Online resources for teaching units on: Ecological footprint of human food

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Abstract

The modern food system involves high consumption of natural resources and other forms of environmental degradation. This paper is a presentation of internet resources such as scientific contributions, graphics, tables, images, animations and interactive atlases that can help to teach this subject. The discussion contains some subjects considered relevant, found among the cited internet resources, such as a comparison between organic and conventional agriculture. The different amounts of natural resources required for growing different crops, the differences between animal and vegetal food, the food system and strategies to save energy are considered as well.

Some documents deal with the consequences of alimentary choices on food security and health.

Some texts concern fishery resources, the sustainability of their catch, physical changes of the ecosystems due to overfishing and aquaculture, a fast growing activity which is offsetting the decline of marine fisheries.

Keywords: farming, ecological footprint, overfishing, internet resources.

Introduction

The modern system of production, collection, preservation, packaging, transportation and distribution of food, involves high consumption of natural resources, eg. water and energy. Unlike ancient times, the amount of fossil energy expended in these activities is much greater than that which, man then obtains from the food. However sustainable choices are possible, depending on the origin and other characteristics of the food.

Aims of the teaching unit

Internet resources have been searched such as documents that can help students understand how consumption of natural resources, environmental degradation, and sometimes health problems may be related to different kinds of food that usually come to our table.

The resources could also be used to stimulate reflexions on the importance of a conscious eating behaviour for the environment and for health.

The subject is very complex and this manuscript, written exclusively on the basis of the cited documents, is just an introduction to the study thereof.

Materials and methods

This manuscript will present to the reader: texts, graphics, tables, images, animations and interactive atlases found on the Internet. Any teacher may use them as he deems, to inform the students on the subject. In our middle school, the use of the computer lab has allowed for the use of images and animations to help during face to face explanations. In addition to the explanation, during the English lesson

the students have translated into Italian some lines from the related documents, thus reinforcing the message and beginning to learn to read scientific papers.

Discussion and conclusion

In agriculture energy is consumed primarily for working the soil, planting, watering, harvesting the crops, producing and distributing fertilizers and pesticides. The heating of greenhouses for getting fresh perishable produce out of season has energy costs as well. Some statistics also consider the energy used to produce agricultural machinery.

According to an analysis of agriculture in Bangladesh between 1980 and 2001 (Alam et al. 2005), modernization has increased yields by 70% allowing the country to achieve food self-sufficiency. During the same period consumption of chemical energy, embedded in the form of pesticides, has increased by 6.8 times, while that incorporated into fertilizers has increased by 261%. The abuse of these products is often associated with pollution, threats to biodiversity and to soil fertility.

In an FAO document, J. Ziesemer (2007) compares the energy consumption concerning organic and conventional agriculture. The former uses natural substances which are often locally produced, instead of the chemically synthesized fertilizers and pesticides utilized for the latter. The production of these chemicals has high energy costs, further increased by transport, often over long distances. In conventional agriculture, the use of these chemicals absorbs 37% of total energy input. The paper concludes that generally, organic agriculture needs 30 to 50 percent less energy than comparable non-organic agriculture, and employs about one third more hours of human labour.

The entire food system in the U.S. accounts for 19% of national fossil fuel energy use.

The processing of agricultural products, eg. drying, cooking, packaging, refrigeration and transportation, often requires much more energy than that which was used up until the harvest.

Some of these processes are essential to ensuring conservation and hygiene of the products.

D. and M. Pimentel (1985) dedicated a paper to energy use in food processing, tables 1 and 2 show the amount of energy required to produce various food packages, and energy inputs for processing various products. Large energy consumption can be involved in the production of packaging; to produce a steel can requires a lot of energy, reusable glass jars can reduce this input.

According to N. Church (2005), for 1 calorie embedded in lettuce imported into the UK from the USA, 127 calories are needed for air transport. Including also the energy used for cultivation, packaging, refrigeration, distribution and shopping, consumption would be even higher.

