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Environmental profile of green asparagus production in a hyper-arid zone in coastal Peru

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ABSTRACT

The Peruvian coast has developed a robust agricultural sector despite the low average rainfall thanks to the availability of water resources from rivers and groundwater. In fact, this area has become one of the main producers of green asparagus worldwide due to the availability of water and the high yield rates that can be reached. However, irrigation and intensive agriculture constitute a significant threat to water depletion in the region, as well as to important changes in land use. In addition, the intensive use of fertilizers and plant protection agents can increase the amount of nutrients and/or toxic agents in river and in the soil. Hence, a Life Cycle Assessment study was conducted for an agricultural farm in Paracas that cultivates green asparagus for export to North America or Europe. The aim of the study was to understand the potential environmental impacts associated with the cultivation of this product in a hyper-arid area. Results showed a considerably lower water use in the cultivation site when compared to business-as-usual values for the region, due to the advanced irrigation system applied. Environmental impacts were strongly influenced by the high energy intensity linked to the production of inorganic fertilizers used on-site and, to a lesser extent, plant protection agents. Transport environmental burdens were also identified as important sources of environmental impact throughout the impact categories monitored, especially when airfreighted to the final country of destination. Finally, the use of methyl bromide to fumigate green asparagus at US customs implied a high burden in terms of ozone depletion. The results in this study intend to be a proxy to understand the specific hotspots linked to the production of green asparagus in Peru, as well as a way forward for local small- and medium-scale companies to get involved in the improvement of their ecological marketing strategies.

1. Introduction

Despite an important urbanization process in Peru in the past couple of decades, the agricultural and fishing sectors still represent 5.8% of Peruvian exports, and 24.2% of the active population was employed in the primary sector in 2012 (INEI, 2013, 2014a, 2014b). In fact, Peru has an important role worldwide in the production of agricultural products, not only in terms of bulk production, but also regarding the variety of products that grow in this multi-climate tropical nation. Given the existence of this climatic variability, agricultural landscapes can vary from endemic potato crops in the Andean highlands to irrigated agricultural farms along the arid Peruvian coast.

For instance, the provinces of Ica and Pisco (both in the region of Ica), 250 km South of Lima, have developed a robust agricultural sector despite the low average rainfall thanks to the availability of water resources from rivers and groundwater (Cárdenas, 2012; Oré and Damonte, 2014). However, irrigation and intensive agriculture constitute a significant threat to water depletion in the region, as well as engendering important changes in land use (Wiegers et al., 1999; Meyfroidt et al., 2010). In addition, the intensive use of fertilizers and plant protection agents can increase the amount of nutrients and/or toxic agents in rivers and in the soil (Huijbregts et al., 2000).

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Peru's agricultural sector is moderately to highly vulnerable, depending on the region, to the El Niño phenomenon, which periodically affects the country causing important disruptions in the countries otherwise fairly predictable climate (Hesse and Baade, 2009; Goldstein and Magilligan, 2011). In addition, Peru is listed as one of the countries with highest risks in terms of vulnerability to the effects of global warming according to the Intergovernmental Panel on Climate Change (IPCC). While many people may associate this vulnerability with greenhouse gas (GHG) emissions exclusively, the problem is more complex, since the consequences may also appear in the form of water scarcity, depletion of natural resources (e.g. anchoveta stocks) or land use changes (IPCC, 2007). Consequently, Peruvian producers are increasingly aware of the need to understand the environmental conditions they work in, including the environmental impacts that arise from their own local practices and production systems.

In this context, Life Cycle Assessment (LCA) has become one of the most important environmental assessment methodologies available in the literature to evaluate the life-cycle environmental impacts linked with a certain service, product or service (ISO, 2006a). Moreover, LCA can quantify environmental impacts for a wide range of environmental dimensions, including global warming, toxicity, use of resources or acidification, among others (Hellweg and Milà i Canals, 2014). Once focussed on industrial processes, it soon developed as an interesting tool to determine the environmental profile of agricultural products (Poritosh et al., 2009). Hence, numerous studies across the world have been published dealing with a variety of environmentally-relevant information. For instance, the most recurrent studies deal with the environmental monitoring of a certain agricultural product in order to understand the main energy or material flows responsible of the environmental impact, as a way to suggest improvement actions (Rugani et al., 2013).

