Environmental Assessment of Precision Farming Techniques in a Pear Orchard

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Abstract. Pears require a substantial number of inputs for satisfactory yield and quality. High inputs increase costs, reducecompetitiveness and induce environmental problems. In thecurrent study the environmental profile of a pear orchard, located in central Greece, was developed under different agricultural practices. More specifically, the environmental impacts of using different nitrogen (N) fertilizer application techniques (uniform and variable rate application, VRA) were revealed and compared. UsingN VRA, less N was used, offering cost reduction to the farmer. A Life Cycle Assessment was performed, following the ISO standards. The results showed that 55 % of the total emissions to air in the Particulate matter impact categorywere due to nitrogen oxide and ammoniaderived from fertilizer use. Moreover, carbon dioxide fossil and dinitrogen monoxide emissions to air coming also from fertilizer production and application were significant contributors to Climate Change exceeding the amount of 80% of the total emissions in this impact category.

Keywords: Nitrogen application, LCA, Variable rate application, GHG, Precision farming

1 Introduction

LCA methodology was frequently applied in the fruit sector during the last ten years, giving a preference to the evaluation of the agricultural production stage. Several studies concluded that young tree growing stage was the most impacting phase in the life-cycle of fruits (Ingrao et al., 2015). Mila i Canals et al. (2006) applied LCA to an apple orchard in an attempt to find the environmental profile of the apple orchards and to identify the hotspots in the production system studied. In that 2-year research, he found that more that 50% of most impact categories results are due to energy-related emissions. He noticed that energy consumption deriving from mechanization (including machinery production) should be a focus of attention. A cradle to market study on commercial pear orchards identified the environmental hotspots regarding only fossil fuel use and greenhouse gas (GHG) emissions in the field production part

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of the supply chain (Liu et al., 2010). They found that fertilization mainly with synthetic fertilizers (since emissions from manure were ascribed to livestock production) and the use of agricultural machinery were the most important contributors to the total of GHG emissions, while more fossil energy was used for irrigation and machinery. A number of relevant impact assessment indicators were chosen to reveal the environmental performance of the agricultural stage in a food-sector study. The results showed that farm stage almost in all impact categories had the higher contribution, e.g., 90% of water footprint, 60% of carbon footprint from which 40% came from nitrogen fertilizer application (Dinitrogen monoxide (N2O) emissions) and 41% from fertilizers and pesticides production.

The present report describes a complete environmental impact research using the LCA methodology. Following the basic steps of a life cycle analysis, the report starts with the goal and scope of the study. In this section the pear orchard is described and the objectives of the study are stated. The important elements of the system boundaries and the functional unit are defined as well. The inventory is the next section of the report, where all the inputs and outputs are presented, as well as the equations needed to calculate the emissions from resource consumption. Moreover, the main assumptions concerning the land use, the production stages, the cultivation system of the pear orchard, and the scenarios needed to show the robustness of the results, are also reported, along with allocation, quality of the data and the default impact assessment method. Result section is coming next where the impacts are quantified using the endpoint and the midpoint method of life cycle impact assessment (LCIA). The software SimaPro 8.0.4.30 (PRé Consultants, Amersfoort, NL) was adopted to analyze all the LCIA steps, characterization, normalization and weighting. At the end of this report the discussion of the results is presented

2 System's Functions and Functional Unit

The main objective of the study was to develop the environmental profile of the particular pear orchard under different agricultural practices. More specifically, the ultimate aim was to reveal and compare the environmental impacts of using different N fertilizer application techniques (uniform and VRA). Many environmental research studies have focused on N application on several crops. This probably is due to the fact that local over-fertilization may enhance nitrate leaching and thus decrease ground water quality. Over fertilization may also induce NH3 volatilization and N2O emissions leading to acidification and increased GHG emissions. An additional motivation for studying the environmental effects of fertilization is the high cost of N fertilizers. Furthermore, there is a need to investigate the magnitude of the impacts induced from fertilizer usage compared to the impacts of other inputs in the system, like the use of pesticides, the production phase of all the agrochemicals and the energy consumption represented by the diesel use in the different agricultural processes. Another objective was to suggest improvements and to detect research needs. The goal was to perform a multiple impact category LCA following the ISO standards for LCA 14040 and 14044 as close as possible.

The functional unit (FU) is a fundamental element in every LCA study. The ‘function’ in the sense of an LCA function means to quantitatively and qualitatively specify the analyzed product. This is generally done by naming and quantifying the qualitative and quantitative aspects of the function(s) along the questions of “what”, of “how much”, of “how well”, and of “for how long” (Production Environmental Footprint Guide, PEF, 2013). This reference or FU provides the quantitative aspect (“how much”) to allow for comparability between different product systems. The reference flow is the amount of product or activity required to fulfill the FU. Typically, life cycle inventory (LCI) data rely on a chosen reference flow. Usually agricultural datasets, i.e. crop products, are based on a mass reference of one kilogram (1 kg) of output fresh product. However, the FU could be represented in the inventory by the unit of land hectare (ha). Productivity per hectare is an important parameter that influences the impact per unit of the product. Also, productivity is related to the amounts of inputs that are used. Nevertheless, using hectare as FU, productivity is not considered. According to Milà i Canals et al. (2006), a mass based functional unit is adequate when only analyzing the agricultural stages of the life cycle of fresh product for descriptive purposes.