The article also describes the emblematic case of a tomato sauce manufactured in Sweden with Italian tomatoes, the screw-cap of the bottle and plug manufactured in Denmark, the bottles produced in England with materials from Japan, USA etc.. In conclusion, to obtain the final product more than 52 transport and process stages were involved.

Sometimes a country simultaneously imports and exports large quantities of the same kind of product. One example is mentioned: Britain imports annually 61.400 tons of poultry meat from the Netherlands and exports 33.100 tons to the same Country.

Reducing unnecessary transport and the distances between producers and consumers, is a suggested strategy to reduce carbon dioxide emissions.

Chapagain A. K. and Hoekstra A. I. (2006) provide a table showing the amount of water required for the production of some foods. On the same paper there is also information on the amount of water required to produce various cereals. The production of rice for example, implies higher water demands than wheat, because of the higher amount of water that evaporates during its cultivation. To produce animal food, there is generally more water consumption than for plant foods since we must consider the water needed to grow grain or hay to feed the animals, as well as that used for watering, hygiene and for maintenance of the facilities. This article provides inter alias the water footprint of several countries, that differ greatly from each other; there are also differences dealing with the efficiency with which water is used in the different countries.

On the website of GRID-UNEP (3), there are many graphics that deal with the environment; here typing *sick water* and then selecting *water for food*, there is a graphic on the volume of water required to produce 1 kg of food.

Today agriculture accounts for more than 70% of total water use (2). In countries with an arid climate the percentage can be higher, since there is a greater dependence on irrigation. The needs for food could roughly double in the next 50 years and this suggests a better water management. Many countries in the Near East, Africa, Mexico as well as large parts of Asia, suffer from water scarcity. Furthermore in several geographical areas, fossil aquifers are being used, which in future will be completely exhausted. This site, is full of animations, posters, educational and interactive atlases.

Animations are available on the water cycle, and on how the rain and water withdrawal from the ground, affects the level of water tables and rivers (2-4).

The modern animal farming, according to an FAO document (1), can be resource intensive. Cattle require 7 kg of grains to produce 1 kg of beef, which suggests how much energy and water are necessary for their farming. Poultry requires 2 kg of cereals to produce 1 kg of chicken.

According to the FAO website (2) dedicated to water, it takes 1,500 l of the latter to produce 1 kg of wheat, while for a kilogram of beef are needed 15,000 l.

The website of Water Footprint (30, *training materials*, *info graphics*) has much information.

Animal farming is by far the activity which requires the largest land use. The pastures occupy 26% of the earth's surface, while the production of feed is using one third of all arable land. Increased global demand for feed is the main reason for deforestation (9). In Latin America, 70% of the area previously covered by the Amazon forest is occupied by pastures whereas a large part of the remaining deforested area is covered by feed crops. Deforestation causes loss of biodiversity, environmental degradation and CO2 emissions. Even when deforestation is carried out without fire, there are strong carbon dioxide emissions since when the forest land is tilled, hence exposed to oxygen, there is rapid oxidation of the organic matter, which this soil contains in large amounts. In fact the oxygen accelerates the activity of soil microbes which feed on organic matter (10).

The effect is even much more marked when deforestation concerns peatswamp forests. Large areas of these soils are being drained for agriculture. As a result of drainage, the organic matter that was built up over the millennia, to a thickness that can reach 15 meters (11, animations and explanations selecting *Palm Oil Production, peatland loss & CO2 Emissions - Peatland CO2 alert*), is suddenly exposed to the atmospheric oxygen. In this situation, the organic matter is oxidized and transformed into carbon dioxide, which is released into the atmosphere.

Often these areas after drainage are exposed to fire, which is difficult to extinguish because it is the soil itself that burns, in addition to trees. This creates enormous clouds of smoke crossing international borders, as happens in Southeast Asia.

Cattle produce large emissions of methane, mostly from enteric fermentation, known to many scientists, as having a greater influence than carbon dioxide on climate change. It is interesting to know, that the methane emissions can be reduced by a balanced diet.

Anaerobic digestion of organic wastes generates methane as well, composting avoids its formation since they aerobically biodegrade (28).

