Journal of Cleaner Production xxx (2014) 1–12

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives

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A R T I C L E I N F O

Article history:
Received 23 September 2013
Received in revised form
8 January 2014
Accepted 14 February 2014
Available online xxx

Keywords:
Life Cycle Assessment
Life Cycle Costing
Organic
Olive
Environmental impact
Profitability

A B S T R A C T

Olive growing is an important cultural and traditional system in the Mediterranean region that has considerable environmental impacts. Italy is ranked second in the world in terms of olive production and olive-cultivated area. Apulia is Italy's largest olive growing region and accounts for 33% of the total Italian surface area planted to olive trees.

Organic farming is assumed to have beneficial effects by reducing the environmental impacts of agricultural practices. However, literature shows that this system is not always less harmful to the environment than the conventional one. This study investigates this hypothesis through the comparison of environmental impacts and economic performances between organic and conventional olive systems in Apulia region. It also provides options to optimize the agricultural practices that could contribute to the reduction of the environmental impacts. Life Cycle Assessment (LCA) was applied to evaluate the environmental impacts, and Life Cycle Costing (LCC) was utilized to assess the economic performance of the studied systems referring to one hectare as functional unit and to a system boundary limited to olive production (cradle-to-farm gate).

Results showed a lower environmental impact of agricultural practices in the organic system, mainly due to the higher efficiency in reducing the impact on fossil fuel depletion. Moreover, the organic system resulted to have higher Net Present Value and Internal Rate of Return values that indicate its higher profitability as compared to the conventional system. Optimization of fertilization is the first priority to optimize olive growing, particularly in the organic system, since manure fertilization results in higher costs and higher environmental impact on almost all impact categories compared to synthetic foliar fertilization. Good agricultural practices with electrically-driven irrigation system, mechanical weeding and biological pest control, no-tillage or reduced tillage can be considered as further optimization options to mitigate environmental burdens and reduce their costs.

1. Introduction

Agriculture is a multifunctional complex system that causes high environmental burdens ranging from the consumption of natural resources to the production of wastes. It is mainly the result of intensive agricultural practices and new techniques.

Agriculture is the first step of the food supply chain and is characterized by additional impact categories related to biodiversity, landscape, soil fertility, erosion and hydrological changes (Guinée et al., 2006). Moreover, emissions from agriculture are highly variable depending on climate, soil type, farming practices and many other inter-related factors (Audsley et al., 1997). Therefore, it is difficult to avoid emissions associated with the agricultural practices, but some measures for the control of farm management practices could reduce them.

Extensive research has been and is still being developed to evaluate farming practices and assess the total agricultural impact on the environment, using different methodologies. Among them, life cycle thinking seems to be the most holistic approach, which includes the whole life cycle of any product or service. LCA was developed primarily for industrial production systems (Heijungs et al., 1992), and then adapted to agriculture (Audsley et al., 1997)

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http://dx.doi.org/10.1016/j.jclepro.2014.02.033
0959-6526/

Please cite this article in press as: Mohamad, R.S., et al., Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives, Journal of Cleaner Production (2014), http://dx.doi.org/10.1016/j.jclepro.2014.02.033

by appropriate adjustments (Cowell and Clift, 1997; Haas et al., 2000). This methodology has become a fundamental tool to compare the environmental impacts between alternative systems in the agricultural sector. One of the major themes in LCA studies related to agricultural production systems is the comparison between organic and conventional farming (Hayashi et al., 2005). With this in mind, De Backer et al. (2009) have assessed the ecological sustainability of leek production, Venkat (2012) has compared the greenhouse gas (GHG) emissions of 12 crops, Mattsson and Wallén, (2003) and Williams et al. (2006) have studied the energy of organic and conventional potatoes. In addressing the environmental impacts associated with the conversion from conventional to organic farming, Wood et al. (2006) have reported the conversion as a viable way of reducing energy use and greenhouse gas emissions in the Australian conditions and Haas et al. (2005) have discussed the environmental impact of 9 categories associated with the conversion from conventional to organic grassland in Germany. Martínez-Blanco et al. (2009) have compared the impacts between organic waste compost and mineral fertilizer.

In agriculture, like in other sectors, LCA practitioners have tended, over the past decade, to link the environmental evaluation to economic and social aspects. The most common economic methodology integrated with LCA is Life Cycle Costing (LCC). Although the basic methodology of LCC is still under discussion and no related databases do exist, researchers are sometimes forced to do things differently than in the LCA (Guinée et al., 2006) keeping the same functional unit and system boundary. There is, however, a little literature on this type of integration concerning the agricultural production (Brandão et al., 2010; De Gennaro et al., 2012; Notarnicola et al., 2004; Strano et al., 2013).

