Environmental assessment of organic protection products towards an agro-sustainable fruit sector

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Abstract

The increase of production rate in the fruit sector brings a new challenge in terms of the sustainability of the agricultural sector. Apart from the social and economic perspective, it leads to identify the environmental challenges across the value chain. In this vein, farmers consider that the plant protection products are key factor to avoid fruit and vegetable losses, estimated at 78% and 54%, respectively. However, the environment and human health can be greatly affected because of their toxicity. An option to reduce this impact is the transition towards agro-sustainable production by using organic products, so that ensuring sustainable agricultural systems. Based on the fact that organic and sustainable are not equivalent concepts, this study is focused in one on these three pillars that hold the sustainable model, namely, the environmental assessment of the application of new organic plant protection and fertilizer products in conventional cherry farming. To do that, the Life Cycle Assessment methodology has been used. First results reveal that a more ecological cultivation does not always show better environmental performance in all indicators and it is very dependent on the functional unit chosen.

Keywords: LCA, fruit sector, organic products, agro-sustainable

1. Introduction

The fruit sector is an important part in EU-28 representing around 40% of the total between fruits and vegetables, which accounts a 17% of the total agricultural output value (European Commission - Agriculture and Rural Development, 2014). Moreover, the importance of the sector is even more relevant in most of the southern Member States, having Spain an average of 30% of the total agricultural output during the period 2011-2013. In 2000, about the 38% of the total Earth's surfaces was estimated to be occupied by agriculture, representing the largest land use of the planet (Ramankutty *et al.*, 2008). However, these figures are globally increasing due to population growth and consumption increase partially promoted by continuous campaigns launched by the World Health Organisation and the Food and Agriculture Organization of the United Nations (FAO). Despite this increase, one out of seven people has food access problems (Foley *et al.*, 2011) and therefore, much production is needed to guarantee future food security. On the other hand, as agriculture has been pointed out as one of the responsible actors behind many environmental concerns including climate change, biodiversity loss and degradation of land and freshwater, this issue brings, therefore, a new challenge in terms of the sustainability of the agricultural sector (Foley *et al.*, 2005). Consequently, great efforts are required to make the agricultural sector able to accomplish the future requirements in terms of growing food needs, at the same time the environmental impact is reduced. In particular, organic farming has been proposed as an alternative to reduce the environmental impact of agriculture (Meier *et al.*, 2015). Nonetheless, it is worth mentioning that the productivity of organic agriculture is usually lower than the obtained by conventional systems and, as a consequence, greater amounts of land are required to produce the same quantity of food (De Ponti, Rijk and Van Ittersum, 2012). Thus, to increase the sustainability of agriculture system, a holistic analysis is required. In this direction, life cycle assessment (LCA) has been proposed as a powerful tool to evaluate the environmental impact of food products (Roy *et al.*, 2009) by the application of a cradle to gate analysis. Although the number of LCA studies on food products is continuously increasing, there are still some gaps on the results, mainly due to the high level of complexity found in the creation of life cycle inventories and in the selection of the functional unit (Roy *et al.*, 2009). This fact is especially relevant in the studies based on the comparison between conventional and organic farming, where the number of studies is clearly lower (Meier *et al.*, 2015) and the level of uncertainty in the farming system modelling is higher since the farmer's management choices have an important influence on the results (Tuomisto *et al.*, 2012). Concerning the LCA analysis of organic products, most of the published works are focused on milk and different types of fruits and vegetables (Meier *et al.*, 2015). In the case of vegetables and fruit cultivation, the production of fertilizers, herbicides and pesticides are responsible of most total environmental impact at this stage (Aguilera, Guzmán and Alonso, 2015), excluding the machinery, which among other uses is also partially devoted to make the application of these products (Litskas *et al.*, 2011). This is one of the reasons why organic cultivation aims to exclude the use of chemical products and substitute them by organic fertilizers and biological pest control (Foteinis and Chatzisymeon, 2016). However, the results found in bibliography reveal that depending on the selected product, the use of emissions models or real measurements and even the reference unit, namely the impact per unit of product or per area cultivated, organic cultivation do not always show better environmental performance (Meier *et al.*, 2015). Therefore, assuming organic and sustainable are not equivalent concepts more efforts in this direction are required to ensure a proper transition to an organic and more sustainable agriculture. In this regard, this study is focused in one on these three pillars that hold the sustainable model, namely, the environmental assessment of the application of new organic plant protection products as a substitute of conventional ones for the particular case of cherry orchards located in Spain. To this end, the LCA methodology has been applied supported by the international ISO 14040:2006 and 14044:2006 (International Organization for Standardization, 2006a, 2006b).

