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Life Cycle Assessment for highlighting environmental hotspots in Sicilian peach production systems

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ABSTRACT

This paper is based upon research designed to investigate the Sicilian red peach production system within two phases. The first regarded application of Life Cycle Assessment to investigate, at the farm level, the red peach production system in eastern Sicily by using one ha of peach orchard as the functional unit, while the second paper in this series will be focussed upon both environmental improvement assessment and sensitivity analysis. In this context, this paper reports on results from the first phase of the research and, therefore, highlights the inventory and the highest impact processes associated with the analysed system. The topic was addressed because agriculture is responsible for major environmental impacts, which must be reduced. The literature review provided insights into deficiencies in environmental assessments in the fruit production sector, especially within the peach and nectarine sectors. The researchers worked closely with an Eastern Sicilian red peach farmer and had access to in-depth data, which were analysed to identify and quantify hotspots that can be improved to enhance environmental and economic sustainability of red peach production in this region. The researchers documented that the largest impacts were due to irrigation due to large volumes of water and energy used. There are opportunities to reduce Greenhouse Gas emissions by improving irrigation practices and in the production and usage of agricultural machinery. Other impacts were found to be due to land transformation, fertiliser and pesticide production and usage.

1. Introduction

Agriculture and food sectors, though contributing to human health and prosperity, are responsible of major environmental impacts. Due to human population growth in number and wealth, an increasing demand for food is expected in the following decades, putting more pressures on land and other inputs for food production, while climate change will pose challenges to agricultural production (van der Werf et al., 2014). A key challenge is to ensure food security in the context of anticipated climate change challenges for a global population expected to grow to nine billion or more people by 2050, while preserving a safe operating space for humanity by avoiding dangerous environmental changes (Soussana, 2014). Sectors such as agriculture, horticulture, forestry, and aquaculture contribute significantly to climate change via land use changes, fertiliser and pesticide usage, embedded and production energy usage. Additionally, during the food processing, packaging and transportation related to the food production system, additional energy and materials are used. For these reasons, it is essential for our food production systems to be managed according to Sustainable Development Principles (SDPs), in order to provide safe, nutritious and eco-friendly foods. During recent years, there have been initiatives, which were designed to promote adoption and diffusion of more sustainable technologies. In this regard, the basic challenge for sustainable agriculture is to make better use of internal resources (Bagheri, 2010; Filho et al., 1999). With regard to emphasis upon sustainable agriculture, there are multiple definitions. For instance, according to McIsaac (1996), sustainable agriculture is designed to support the environmental quality and the resource base on which agriculture depends as well

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as the quality of life of the farmers and society as it provides the basic human food and fibre needs. According to Aerni (2009), advocates of sustainable agriculture believe that agricultural modernisation in the 20th century undermined these values, thereby producing negative externalities for both society and environment. As Moss and Schmitz (2013) stated, most of these externalities were related to: consumption of ground water for irrigation activities; production and usage of chemical fertilisers and pesticides; and, consumption of fossil fuel and energy for all agricultural activities, namely tillage, water pumping, harvesting, processing, packaging, storage and marketing. These activities contribute to impoverishment of natural and non-renewable resource stock and, also, to increased impact on climate change due to emission of Greenhouse Gases (GHGs) as well as on ecosystem quality because of chemical fertilisation. Therefore, these externalities must be addressed by recognising the '*public good*' characteristics of agriculture, while also internalising their negative impacts by making improvements in management practices. In this regard, the concept of multifunctional agriculture was designed to address this public good character through adoption of a system's perspective that takes into account the needs of rural communities and of food security, as well as the impacts of agricultural practices on local and regional ecosystem services and on the global environment, as well (Aerni, 2009). For this reason, rather than providing absolute dimensions of sustainability of an agricultural system, it is useful to compare various farming scenarios in order to highlight similarities and differences. According to Thomassen and de Boer (2005), a variety of tools and methods can be used to assess comparative environmental impacts and the economic costs of agricultural production systems at the farm level: among these tools, Life Cycle Assessment (LCA) is a useful one. As Rebitzer et al. (2004) and Baldo et al. (2008) stated according to ISO 14040:2006 and 14044:2006 (International Organisation for Standardization (ISO), 2006a; International Organisation for Standardization (ISO), 2006b), this methodology examines products' life-cycle enabling identification and analysis of the related environmental impacts from the compilation of both input and output flows. In this context, this author-team used LCA to environmentally assess the production of the reddish-yellow variety of peaches in eastern Sicily with the objective of qualifying and quantifying the resulting environmental impacts. The study was divided into the following steps: the first dealt with peach-orchard inventory and environmental impact assessment, while the second will address the assessment of actual environmental improvements that can/should be made in orchard management. Also, if needed, sensitivity analyses will be done with the objective of comparing different material inputs, processes and end-of-life scenarios to find those having lower impacts.