Mixed farming systems that include livestock, as often practiced in Third World Countries (12), are environmentally sustainable and can be more productive than systems that rely exclusively on either crops or animals. Animals are fed with agricultural by-products, eg. straw or chopped sugarcanes or juicing residues. In some cases the animals graze the unwanted vegetation growing under plantations, thus reducing the cost of weed control. The possibility to feed animals using agricultural by-products, rather than through fodder plants, can allow using more land for crops for direct human consumption; this clearly favours food security. Furthermore the possibility of using animals for tilling the soil, as commonly happens in Developing Countries, reduces human fatigue in poor areas where machines are not available. Animal manure added to the soil acts as fertilizer, while improving structure and water retention.

Livestock farming on a small scale, spread over the territory, may allow the marketing of products such as meat and milk within short distances, reducing economic and environmental costs of long transport (author's note).

The FAO document (1) also expresses a consideration on World food security. Larger and larger amounts of cereals are shifted from direct consumption of the peoples to animal farming for meat production. This influences the market price of cereals, causing its increase, which affects the poorest segments of the society. Undernutrition is therefore not only due to poverty, but also to increasing consumption of meat from other segments of the society, having as consequence smaller quantities of grains available on the market and at higher price.

According to an FAO document, in the Industrial Countries per capita consumption of meat increased from 61.5 kg in 1964-66 to 88.2 kg in 1997-99, forecasts for 2030 are 100.1 kg. On the same website (5), there are tables on global and regional food consumption.

Some documents below mentioned deal with the relationship between health, consumption of animal products and over-eating.

According to the WHO, to lower the risk of cardiovascular disease a reduced intake of fat from meat and dairy sources (6) is recommended.

The American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention recommend limited consumption of red meat and preserved meat (7) for reducing cancer risk.

According to Young et al. (2002), the increase of food consumption in the U.S., which led to the prevalence of overweight and obesity, has occurred in parallel with the growth of the commercial portions of food and beverages in shops and restaurants. An animation (8) shows that the prevalence of obesity in the U.S. proceeds in parallel with the spread of type 2 diabetes.

The yields of marine fisheries are in decline (13-14), mainly because of environmental degradation and overexploitation of fish stocks. In some cases eg. for Atlantic cod in the East Coast of Newfoundland it has been a real collapse (15 graphic).

Fishing fleets have grown a lot, using increasingly efficient fishing systems. According to a World Bank report (17), rich with graphics, 75% of fish stocks in the world are either fully or overexploited and many fisheries are supported by subsidies. Excess fishing fleets, making big efforts to find and catch increasingly limited fish resources, realize poor productivity and economic inefficiency.

Fishing is among the activities that consume on average more energy, compared to the amount of food produced (18-19). Globally, for every ton of fish caught, half a ton of fuel is consumed.

In fisheries that are subject to either little or no management, attempts of some fishermen to moderate the intensity of their own catch to prevent overexploitation, will only result in a benefit to others who would see their yield increased. This situation has tended therefore, to cause overuse, instead of conserving the resources (16).

If fish stocks were rebuilt, fishing efforts could be halved, still achieving the current fishing levels.

As rebuilding measures, seasonal closures have also often been proposed, but they were not effective when fishing capacity remained excessive. Moratoria proved useful, eg. in restoring herring fisheries in the North Atlantic and Northeast Pacific. The allocation of fishing rights based on quotas has proved effective.

Given the fundamental importance that there is no interference with the life cycle of fish stocks, area closures, both permanent (sanctuary) or not, to protect spawning or nursery habitats or migratory corridories, in some cases have been used (20).

According to the Committee on Ecosystem Management for Sustainable Marine Fisheries (1999), *overfishing may physically change an ecosystem*.

The Caribbean coral reef ecosystems, formerly included sea urchins, which feed on algae, herbivorous fishes and several species of corals. There has been a strong reduction of herbivorous fishes, removed by overfishing over a long period. In 1980, a hurricane produced massive devastation to the coral reefs around Jamaica. The corals began to recover, but in 1983 when a disease decimated the population of sea urchins, the recovery stopped since in a situation of almost total absence of herbivores, algae could spread without being controlled, thus completely covering the corals. So while in 1977 the coral cover was 52%, this was reduced to 3% in the early 1990s and the cover of algae increased from 4% to 92%. High nutrient concentration in the water, contributed to promote the growth of algae at the expense of corals, thus adversely affecting the coral reef ecosystems.

