overall impact is 35–44% of the total impact.

If animals are considered as 'food production machines', these machines turn out to be extremely polluting, to have a very high consumption and to be very inefficient. When vegetables are transformed into animal proteins, most of the proteins and energy contained in the vegetables are wasted; the vegetables consumed as feed are used by the animals for their metabolic processes, as well as to build non-edible tissue like bones, cartilage, offal and faeces (Moriconi, 2001).

A large amount of energy is also employed in production of animal feed and the upkeep of animal husbandry facilities, from stables to slaughterhouses.

If we only take into account fossil fuel consumption, production of one calorie from beef needs 40 calories of fuel; one calorie from milk needs 14 fuel calories, whereas one calorie from grains can be obtained from 2.2 calories of fossil fuels (Pimentel and Pimentel, 2003; Reijnders and Soret, 2003).

(4) Water consumption represents by itself the most dramatic impact: it counts for 41–46% of the overall impact: Animal farming and agriculture are responsible for 70% of freshwater consumption on the planet, whereas only 22% of water is used by industry and 8% is used for domestic purposes (World Watch Institute, 2004).

This is the reason why, during the yearly 'Water Week' which took place in Stockholm in August 2004, the foremost specialists in water resources explicitly linked the issue of water shortage with eating habits and explained that the planet's freshwater reserves will no longer be sufficient to feed our descendants with the present Western diet: 'Cattle feed on grains; even those which are left to graze need much more water than is necessary to grow cereals. Nevertheless, consumers in the developed countries, and even in developing ones, are asking for more meat. It will be almost impossible to feed coming generations on the same diet which we now have in Western Europe and in North America.' The executive director of the Stockholm International Water Institute added that the rich countries will be able to buy their way out of the dilemma by importing 'virtual water', that is, food (cattle feed or meat) from other countries, even from water-poor ones.

The concerns of the water experts can be more easily understood if we consider that most of the water consumed from agriculture is used to irrigate cereals or oleaginous seeds (soy, sunflower, cotton, linseed, etc.), which are, in turn, used as: food and protein integrators in cattle feed; to keep agricultural productivity high in order to feed cattle and to keep their intestines active; to quench their thirst; to clean stables, milking halls; slaughterhouses and so on (Pimentel *et al*., 1997; Renault and Wallender, 2000).

The above considerations seem to support the opportunity of educating people living in developed countries to 'change their attitude with regard to consumption and to individual behaviour', as stated in the first objective of the 'EU programme in favour of the environment and of a sustainable development'. A shift in eating habits towards the increase of the direct consumption of plant foods seems to be a desirable objective in this perspective. Owing to their lighter impact, confirmed also by our study, vegetarian and vegan diets could play an important role in preserving environmental resources and in reducing hunger and malnutrition in poorer nations (Gussow, 1994; Fox, 1999).

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