2. Methodology

The LCA is a standardised methodology which can be mainly divided in four closely interrelated phases: (1) goal and scope definition, (2) inventory analysis, (3) impact evaluation and (4) interpretation of the results. Moreover, these phases take part in an iterative process where the old data is replaced by new, achieving more realistic evaluations.

<u>*Goal and Scope definition:*</u> The first step to implement a LCA methodology is defining the main aspects involved in the case of study, the system boundaries and the functional unit. This study is focused on the evaluation of the environmental impact of two scenarios of cherry production: conventional farming (Conv) and farming based on new ecological techniques (NET), where chemical fertilizers and plant protection products are substituted by organic ones. The functional units are 1kg of cherries or 1ha of cultivated area. The study is limited to the cultivation stages from pre-harvesting to harvesting, as shown in Figure 1. According to the limits and the functional unit defined, the life cycle inventory (LCI) has been carried out.

<u>*Life Cycle Inventories*</u>: LCI contains the type and quantity of all the material and energy input/output flows involved in the two selected scenarios. An important part of the information was obtained from the experimental orchards analyzed during ECOPLUS project. Then, the final LCI data were obtained by the combination of different sources and considering the functional units previously set up. European references and databases, such as Ecoinvent, were carefully selected and contrasted to own LCI information in order to generate a relevant, reliable, transparent and in-house made database.

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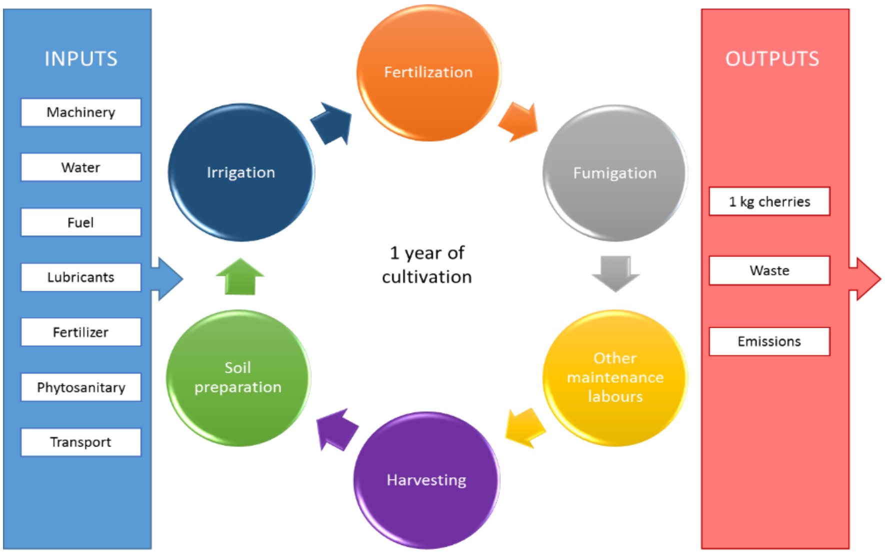


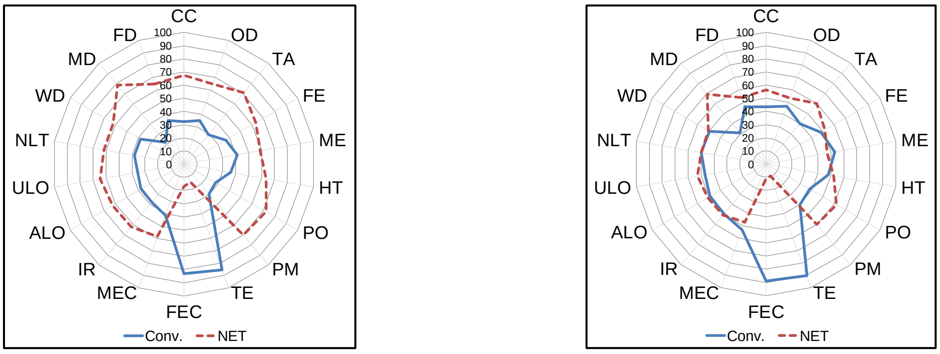
Figure 1. Description of the system boundaries