In this context, this paper reports results from the first part of that journey and highlights the inventory and the processes, which produce the main impacts.

2. A brief overview of environmental and economic assessments in the fruit sector

In the light of the topic addressed in this phase of the research, this section was dedicated to over-viewing research papers that dealt with environmental assessment of fruit supply chains. The literature review was especially focussed upon the work done by Cerutti et al. (2014) whose paper provided a review of the scientific and technical literature on the fruit-growing sector available from 2005 to January 2013. However, differently from Cerutti et al. (2014), in the present study, this team decided to focus only upon peer-reviewed papers from international journals of acknowledged scientific relevance since considered as recipient of most of the studies developed in this field. The latter aspect was confirmed by the greater number of peer-reviewed papers published in those journals compared to papers in conference proceedings as documented by Cerutti et al. (2014). The literature review revealed twenty-two papers published from 2001 to 2013, which dealt with citrus, tropical, stone fruits as well as with pome fruits and grapes. The twelve articles published in accredited journals from 2005 to 2011, as detected by Cerutti et al. (2014), were reviewed. Additionally, this review highlighted the following papers: one published in 2001 (Reganold et al.) and in 2008 (La Rosa et al.); three in 2012 (Dwivedi et al.; Ingwersen; Vázquez-Rowe et al.); and, finally, five in 2013 (Alaphilippe et al.; Cerutti et al.; Lo Giudice et al.; Pergola et al.; and, Svanes and Aronsson). In this regard, it should be observed that no studies have been published so far in 2014. Furthermore, the eight peer-reviewed papers published in conference proceedings, as listed in Cerutti's et al (2014) paper, were not considered for the reasons previously explained. All that highlighted, Fig. 1 shows the number of relevant papers published from 2001 to 2013; it should be observed that: only one paper was found in 2001; no papers were published in three years (2002–2004); while, a considerable number of papers were published from 2005 to 2013. The latter aspect was considered to be attributable to the growing interest and attention towards the topic by the involved stakeholders, especially farmers and company owners. This was because they are increasingly becoming aware of the environmental and economic benefits resulting from assessing and improving fruit supply chains, thus providing researchers and practitioners the support needed for development of environmental and economic studies. Based upon this growing concern, it can be concluded that research on the economic and environmental aspects associated with fruit production and processing systems began in 2005. In that year, the studies of Sanjuan et al. (2005) and Blanke and Burdick (2005) were published based upon assessment of environmental issues and primary energy requirements in orange and apple production, respectively.

The authors of the reviewed papers used different Functional Units (FUs) such as mass-based amount (kg or t) of fruit produced, surface areas of the orchard (mainly expressed as hectares) and income of the grower from fruit sales. In terms of system boundaries, different approaches were adopted: some used a 'cradle-to-gate' approach intending the gate to be the growing-farm level; some extended the approach to fresh-fruit processing and 'end-of-life', while others expanded their system boundaries to include processing of fruits into derivate-products, such as juices and oils. For instance, Beccali et al. (2010) analysed the environmental profile associated with essential oil, natural and concentrated juice from oranges and lemons starting from their cultivation at the farm level. This phase was considered by the authors as the upstream process for the analysed products' life-cycles, as also reported by Beccali et al. (2009). From both of the studies, this phase was documented to be the most significant contributor to the environmental impact associated with the analysed derivatives' life-cycles.

Furthermore, in agreement with Cerutti et al. (2014), the review highlighted that most of the studies were developed using data collected from commercial orchards, either directly in field surveys or with questionnaires or interviews to farmers. For instance, Coltro and Mourad (2009) and Liu et al. (2010) investigated orange and pear orchards in the major growing areas of Brazil and China, respectively. Similarly, in the here-presented research, data were collected on site via interviews of farmers and managers and, then, recorded using specifically designed checklists, which facilitated the crosschecking and analysis of the data. Knudsen et al. (2011) gathered statistically robust datasets accessing a large number of commercial orchards and were able to develop average values for