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Optimization of olive growing practices in Spain from a life cycle assessment perspective

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ABSTRACT

Recently, the Spanish olive sector has undergone deep changes regarding agronomic practices. Olive grove cultivation tends to move from traditional low-density to new high-density cropping systems. Irrigation has produced a major change in the olive grove sector and the integrated production plays an important role due to the application of rational farming techniques. The aim of this study was to compare the environmental impacts of a high diversity of olive growing systems existing in Spain, including the integrated production systems. The Life Cycle Assessment methodology has been used to calculate and evaluate potential environmental impacts associated to the olives production phase from the extraction of the raw materials to the oil mill gate. Eight traditional systems, three intensive systems and one super-intensive system were selected to be compared. The agricultural practices were grouped in different stages each one including processes and flows: irrigation, soil management, pruning, fertilizers, pesticides and harvesting. Impact categories such as climate change, acidification, freshwater eutrophication, freshwater ecotoxicity, land use and water resource depletion were selected. The fertilizers stage was clearly the highest contributor in all impact categories, specifically, in the climate change and acidification categories in the intensive not irrigated conventional system. Thus, optimization of fertilization should be the first priority to optimize olive growing. The systems that showed the largest environmental impact for most categories were the intensive irrigated integrated system and the super-intensive irrigated integrated system, despite having higher productivity compared to the rest. The organic systems presented the lowest impacts but should improve their productivity. Integrated production was the best olive fruit production system from an overall environmental and productive point of view, especially the traditional mechanized systems.

1. Introduction

Olive grove is one of the most important crops in the Mediterranean region due to the large surface area covered and its great socioeconomic impact. Olive oil is a typical Mediterranean product of great economic importance in the European Union (both in terms of production and consumption). Spain, Italy and Greece are the three major olives producers in the world, respectively (56.8% of the world's olives; FAOSTAT, 2016). The olives fruit production in Spain covers about 48.5% of the European production (FAOSTAT, 2016). Andalusia, located in the south of Spain, is by far the country's most important olive-growing region. Andalusian olive cultivation represents 61.7% of the olive surface area and 79.0% of olive production in Spain (MAGRAMA, 2015). The olive sector has developed rapidly in the main producing regions of Andalusia: Jaén (40.3% of total area) and Córdoba (23.6%), with notable increases in both productivity and quality of production (MAGRAMA, 2015). The main olive cultivars in Andalusia are 'Picual' (59.6% of total area) and 'Hojiblanca' (17.8%) (CAPDER, 2015a).

In recent years, the Spanish olive sector has undergone deep changes regarding agronomic practices. Olive grove cultivation is moving from traditional low-density to high-density cropping systems. The later could pose an interesting alternative for olive growing profitability (Camposeo et al., 2008). The productivity of traditional olive systems can be improved as well as the level of mechanization of soil management, pruning and harvesting operations. Intensive olive systems (high density) and super-intensive (super high density) produce high yields within a few years of planting. The super-intensive systems have showed a strong

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reduction of costs due to their high level of mechanization (Godini et al., 2011) but they can generate higher environmental impacts compared to traditional systems, due to a high dose of pesticides and fertilizers applied and to total mechanization from planting to harvesting. Olive growing in Andalusia is characterized by having 56.4% of its area with traditional mechanized systems (<20% slope and <180 trees per hectare), 27.5% with traditional non-mechanized systems (>20% slope and <180 trees per hectare), 14.6% with intensive systems (between 180 and 325 trees per hectare) and 1.4% with super-intensive systems (>325 trees per hectare) (CAPDER, 2015a).

Irrigation has produced a major change in the olive grove sector. In south Spain, the irrigated surface is about 500,000 ha, of which 22.7%, 8.1% and 1.4% of the total area are traditional, intensive and super-intensive cropping systems, respectively (CAPDER, 2015a). Integrated pest control and organic production of olive oil have been steadily increasing during the recent years. Organic farming covers about 4.9% (CAPDER, 2015b) and the integrated production about 26% of the total area (CAPDER, 2015c). Regarding to integrated production, there is a relatively high adoption rate compared to other countries, as Italy (Sicily), with an area of 3% (Salomone and Ioppolo, 2012).