However, most studies have focused on agricultural production systems in temperate areas of the world, namely Europe and North America, whereas the analysis of the environmental profile of agricultural crops in Latin America is currently underrepresented in the literature available (Reap et al., 2008). In this study, a green asparagus production site in the abovementioned province of Pisco (13°42′S; 76°12′W) was analyzed with the aim of understanding the environmental impacts of the cultivation of this crop under extreme climatic conditions. The study is justified in terms of the weight of Peruvian green asparagus production (i.e., 374,000 metric tons in 2013), being the second producer worldwide after China (INEI, 2014a). Moreover, green asparagus has shown to have a high nutrient/calorie ratio, and can help prevent cancer, ageing or cardiovascular diseases due to its high content in antioxidants, such as ascorbic acid or glutathione (Sun et al., 2007; Kim et al., 2009; Wang et al., 2011). Its healthful food characteristics imply that its cultivation and consumption will continue to increase in years to come. Hence, the identification of the environmental impacts linked to the cultivation of this vegetable is an important milestone in terms of sustainable production and consumption. Finally, beyond the nutritional and health benefits of this vegetable, the producer expressed interest in understanding the equilibrium between GHG emissions and water use at the site, without disregarding the impacts in other environmental aspects from a life-cycle perspective.

2. Materials and methods

2.1. Goal and scope

As previously mentioned, the main objective of this research was to evaluate the environmental profile related to the production of green asparagus in Ica (Peru). The aim of the study was oriented mainly towards the identification of the environmental hotspots throughout the production system, as well as suggesting a series of improvement measures to reduce the environmental burdens of the product under analysis. The study was carried out for four different years of cultivation (2010–2013), which represent the first four years of farming. This fact is of special interest considering that the crop yield curve will show an increasing trend throughout the years assessed. Consequently, the analysis of how this yield curve affects the environmental profile of the final product delivered will also be a matter of discussion. Nevertheless, results also present an estimation of selected environmental impacts in 2014, for which partial primary data regarding water and electricity use, as well as harvest yield were available, and 2015, which was based on current practices in years 2013 and 2014 and on the aid of the agronomic engineers working at the site (J.P.B., personal communication, January 2015).

For this case study the ISO standards specified in ISO 14040 and 14044 for LCA studies were followed (ISO, 2006a, 2006b). The function of the system was the delivery of green asparagus cultivated at the site to the main export destinations ready to supply the wholesalers. Hence, the selected functional unit (FU), which is the reference to which the material and energy flows are referred to (ISO, 2006b), was a 5 kg box of fresh green asparagus exported to the United Kingdom (UK) or the United States (US) by plane or transoceanic cargo at the port or airport of Callao – 12° 2′S; 77° 8′W (Peru), showing the function of delivering green asparagus ready for distribution to wholesalers in European and North American countries. The selection of the FU was based on the standard package dimensions and content, as described in the Peruvian technical specification for fresh asparagus packaging (NTP, 2013).

2.2. System boundaries

The production system analyzed included all the processes linked to the production of green asparagus in the cultivation site, such as field operations, soil management, fertilization or harvest operations, as well as post-harvest activities (i.e., storage and packaging). In addition, upstream processes were followed to account for the extraction of raw materials, production and distribution of a variety of materials used at the cultivation site, such as inorganic fertilizers, plant protection agents, packaging materials or diesel, among other inputs. Downstream processes included the freight operations from the gate of the cultivation site to the port of Callao. The system boundaries were not only limited to green asparagus freighting on Peruvian soil, but the impact of oceanic or airfreight to the final nations of destination were modelled considering the different modes of transport. Therefore, the analyzed system represents a cradle-to-gate approach in which the products are followed up to their departure from Peruvian soil and, in an extended manner, to their arrival in customs at the country of destination. Post-export operations, such as wholesaling, retailing or consumption were excluded from the system boundaries (see Fig. S1 in the Supplementary material for a graphical representation of the flow diagram for the modelled production system).

2.3. Data acquisition and quality

Primary data obtained for this study were acquired mainly from the producer (Table 1). In the first place, a questionnaire was developed by the LCA practitioners in order to obtain data regarding the main material and energy flows occurring at the cultivation site. Secondly, in several meetings with the technical staff from the agricultural company, the questionnaire was