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Life Cycle Assessment (LCA) of protected crops: an Italian case study

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ABSTRACT

In this paper a Life Cycle Assessment (LCA) of protected crops was carried out. In particular, energy and environmental performances of peppers, melons, tomatoes, cherry tomatoes, and zucchini in different typologies of greenhouses (tunnel and pavilion) were assessed. The study aimed at assessing the eco-profile of each product and the share of each life-cycle step on the total environmental impacts. The related process flow chart, the relevant mass and energy flows and the key environmental issues were identified for each product. Collection of primary data was conducted by means of a detailed questionnaire distributed to a producer company in southern Italy. The analysis was developed according to the LCA standards of the ISO 14040 series.

The results showed that for all the examined vegetables the packaging step and the greenhouse structures have a relevant share in the environmental impact distribution. Further tunnel and pavilion greenhouses are characterized by comparable ecoprofiles and both of them are characterized by lower energy consumptions than greenhouses in the North of Europe, due to the non-use of auxiliary heating systems in the former.

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1. Introduction

In recent years the food sector has increased its economic and political relevance, attracting the attention of policy makers (Foster et al., 2006).

Food production and consumption has been detected as a system with very varied energy use and carbon emissions between sectors. There are positive opportunities in looking more closely at connections between players in the food system that hold a lot of influence along the production chain. The food production and consumption system could be improved by means of a set of mechanisms, some of which include:

- To address the consumer demand for food goods and services to the creation of a lower carbon food system-based market (for example with carbon labeling of food goods).
- A regulatory incentive structure that leads to whole systems realignment.

To achieve system change, a set of suitable policies will be required and the understanding of how energy is used and greenhouse gases are emitted in food production and consumption. Gaining a good understanding of that represents a challenge. Development and implementation of policy-based tools built on current knowledge needs to take place, close to further research based on LCA and the interconnections of food related energy use.

The above considerations, together with current consumption patterns, have involved an increasing interest to report the environmental performance of food products (Mintcheva, 2005).

The European study on the Environmental Impact of Products (EIPRO) showed that the "food and drink" sector involves 20–30% of the total environmental impacts of EU consumption, with regard to global warming, acidification, photochemical ozone formation, and eutrophication (Tukker et al., 2006; Schau and Fet, 2008). Thus "food and drink" is a priority sector within Sustainable Production and Consumption (SCP) policies developed by the European Commission. SCP promotes the assessment of the environmental performance of these products' supply chains, the identification of improvements and the communication of environmental information to consumers (European Commission, 2007).

Depending on the large number of processes, of the operational units and of the companies that contribute to the overall product chain, the assessment of the whole chain burdens becomes relevant to improve the energy and environmental performances of food products (Cellura et al., 2010; Meisterling et al., 2009). In this context, the Life Cycle Assessment (LCA) methodology, as described

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by the international standards of series ISO (2006a,b) 14040, represents the methodological "backbone" of sustainable production and consumption patterns, allowing the gathering of data on environmental issues to be applied to restructure the supply chain in order to improve its global environmental performances (Hagelaar and van der Vorst, 2001).

LCA methodology is becoming more and more important in the agro-food sector, as it allows to assess the environmental performances of products, from their very beginning, throughout their whole life cycle and to identify differences in resource consumption and environmental impacts among different systems with equivalent functions (Beccali et al., 2009; Blengini and Busto, 2009). For these reason, it can be used as a decision tool to support the choices of the following groups of stakeholders:

- The producers of the investigated product, to improve the ecoprofile of the related production system.
- The consumers of the investigated product to address their purchasing decisions.
- Policy makers, to inform longer-term strategy.

The extension of the assessment to the entire food chain analysis allows the identification of "where" and "how" the resources are consumed and the emissions occur.

This approach can ensure that the environmental impacts throughout the life cycle are treated in an integrated way and consequently they are not just shifted from one step to another.