<u>*Cut-off criteria:*</u> Materials and energy flows implying less than 1% of the cumulative mass/energy of all the inputs and outputs (depending on the type of flow) of the LCI model can be excluded due to practical limitations. However, the sum of the neglected material flows cannot exceed 5% of mass, energy or environmental relevance.

<u>*Environmental impacts evaluation method*</u>: In this research RECIPE midpoint method was selected and implemented using SIMAPRO v8 software, due to being one of the most recent and harmonised indicator approaches (Goedkoop *et al.*, 2009). A total of 18 environmental impact indicators were evaluated: climate change (CC), ozone depletion (OD), terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME), human toxicity (HT), photochemical oxidant formation (PO), particulate matter formation (PM), terrestrial ecotoxicity (TEC), freshwater ecotoxicity (FEC), marine ecotoxicity (MEC), ionising radiation (IR), agricultural land occupation (ALO), urban land occupation (ULO), natural land transformation (NLT), water depletion (WD), metal depletion (MD) and fossil depletion (FD).

3. Results and discussion

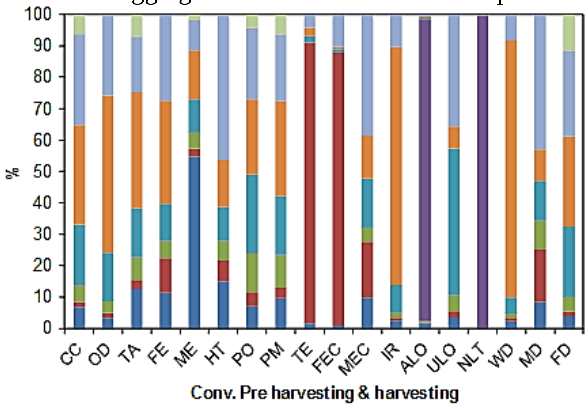
The main objective of the evaluation is to measure and assess the environmental impact by comparing the newly developed technologies based on organic extracts with conventional technologies of cherry cultivation. It is worth noting, on the one hand, that the definition of the limits and the functional unit are key factor in the interpretation of results. On the other hand, the selection of the evaluation method and the indicators should be well defined and wide to cover different environmental impacts.In this vein, Figure 2 gathers the LCA results distinguishing the two different functional units for the cultivation process. Then, a more detailed distribution of the stages impact in pre-harvesting and harvesting is presented. Finally, the most influencing factors will be highlighted for the CC indicator. First of all (a), it can be seen that the results vary significantly depending on the selected indicator per kg of cherries. Conv. cultivation stands out in FEC and TE indicators, representing approximately 70% more than NET cherries. This is caused mainly by large amounts of fungicides and water consumed during the cherries cultivation. By contrast, the rest of indicators are from 17 to 57% higher in the NET cultivation, because of the difference between the productions. Since the production of conventional cherry was 1.6 times greater than the NET farming, the impact share per kg of cherry is reduced in Conv. LCA results. Therefore, the results are strongly dependent on the final production for this functional unit, since some of the stages involve similar inputs and outputs (i.e., irrigation, transport of workers, soil preparation and maintenance labours).Secondly, in Figure 2 (b), Conv. cultivation shows again higher impact than NET one; up to 81% in FEC and TE indicators; but also a 6% more in ME in this case. It is worth mentioning that the rest of indicators were higher in NET cultivation when the functional unit is 1 kg of cherries; while in case b, they are more similar. Thus, when the results are presented by 1 ha cultivated, the new organic extracts used during pre-harvesting proof to have less impact in most environmental indicators. However, the impact of NET is still relevant in some indicators, especially for MD, TA, PO, PM and CC indicators; whose impact is greater (from 13 to 39%) than in the conventional cultivation.