In other situations, where a heavy reduction in the number of predators has been observed, caused by overfishing or other causes, the consequence has been an

uncontrolled growth of herbivorous animals' populations. An excess of the latter, feeding intensively on vegetation, can greatly reduce the algal cover of the bottom, thus limiting food availability for herbivores themselves, spawning and nursery grounds for fishes and other animals.

Discards are animals returned to the sea after being caught, because they have no interest for the fishermen. During 1988-90, on a global base, the discards amounted to about 27 million tonnes per year, or about one third of the World total fishery yield, which is hovering at around 80-85 million tons per year. In some fisheries discards are quite limited, while in others they are very high.

Shrimp trawling results in 10 million tons/year of discards, the biomass of the latter is *5 times* greater than that of shrimps. Among the discards are included young fish of commercial interest and adults of species that mature at less than 10 cm in length.

Some mitigation of the problem is possible through the development of gears with better selectivity. Shrimp trawling was killing 11,000 endangered sea turtles a year in the Gulf of Mexico and off the South-Eastern U.S. coast. The adoption of the turtle excluding device (21 image) reduced this mortality. Other large animals like sharks, accidentally entering into the net, can escape thanks to this device.

Certification and ecolabelling programs issue a label on fish products from sustainable fishing operations; one of these (22 select *Playroom, fun &games*) produces animations and other educational materials for schools on the subject.

Aquaculture is a fast growing activity, and is offsetting the decline of marine fisheries (13 fig. 1).

Fishes reared in the rice fields feed on unwanted plants and insects that damage the rice, they also fertilize the rice fields with their droppings. Some fish feed on mosquito larvae, thus reducing the spread of diseases like malaria (23-24). In China fish production in rice fields, on average, is 180 kg per hectare. This practice can reduce or eliminate pesticide use, thus promoting biodiversity. In addition to environmental benefits, there can be more positive effects from the nutritional point of view, enabling farmers' communities to collect a lot of crabs, snails and frogs, living in the rice fields.

Growing fish in tanks or ponds may require different energy inputs, depending on how they are fed.

The International Centre for Aquaculture and Aquatic Environments provides a technical brochure with images, on polyculture fish farming (25). Mixed fish farming entails better utilization of the available natural food produced in a pond. The yield can be increased by fertilizing the pond or providing additional food, such as agricultural by-products.

In the World, out of about 80-85 million tons caught yearly, 30 million tons of fish are processed to produce fish meal, which is then used as feed for animals, including carnivorous farmed fish. For example, edible fish considered of low economic value such as anchovies and sardines, are processed to produce highly valued fish such as salmon. According to Pinto F. and Furci G. (2006), in Chile to produce 1 kg of salmon, 8.5 kg of such food-grade fish are consumed. Although this activity is an economic success, it consumes far more protein than it produces. The FAO Review of the State of World Fisheries reports increasing doubts (26), about the efficiency and the ethics, of feeding to farmed animals food-grade fishery resources, instead of using them directly for humans.

The website of LCA Food has much information, here (29, *fish*), impressive footprint differences among fishes can be observed.

According to US Environment Protection Agency predatory fish farming also entails the phenomenon of biomagnification of pollutants (27), which may be present in the ecosystem. Many chemicals such as DDT and PCBs tend to concentrate at every step of the food chain from plants to herbivores, and predators. They reach the highest concentrations in predators that are at the end of long food chains. The concentration of certain pollutants in the fatty tissues of predators may be millions of times higher than in the water where they live. For example, eating just one meal of lake trout from the Lake Michigan has the consequence of an exposure to more PCBs, than in a lifetime of drinking the water from the same lake.