Besides, by means of organization specific life cycle-based tools, as Environmental Management Systems (EMS) and Environmental Products Declaration (EPD), food producers can support the choice of consumers with environmental information on their products (European Commission, 2001; IEC, 2008).

Starting from the above considerations, the authors carried out a LCA study aimed at investigating the environmental performances of the food sector, with a particular focus on the cultivation of protected crops in the Mediterranean area. In particular, the study was aimed at assessing the ecoprofile of peppers, melons, tomatoes, cherry tomatoes, and zucchini in different typologies of greenhouses and the contribution of each life-cycle step on the total environmental impacts. Further the key environmental issues were identified for each product.

2. Materials and methods

The following energy and environmental analysis was developed in compliance with the international standards of series 14040 (ISO, 2006a,b).

2.1. Goal and scope definition

The ecoprofile of five protected crops was estimated (tomatoes, cherry tomatoes, peppers, zucchinis and melons), including indirect environmental impact related to energy source generation, water and raw materials supply. Energy and environmental hot-spots were identified to define suitable options of improvement.

The method used for the impact assessment was CML 2001, developed by the Centre for Environmental Studies (Guinee et al., 2001), according to which the following impact categories were assessed:

- Global warming
- Ozone depletion
- Photochemical Oxidation
- Acidification
- Eutrophication
- Human Toxicity
- Fresh water aquatic Ecotoxicity
- Marine aquatic Ecotoxicity
- Terrestrial Ecotoxicity.

Global Energy Requirement (GER) was accounted according to the Cumulative Energy Demand Method (PRè-Product Ecology Consultants, 2010). Further water consumption and wastes were estimated.

2.2. Description of the production process

The case study was referred to a single company in southern Italy, which is characterized by a high level of specialization, with different productive rotating cycles in greenhouses that allow an almost continuous yield of different crops all year. It owns 50,000 m^2 of cultivated fields, subdivided in:

- 3 pavilions of 10,000 m^2, which are used to crop tomatoes, cherry tomatoes and melons, respectively;
- Two tunnel of 10,000 m^2, both for zucchinis and peppers.

In detail, cultivation process can be subdivided in the following steps:

- *Management of greenhouse*: construction, maintenance and disposal of pavilions or tunnels.
- Land preparation for the seeding, which includes ploughing and leveling of the soil.
- Preliminary treatments, which include the use of pesticides and herbicides inside the greenhouse. Successively, organic manure and chemical fertilizers, applied into water solutions, are added to enrich soil.
- *Mulching*: the bottom of the greenhouse is covered with a protective plastic sheet, generally a layer of LDPE with a thickness of 30–60 μm, aimed to reduce water consumption for irrigations, to limit the growth of parasitic plants, to avoid the soil erosion and protect the plants roots, to reduce heat losses in the greenhouses, and to support the growth of the useful micro-flora.
- *Seeding*: vegetables are first grown into apposite boxes of expanded polystyrene (EPS). Their use increases not only the chances of survival of small plants, but also involves resource consumption and plastic waste generation. The use of insects for pollination was not taken into account.
- Chemical fertilization and pesticide-based treatment, corresponding to the vegetative cycles of the plants. Chemicals are distributed by means of the irrigation systems.
- Irrigation, which takes place with water extracted from local wells, applied throughout the entire vegetative cycles, depending on the plant demand. Irrigation uses the efficient technique of micro-irrigation with small pierced pipes, where the water flow is reduced correspondingly to the absorption capacity of the plants and is limited only to the upper part of the soil. Such a system allows to save water source, to optimize the distribution of fertilizers and to reduce the transfer of nitrates to the water table. Water pumps are fed by a diesel generator.
- *Harvest of matured crops*: at the end of their vegetative life plants are chopped and mixed to the soil as organic manure, involving a double benefit: to reduce the impoverishing of the soil and to decrease the waste production.

2.3. Functional unit

A *product system* is a set of materially and energetically connected unit processes that performs one or more defined functions

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