(a) (b)

Figure 2. LCA of pre-harvesting and harvesting (a) functional unit = 1 kg (b) functional unit = 1 ha

In order to analyse the most influencing steps during the cherry cultivation, from the environmental point of view, the disaggregated share is depicted in



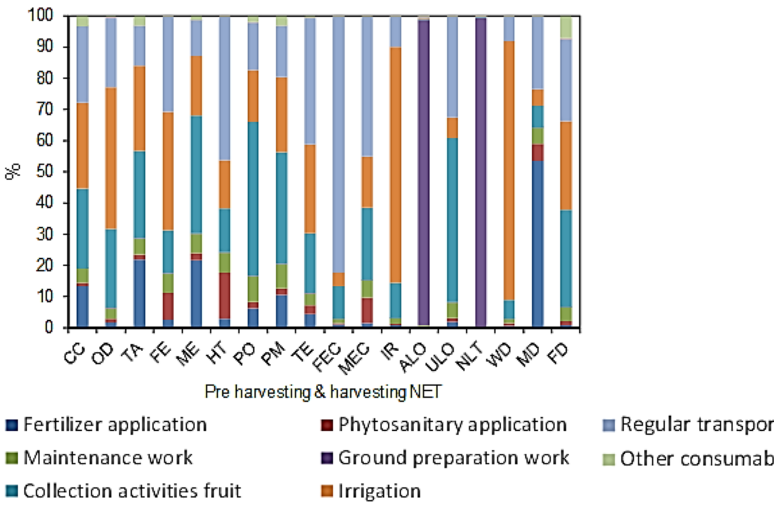


Figure 3. There is evidence that the effect of the phytosanitary product application is notoriously reduced with NET. Especially in TE and FEC indicators, where there is a decrease of approximately 85%, because of conventional fungicides are substituted by organic ones. Only in HT, the use of a new foliar fungicide provokes an increase (8% more than in conventional application). Regarding the fertilizer application share, NET organic products beneficially reduces the impact, especially in ME (-33%) and HT (-12%) indicators. Conversely, other

indicators augmented, such as MD (+45%), TA (+9%) and CC (+7%), what could be attributed to the fact that more quantity of products were applied on field in NET cultivation. Moreover, the regular transport of employees rises up from 4% in Conv. to 82% in NET for the FEC indicator. Apart from that, the rest of stages present a similar distribution of impact in both scenarios. Among them, ALO and NLT indicators reveal a great impact, more than 95%, caused by the ground preparation work; while the rest of stages show a well-balance share. On another note, irrigation varies from a great impact in both conventional and NET harvesting, nearly 80% in WD and IR.