Mangrove coastal forests can provide significant mitigation against tsunamis and storm waves. The villages protected by dense coastal mangrove forests exhibited a low level of damage after the tsunami that struck South Asia in 2004 (31). Where mangroves no longer existed, the damage was generally more severe.

A leading cause of the quick mangrove forest loss is their conversion for aquaculture, especially shrimp farming (32, p. 9). The ponds used for shrimp farming are abandoned, after a few years, and there is little chance of mangrove regeneration in the remaining barren lands.

"International Principles for Responsible Shrimp Farming" (33) is a document which provides principles for a more sustainable development of shrimp farming. Among these principles, there should be no net loss of mangroves when locating ponds for shrimps, and environmental rehabilitation should be taken into consideration when the farms stop operations.

The students always appeared interested in the proposed activities.

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References

Websites

1) P. A. Yatopulos (1987), The "new" Food-Feed Competition FAO http://www.fao.org/DOCREP/003/X6930E/X6930E02.htm

2) FAO Water (2010), Natural Resources and Natural Department http://www.fao.org/nr/water/infores_multimedia.html

3) UNEP-GRID (2008), Millennium Ecosystem Assessment http://maps.grida.no/go/collection/millennium-ecosystem-assessment

4) Investigating Groundwater, Earthguide diagrams http://earthguide.ucsd.edu/earthguide/diagrams/groundwater/index.html

5) Agriculture and consumer Protection FAO/WHO (2003), Diet, Nutrition and the Prevention of Chronic Diseases http://www.fao.org/docrep/005/AC911E/ac911e05.htm

6) World Health Organisation (2011), Nutrition http://www.who.int/nutrition/topics/5_population_nutrient/en/index12.html

7) American Cancer Society (2008), Guidelines on Nutrition and Physical Activity for Cancer Prevention

http://www.cancer.org/acs/groups/cid/documents/webcontent/002577-pdf.pdf

8) L. Dean, J. McEntyre (2004), Chapter 1 Introduction to Diabetes. The Genetic Landscape of Diabetes (Internet). http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=diabetes&part=A3

9) Agriculture and Consumer Protection Department (2006), Livestock impacts on the Environment FAO http://www.fao.org/ag/magazine/0612sp1.htm

10) Natural Resources Management and Environment Department (2005), The Importance of Soil Organic Matter FAO http://www.fao.org/docrep/009/a0100e/a0100e07.htm

11) Wetlands International (2007) Wetlands for Water and Life http://www.wetlands.org/WatchRead/Videos/PalmoilproductionpeatlandlossCO2emissions/tabid/1471/Default.aspx

12) Natural Resources Management and Environment Department (1996), World Food Summit, FAO http://www.fao.org/docrep/x0262e/x0262e13.htm

13) Fisheries and Aquaculture Department (2000), The State of World Fisheries and Aquaculture Part 1 FAO http://www.fao.org/DOCREP/003/X8002E/x8002e04.htm#TopOfPage

14) GRID-UNEP (2008), Estimates Global Marine Fish Catch UNEP-GRID http://maps.grida.no/go/graphic/estimated-global-marine-fish-catch-1950-2001

15) GRID-UNEP (2008), Collapse of Atlantic Stocks off the East coast of Newfoundland in 1992 UNEP-GRID http://maps.grida.no/go/graphic/collapse-of-atlantic-cod-stocks-off-the-east-coast-of-newfoundland-in-1992

16) Fisheries and Aquaculture Department (2011), Regulating Fishing Capacity FAO http://www.fao.org/fishery/topic/14857/en

17) Agriculture and Rural development (2011), Sunken Billions: The economic Justification of Fisheries Reform The World Bank http://web.worldbank.org/WBSITE/EXTAgiculture and Rural Development/TOPICS/EXTARD/0,,contentMDK:21930578~pagePK:148956~piPK:216618~theSitePK:336682,00.html

18) Fisheries and Aquaculture Department, The Kyoto Declaration and Plan of Action,..... FAO http://www.fao.org/docrep/006/ac442e/AC442e6.htm

19) Media Centre (2008), US $ 50 billion lost by marine fishing each year FAO http://www.fao.org/news/story/en/item/7972/icode/