In the present study the reference unit was defined as the 1 kg of pears, unpackaged, at farm gate. This means that the LCA study is a cradle- to –gate study, which means that includes all the processes until the pear fruit is harvested at the farm. So, the “what”, is recently harvested pears of the cultivar Coscia from a pear orchard located in Tirnavos, Central Greece. Since this particular cultivar, Coscia, cannot be stored for long periods at refrigerators, the time period of the fruits being consumable (“how long”) is limited to almost one month. After this time the ripening phase of the fruits proceeds very fast to end up to wastes.

3 Results

All the emissions of substances to air, water and soil from the pear orchard production phase (include all the inputs to the field) are represented by Pear Orchard in the graph of Figure1. The pear production system is almost exclusively responsible for the emissions in the Terrestrial ecotoxicity and Agricultural land occupation impact categories. The Terrestrial ecotoxicity category include the emissions coming from pesticides application and concerned emissions to the soil, while in the Agricultural Land occupationcategory the impacts are due to the land use for specific period of time. The Average fruit yield (20.3 t/ha) for the whole life span of the pear orchard is smaller compared to the global average pear production. Thus, land occupation is found to be 0.05 ha*year/ton of pears, justifying a high impact of Agricultural land occupation in this pear study. Also Pear Orchard group covers a substantial part of the Particulate matter formation due to NOx and NH3 and of Climate Change due to N2O and CO2. These air emissions are all produced from the use of fertiliser inputs in the orchard. Finally, in water depletion the negative percentage represents the water irrigation pumped from the ground for the pear fruit yield.

The diesel consumption in tractor operation, petrol consumption in transportation and electricity use in irrigation are represented from the Operation in the graph. As it is depicted mainly in Water Depletion impact category and consequently in Particulate matter formation and Climate Change the operations show significant contribution.

Concerning the background processes it seems that the agricultural machinery production and the maintenance of all the equipment and machinery used, which are included in the Capital goods, has an important contribution in the majority of the impact categories. This result was confirmed by Audsley et al., (1997), who stated that it is necessary to include not only the impacts derived from the use of the machinery (mainly from fuel consumption), but also the impacts arising from the production of the machines themselves. However, in the present study the agricultural machinery production and maintenance have been higher than the research done by Mila i Canals et al. (2006), where the proportional impacts of machinery production were ascribed to the different operations on the basis of use time as a proportion of the predicted useful life-time of the machine.

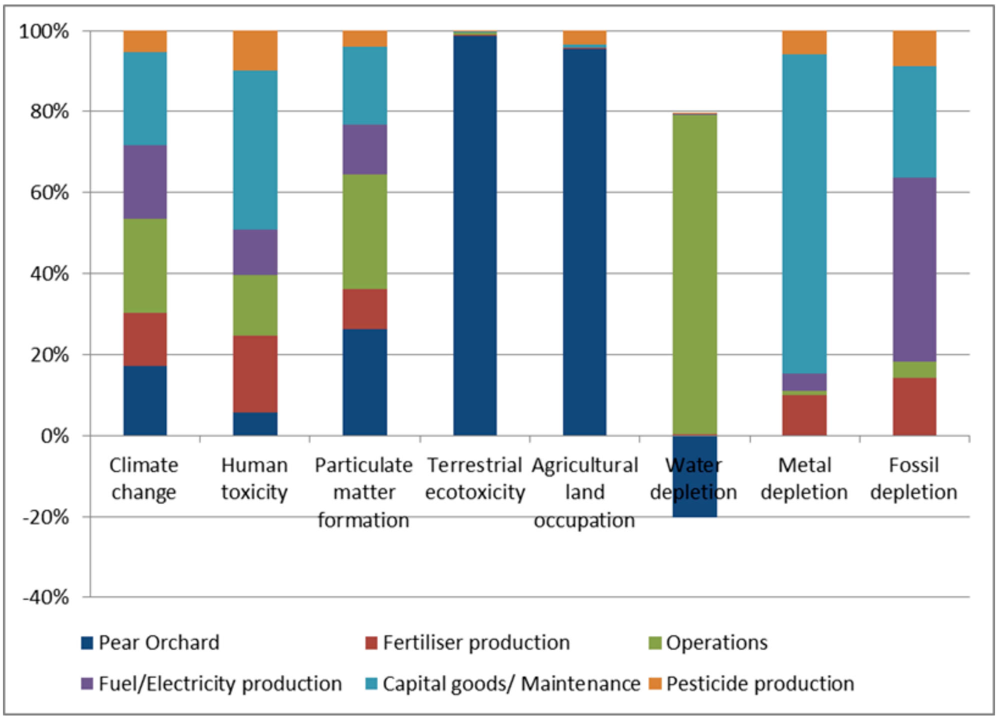

Fig.1. Processes contribution to the most significant impact categories

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