Integrated production started as an alternative to high intensive systems and to reduce problems derived from the use of conventional chemical agriculture. Among these problems, Parra-López et al. (2008) mentioned the decreased of beneficial insects and the increase of residual traces in olive fruits. Integrated production is undoubtedly a key element in applying the concept of sustainable farming and may provide a reference point for where the European Union farming model should be headed (Official Journal of de European Union, 2014). According to Hinojosa-Rodríguez et al. (2013), integrated production aims to guaranteeing the implementation of farming practices that are sustainable, profitable and produce healthy products. Within the Andalusian olive-growing sector, the largest in the world, integrated production plays an important role. Environmental studies confirm the higher quality of integrated production olive products and processes in Andalusia, due to the application of more rational farming techniques than conventional production (Parra-López et al., 2006). Hinojosa-Rodríguez et al. (2013) showed that the best integrated practices were soil management, irrigation, phytosanitation and harvesting. The environmental and social benefits provided by the transition from conventional management to integrated and/or organic management have been reported in several works, and those include the increase of biodiversity, the reduction of pesticides, soil erosion and environmental impact (Mzoughi, 2014). Despite the relative success of the adoption of integrated production as a form of technological innovation, it is remarkable the little information available in the international literature from a life cycle assessment perspective, especially for the case of olive cultivation in Spain.

The environmental impacts caused by the agricultural activities in the olive growing systems may vary significantly depending on the different practices and techniques employed in olive cultivation and oil production from one country to another, and more specifically, on management practices, socioeconomic, climatic and cultural conditions (Beaufoy, 2000). For this reason, it is important to understand and manage the environmental impacts of olives production with a depth analysis of different agricultural and production practices.

Life Cycle Assessment (LCA) is a widely accepted methodology to evaluate the environmental impacts of agricultural systems (Audsley et al., 1997). LCA could be the most appropriate tool for assessing the sustainability of an agricultural process by allowing the identification of the environmental loads associated to field activities and those related to production, installation and disposal of the components used for weed control in olive cultivation. In recent years, the environmental effects of olive farming and olive oil production, especially quantitative data on specific impacts have been investigated in countries as Greece, Italy and Iran (Rajaeifar et al., 2014; Russo et al., 2015). Intensive olive farming has been reported as being the major cause of environmental problems in the EU, mainly soil erosion and desertification which specially affect Spain, Greece, Italy and Portugal (Beaufoy, 2001). De Gennaro et al. (2012) have evaluated the environmental impacts of innovative olive growing models comparing high density and super-high density olive systems. Russo et al. (2015) studied the environmental impacts of different soil management techniques in high-density olive groves. In addition, some researchers have analyzed the carbon footprint of an olive tree grove in Italy (Proietti et al., 2014) or greenhouse gas emissions of olive oil production in Iran (Rajaeifar et al., 2014) applying LCA. Previous studies, among others, agree that the cultivation of olive trees is the main responsible for the majority of the environmental impacts present in the olive oil production and thus, any effort to minimize the overall life cycle impact from olive oil production should include them. Hence, this work has focused on field agricultural practices of olive systems to identify what are the practices that have the highest environmental impacts and how to optimize them.

One of the major themes in LCA studies related to olive oil production systems is the comparison between organic and conventional farming (Notarnicola et al., 2004; Salomone and Ioppolo, 2012; Mohamad et al., 2014; etc). Overall, these studies agree on the lower environmental impact in the organic systems with respect to conventional systems. However, literature shows that organic farming is not always less harmful to the environment than conventional farming.

2. Materials and methods

2.1. Goal and scope definition

The objectives of the study were to analyze the environmental impacts of olive fruit production systems existing in Andalusia, especially the integrated production systems; to select and improve the agricultural practices in order to identify the processes which produce the most significant environmental problems and design a more efficient and environmentally friendly olive cropping management system. This is the first study in Spain that shows the environmental impacts for the high diversity of olive oil growing systems using life cycle assessment, including the integrated production systems.

The scope of this study was limited to crop production, considering all the input and output flows of materials and energy up to the farm gate when the olive is harvested and transported to the oil mill. The functional unit, to which all inputs and outputs of the analysis were related in order to allow normalization of all extractions and emissions for the product, was defined as mass unit 1 ton of olives, since the main objective of agricultural systems is food production (Audsley et al., 1997).

The research focused on comparing twelve systems representative of the actual situation of the production of olive fruit in Andalusia (Table 1). Eight traditional systems, three intensive systems and one super-intensive system were selected to be compared. Within these systems, differences on type of cultivation (conventional, integrated or organic), in the level of mechanization (manual machinery used in not mechanized systems and the mechanical machinery used in mechanized systems for soil management, pruning and harvesting operations) and in the irrigation management (drip irrigation or rainfed) were made.

The system boundaries included in this study were the olive