Olive oil production is the most common and traditional cultivation in the Mediterranean countries. Olive area is increasing yearly at global scale particularly in Italy which is ranked second in the world for olive production and cultivated area (FAOSTAT, 2010) and first for the world's organic olive areas (Willer and Kilcher, 2012). Apulia, as the Italian leader region of olive area, represents 33% of the total olive area in Italy (ISTAT, 2009) and 30% of Italian organic olive area (SINAB, 2010).

Intensive olive farming is a major cause of one of the most serious environmental problems affecting the EU today, namely soil erosion and desertification that concern specifically Spain, Greece, Italy and Portugal (Beaufoy, 2001; Tombesi et al., 1996). The European Communities (EC) have reported the harmful effects caused by intensive olive production on the environment (EC, 1999).

Despite the lack of concrete data on the environmental effects of olive farming in EU Member States, especially on specific impacts such as soil erosion, water use, biodiversity and chemical pollution (Beaufoy and Pienkowski, 2002), some authors have studied the influence of soil management on soil erosion in olive orchards in different Mediterranean areas (Francia Martínez et al., 2006; Kosmas et al., 1996; Pastor and Castro, 1995). However, few researchers have investigated the environmental impact of olive cultivation using LCA methodology. Some of them have assessed the environmental impact of the olive oil production process for the purpose of designing an environmental profile to improve the olive oil production chain (Michalopoulos et al., 2011; Salomone and Ioppolo, 2012) or evaluating the consumption of raw materials and emissions of pollutants (Avraamides and Fatta, 2008). These studies were also aimed at identifying the processes that cause the most significant environmental problems. They have reported the agricultural production phase as the heaviest contributor to the environmental impact of olive oil production. De Gennaro et al. (2012) have assessed the environmental impacts of innovative olive growing models through a comparison between the high density and super-high density of olive systems. Salomone and Ioppolo (2012) have included organic scenarios in the evaluation of olive oil supply chain. Another study has concerned the organic system analysis (Notarnicola et al., 2004) through the comparison between conventional and organic olive oil production systems in order to assess whether the organic olive oil is more eco-compatible than the conventional one.

However, all previous studies have focused on the whole olive oil production system without going into the details of each single field operation. Hence, the present study has focused on field agricultural practices of organic and conventional olive systems to identify what are the practices that have the highest environmental impacts and how to optimize them. Moreover, LCC was integrated with LCA analysis to assess the economic dimension of all agricultural practices and of the whole system. The analysis involved the entire 50-year life cycle to extend the comparison to different scenarios of each agricultural practice and to evaluate economically both systems as a long term investment.

Based on the above, the objectives of this study are:

- To compare the environmental impacts and the economic performances of two (organic and conventional) olive production systems through their life cycle.
- To identify the environmental and economic hot-spots of each system for the potential optimization of olive agricultural practices.
- To compare, environmentally and economically, different scenarios of each agricultural practice.

2. Methodology

2.1. System description

The study area was the province of Bari, in Apulia, a region in southern Italy. In this province, around 10.4% of olive-growing area is managed organically (the largest organic olive-growing area) and accounts for 30.4% of the total organic olive-growing area of Apulia region (ORAB, 2009).

In the present study, two drip-irrigated olive systems, i.e. organic (Org.) and conventional (Conv.) plantations of 30–40 year-old olive trees were selected to be compared. Both systems are oriented to olive production and planted with 200–280 trees/ha following the system indicated as traditional in the classification of Gabrielli et al. (2008) or as intensive traditional (Beaufoy and Pienkowski, 2002) by the European Environmental Agency (EEA). Moreover, both systems are planted with *Olea europea* L., cv. Coratina as the prevalent variety in the region (Vossen, 2007).

On the basis of farmers' information and according to the classification of olive life cycle stages proposed by Barone and Di Marco (2003), the total olive life cycle was assumed to extend over 50 years and was divided into the three following stages:

- Juvenility stage from planting till the fourth year of the tree. This stage is characterized by training pruning without significant production from olive trees.
- Growth stage from the 5th (start of bearing) till the 17th year when the tree is shaped to produce optimal yield. During this stage, the tree continues to grow and is pruned so as to ensure both training and production.
- Productive stage from the 18th year – when the production can be considered as being constant – till the 50th year when olive yield starts to decrease. In this stage, the tree is subjected only to productive pruning that ensures productivity and reduces the effect of alternate bearing.

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