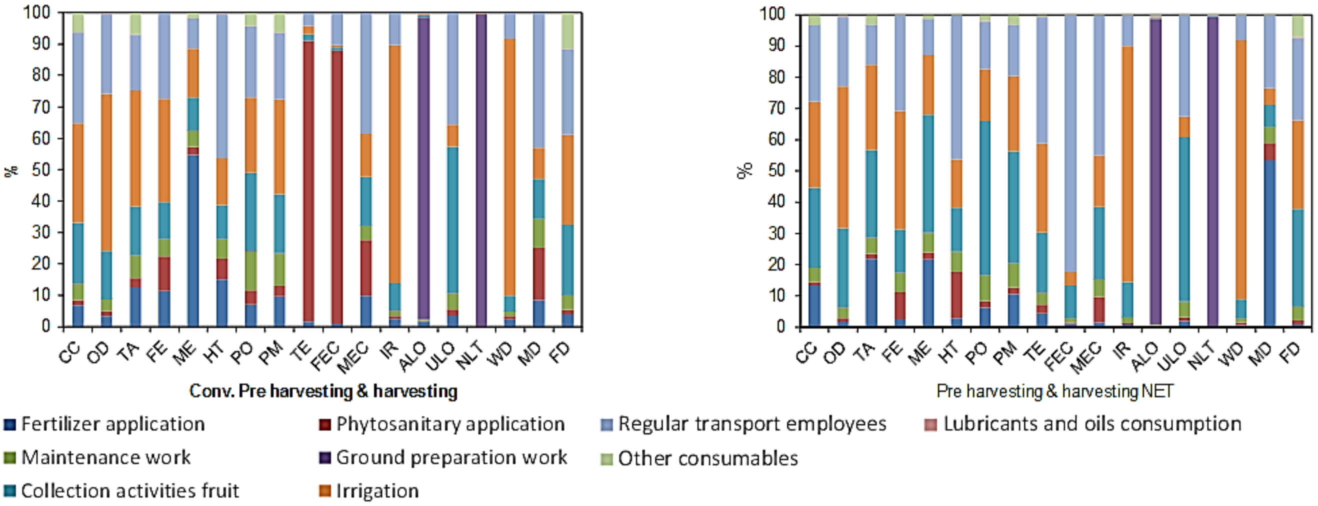


Figure 3. Percentage distribution of environmental impact: (left) Conv, (right) NET

Given its importance and awareness of global warming, a more detailed analysis is presented regarding CC indicator of pre-harvesting and harvesting using NET. According to Figure 4, the major contribution on this indicator lies on the irrigation, the use of a car and a van for the regular transport of employees to the country field and the transport in the harvesting period (all around 25% of the impact share). Secondly, the fertilizer application is also relevant in CC indicator (13.5%). Most of this latter impact is caused by the use of a humic amendment, which is composed mostly by organic matter. Because of its benefits for the soil and the ecological connotation, great quantities of this organic amendment were applied during the NET pre-harvesting (5000 kg/ha). What is more, although in a small concentration, there are some heavy metal particles (Zn, Cu, Ni, Pb, etc.) in its composition. Thus, the utilization of the ecological new plant protection and fertilizers products must be properly optimized, in order to avoid unnecessary surplus of application on field.

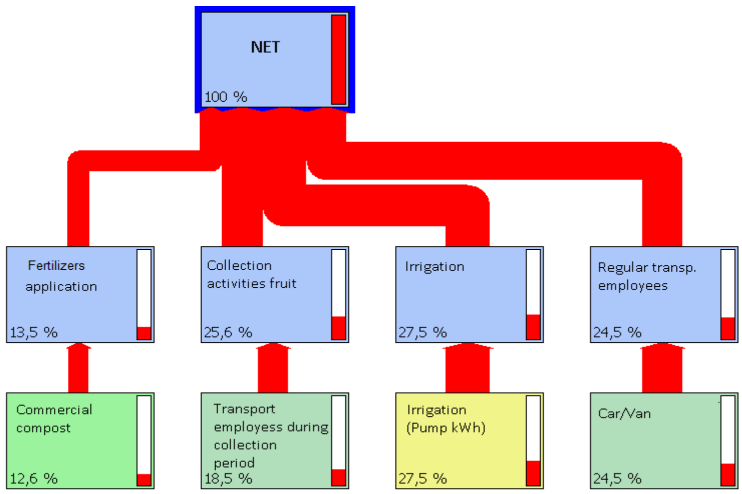


Figure 4. Network of products that contribute to CC indicator of pre-harvesting and harvesting using NET. In order to highlight the main product, the network's products are partially shown with a cut-off of node below 10%

4. Conclusions

New techniques based on organic products in cherry farming were conducted in order to shift towards a more sustainable agriculture. But, since it is not always so evident, the objective of this study is well justified by assessing the environmental perspective of those new techniques. The environmental LCA results showed that a more ecological cultivation does not always show better environmental performance in all indicators and it is very dependent on the functional unit. Thus, 1 cultivated ha with NET showed better environmental performance for most indicators when compared to 1 kg of cherry. This difference yields on the production of the plantation, which is very much influenced by controllable and uncontrollable factors, and so the cherries production yield can vary crucially. So, the NET cultivation showed an increase of global impact per ha on some indicators respect to the conventional one, namely MD (39%), TA (21%), PO and PM (around 20%) and CC (14%). Besides, the contribution of the plant protection application decreased with the new organic products used in NET pre-harvesting, above all in TE and FEC. On the contrary, the fertilizers gained more impact share due to the great amounts of products applied comparing to the conventional cultivation. An example was itemized for the fertilizer use in CC indicator. The application of amendment and fertilizers can be a main contributor (13.5%), despite its organic origin. As a summarised conclusion, it is worth mentioning the importance of optimizing the quantities of phytosanitary and fertilizer products, even though considered as ecological, due to their relevant contribution in the environmental impact.

Acknowledgments

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