20) Fisheries and Aquaculture Department (2011), Depleted stocks recovery: a challenging necessity FAO http://firms.fao.org/fishery/topic/14767/en

21) Office of Protected Resources, Turtle Excluder Devices NOAA Fisheries http://www.nmfs.noaa.gov/pr/species/turtles/teds.htm

22) Marine Stwwardship council (2010), Welcome to Fish and Kids MSC http://www.fishandkids.org/

23) Fisheries and Aquaculture Department (1987), Fish Culture in Rice Fields FAO http://www.fao.org/docrep/field/003/AC180E/AC180E05.htm

24) M. Halwart (1998), Trends in Rice-Fish Farming Fisheries and Aquaculture department FAO http://www.fao.org/docrep/005/w8516e/w8516e3.htm

25) International Centre for Aquaculture and Aquatic Environments, Water Harvesting and Aquaculture for Rural Development Auburn University, Alabama http://www.auburn.edu/~clinedj/Spanish%20Publications%20Website/publications/English%20WHAP/GT5%20Polyculture.pdf

26) A.G.J. Tacon (1997), Review of the State of World Aquaculture FAO http://www.fao.org/docrep/003/w7499e/w7499e16.htm

27) EPA (2011), Great Lakes http://www.epa.gov/glnpo/atlas/glat-ch4.html

28) EPA (2008), Wastes- Resource Conservation http://www.epa.gov/wastes/conserve/rrr/composting/benefits.htm

29) LCA Food Database (2002) www.lcafood.dk/

30) Water Footprint (2008), Water Footprint Network www.waterfootprint.org/

31) K. Forbes, J. Broadhead (2007), The role of coastal forests in the mitigation of tsunami impacts FAO Regional office for Asia and the Pacific http://www.fao.org/docrep/010/ai389e/ai389E00.htm

32) UNEP (2006), Shoreline protection and other ecosystem services from mangroves and coral reefs http://www.unep.org/pdf/infrontline_06.pdf

33) FAO/NACA/UNEP/WB/WWF (2006), International Principles for Responsible Shrimp Farming. Network of Aquaculture Centres in Asia-Pacific (NACA). http://library.enaca.org/shrimp/publications/shrimp-principles-2006.pdf

Bibliography

Alam M.S., Alam M.R. and Islam K.K. (2005). Energy Flow in Agriculture: Bangladesh. *American Journal of Environmental Sciences*, 1(3), 213-220. [Online] http://www.scipub.org/fulltext/ajes/ajes13213-220.pdf

Church N. (2005). Why our food is so dependent on oil. *Energy Bulletin*, Published April 1, 2005. [Online] http://www.energybulletin.net/node/5045

Committee on Ecosystem Management for Sustainable Marine Fisheries, National Research Council (1999). Sustaining Marine Fisheries. *The National Academies Press*, 36-116. [Online] http://www.nap.edu/openbook.php?record_id=6032&page=77

Hoekstra A.Y., Chapagain A.K. (2006). Water footprints of nations: Water use by people as a

function of their consumption pattern. *Water Resour Manage* http://www.waterfootprint.org/Reports/Hoekstra_and_Chapagain_2006.pdf

Pimentel D. and Pimentel M. (1985). Energy use in food processing for nutrition and development. *Food and Nutrition Bulletin, 7*(2). [Online] http://archive.unu.edu/unupress/food/8F072e/8F072E06.htm

Pinto F. And Furci G. (2006). Salmon Piranha Style: Feed Conversion Efficiency in the Chilean Salmon Farming Industry. *Terram* http://www.terram.cl/nuevo/images/storiessalmonpiranhastyle.pdf

Young L. R., Nestle M. (2002). The Contribution of Expanding Sizes to the US Obesity Epidemic. *American Journal of Public Health*, 92(2). [Online] http://steinhardt.nyu.edu/nutrition.olde/PDFS/young-nestle.pdf

Ziesemer J. (2007). Energy use in organic food systems. *Natural Resources Management and Environment Department Food and Agriculture Organisation of the United nations.* Rome August 2007. [Online] http://www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf