Journal of Cleaner Production xxx (2016) 1–10

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Life Cycle Assessment of organic and conventional apple supply chains in the North of Italy

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ARTICLE INFO

Article history:
Received 11 November 2015
Received in revised form
27 January 2016
Accepted 9 February 2016
Available online xxx

Keywords:
Apples
Life cycle assessment
Organic
Conventional
Energy
Environmental impacts

ABSTRACT

This paper compares the energy and environmental impacts of organic and conventional apples cultivated in the North of Italy, by applying the Life Cycle Assessment (LCA) methodology.

The authors examined the supply chain of apples, including the input of raw materials and energy sources, the farming step, the post-harvest processes and the distribution of apples to the final users.

The paper develops two original contributions: 1) it enhances the limited number of studies on LCA applied to apples; 2) it compares organic and conventional apples produced in lands characterized by the same climatic conditions, to evaluate which of the two products is more competitive from an energy and environmental point of view.

The results showed that, despite a lower productivity, preferring organic apples versus conventional apples could help to reduce the environmental impacts for most of the examined impact categories. With a few exceptions, differences lower than 7% occur between the eco-profiles of the two examined products.

A relevant share of the primary energy consumption and almost all of the examined environmental impacts are caused by the post-harvest processes and by transport to the final users, assuming that the products are distributed on local, national and international markets.

Furthermore, a detailed analysis of the farming step showed that a significant share in the overall energy and environmental impacts is due to the use of fertilizers and pesticides and to diesel consumption of agricultural machines.

1. Introduction

The agricultural sector has a relevant impact on the environment through the resource use and emissions (Cellura et al., 2011a). In detail, farmers manage 40% of the land and every year an estimated 12 million hectares of agricultural soil are lost to land degradation. Agriculture consumes 70% of total global 'blue water' withdrawals from available rivers and aquifers (Beddington et al., 2012). The increasing use of fertilizers involves a significant contribution to greenhouse gases emissions and causes nitrogen emissions (NH_3, N_2O), nitrate leaching, and potassium and phosphorus losses to water (UNEP, 2002).

Agricultural activities in the EU-28 generated 464.3 million tons of CO_{2eq} in 2011, corresponding to about 10% of total greenhouse gas emissions on a world scale. The majority of these emissions are related to agricultural soils (accounting for about a half of agricultural emissions), enteric fermentation (about one third) and manure management (about one sixth). The other sources of agricultural greenhouse gas emissions (field burning of agricultural residues and rice cultivation) are only minor contributors (EU, 2013).

Generally, the environmental impacts from agriculture can be reduced through organic farming, which is an agricultural system that respects natural life-cycle systems.

This technique combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production

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http://dx.doi.org/10.1016/j.jclepro.2016.02.049
0959-6526/

Please cite this article in press as: Longo, S., et al., Life Cycle Assessment of organic and conventional apple supply chains in the North of Italy, Journal of Cleaner Production (2016), http://dx.doi.org/10.1016/j.jclepro.2016.02.049

Nomenclature

Acronyms

Acw	acidification
BS	base scenario
CC	climate change
FE	freshwater eutrophication
FE_{tox}	freshwater ecotoxicity
FU	functional unit
GER	global energy requirement
HT_{ce}	human toxicity – cancer effects
HT_{nce}	human toxicity – non-cancer effects
IR_{hh}	ionizing radiation HH
IR_{e}	ionizing radiation E (interim)
LCA	life cycle assessment
LU	land use
ME	marine eutrophication
OD	ozone depletion
PM	particulate matter
POF	photochemical ozone formation
RD	mineral resource depletion
SA	sensitivity analysis
TE	terrestrial eutrophication
WRD	water resource depletion

method in line with the preferences of some consumers for products grown using natural substances and processes (EU, 2007).

Organic farming practices include[1]:

- Wide crop rotation for an efficient use of on-site resources;
- Strict limits on chemical synthetic pesticide and fertiliser use, livestock antibiotics, food additives and processing aids;
- Prohibition of the use of genetically modified organisms;
- Taking advantage of on-site resources;
- Using plant and animal species resistant to disease and adapted to local conditions;
- Raising livestock in free-range, open-air systems and providing them with organic feed;
- Using animal husbandry practices appropriate to different livestock species.

The European Commission adopted different regulations and guidelines on organic farming. Among these, it is important to report:

- Council Regulation (EC) No. 834/2007 that provides the basis for the sustainable development of organic production (EU, 2007);
- Commission Regulation (EC) No. 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 (EU, 2008);
- Action Plan for the future of Organic Production in the European Union (EC, 2014).

Organic production allows farmers to be more competitive and market-oriented, to keep their land in good agricultural and environmental conditions and to comply with European standards in the fields of environment, food safety and animal health and welfare.

In recent years, prompted mainly by quality concerns and environmental and food safety and in spite of the economic crisis and the growing price of organic products, the European consumers spent over €22 billion in 2013 in this sector, helping the organic market to grow by nearly 6% in comparison to the previous year (Katsarova, 2015).

Policy-makers also have recognised the potential of organic farming as a mean of food production that meets the demands of sustainability and market place.

Around one eighth of the world's organic producers (260,000) are in Europe and, in 2013, they were associated with 10.2 million hectares of land (5.7% of the EU's agricultural area).

[1] http://ec.europa.eu/agriculture/organic/organic-farming/.

In 2013, over 43 million hectares in 170 countries around the world were cultivated organically. However, organic farmland only accounts for 1% of the total worldwide farmland.

Over the past 30 years, international sales of organic foods have grown from almost nothing to over €66 billion in 2013. The largest single market for organic food is USA (€24.3 billion) followed by Europe (€22.2 billion) and China (€2.4 billion) (Katsarova, 2015).

The above figures show that the market of organic food is increasing, and this growth can make important contributions to food supply stability and farmer livelihoods by establishing soil fertility and providing diversity and thus resilience to food production systems in light of the many uncertainties of climate change (Niggli et al., 2007).

The Life Cycle Assessment (LCA) methodology can be the basis for assessing the environmental sustainability of organic agriculture, and for identifying options aimed at improving the global environmental performance of agricultural products.

In detail, three distinct stakeholder groups could benefit from using LCA as a decision support tool (Ardente et al., 2012):

- Producers: to improve the environmental performance of a productive system;
- Consumers: to orient purchasers;
- Policy-makers: to inform and direct long-term strategies.

The extension of the assessment to the whole supply chain allows identifying "where" and "how" the resources are consumed and the emissions occur (Cellura et al., 2012). The life-cycle thinking approach can ensure that the environmental impacts throughout the life-cycle are viewed in an integrated way and consequently that they are not just shifted from one step to another (Ardente et al., 2006). Such a product-based approach addresses competitiveness issues and key environmental impacts of selected products where it is most appropriate in their life-cycles (EC, 2007).

In this context, the aim of this paper is to investigate the potential energy and environmental advantages due to the cultivation of organic products in comparison to conventional ones. In detail, the LCA methodology was applied to compare the eco-profiles of apples cultivated with organic and conventional agricultural techniques.

The paper is organized as follows: Section 2 presents the state-of-the-art of LCA applied to organic and conventional products, and in particular to apples. Section 3 describes the case study of the LCA applied to apples, including the goal and scope definition (Section 3.1), life cycle inventory (Section 3.2), life cycle impact assessment (Section 3.3), and interpretation (Section 3.4). In Section 4, the authors provide some final remarks.