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Evaluating the sustainability of Ecuadorian bananas: Carbon footprint, water usage and wealth distribution along the supply chain

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A B S T R A C T

The environmental impacts of banana production in Ecuador are expected to be of comparable importance to its influence in the country's economy, as the agricultural sector is known to be a major contributor to climate change, and also to water consumption and pollution.

The aim of this paper is the environmental analysis of the banana value chain through two indicators, carbon footprint (CF) and water footprint inventory analysis (WF), enabling the identification of hotspots and the comparison with the environmental impacts of banana from previous studies.

First, following a cradle to gate approach, the focus is paid on banana farming, by taking into account not only the agricultural practices but also banana washing and packing after harvesting, before fruit leaves the farm.

The CF of banana grown in conventional farms (302g CO₂e/kg banana) is higher than that from organic ones (249 g CO₂e/kg banana), mainly due to the higher amounts of nitrogen fertilizers applied in the former. These N application rates determine grey WF too, which is also higher in conventional farms (135 l/kg vs. 58 l/kg). In contrast, the amounts of water consumed per kilogram of banana at the farming stage (green plus blue WF) were higher in the organic farms (313 l/kg vs. 289 l/kg), mainly due to their lower yields. No significant correlations were found among both footprints and farm sizes.

Moreover, CF and WF have been calculated for the remaining stages of the whole banana value chain up to final consumption in Europe (1.28 kg CO₂e/kg banana and 330 l/kg banana at the consumers' hands, respectively) and complemented with the analysis of the economic contribution of each phase to the final price (1.40 €/kg), to get a more complete picture of this commodity.

The farm system was found to be the major contributor to the whole WF, and the second largest (after fruit distribution) to CF. In contrast to the high environmental impacts of farming (which reveal high water and energy consumption), the economic value of this stage is less important than most of the remaining ones, representing only 15% of the final price and showing that wealth distribution along the value chain is still unfair for the farmers.

Keywords: Food–energy–water nexus; Carbon footprint; Water use; Ecuadorian bananas; Value chain

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1. Introduction

Food production and consumption is an important contributor to environmental degradation, being responsible from 20% to 30% of the impacts of private consumption (Tukker et al., 2006). In developed countries, consumers start demanding food produced with minimal environmental burdens (de Boer, 2003) and increasingly base their purchase decisions on environmental indicators (Nishino et al., 2014). Within these indicators, carbon (CF) and water footprint inventory analysis (WF) have achieved great diffusion: the former has experienced a wide diffusion throughout the last decade, when carbon footprint assessments of food products have been multiplied considerably (Jensen and Arlbjørn, 2014; Vázquez-Rowe et al., 2013; Virtanen et al., 2011); while the latter has achieved great development and dissemination both at academic and corporate level since its definition (Hoekstra and Hung, 2002), being also calculated for numerous food products (Mekonnen and Hoekstra, 2011a; Milà i Canals et al., 2010).

This paper approaches the food–energy–water nexus by means of an environmental analysis of fruit production. Extracting, delivering, and disposing water requires energy, and similarly, many processes for extracting and refining various fuel sources and producing electricity use water (Siddiqi and Anadon, 2011). Both inputs are required for fruit production: water is necessary for irrigation (which, in most cases, requires energy use for extraction), and energy, mainly obtained from fuel combustion, is necessary to perform the most usual farming practices (fertilizing, pesticide application), and also to fruit washing after harvesting. However, water and energy requirements do not end at the farm gate, since both will be used to bring fruit to the final consumers: energy and water consumption take place in the remaining stages of the value chain, either in a direct (fuel combustion in transport vehicles) or indirect way (water consumption to produce that fuel). Even once at the consumption stage, and depending on the consumers' habits, energy and water may be required for cooking the fruit or for hand washing. Taking this into account this paper analyses energy and water consumption from an environmental point of view (by means of carbon and water footprint) along the value chain of a foodstuff: banana produced in Ecuador and consumed in Spain.

The CF of a certain product is defined as the total greenhouse gas (GHG) emissions over its whole life cycle, stated as CO₂ equivalents (Carbon Trust, 2012), and communicates the global warming potential of the product under evaluation.

The WF of a product measures the indirect and direct use of freshwater associated with its production, and includes three components: blue water (or amount of water taken from aquifers and not returned to the original watershed), green water (or soil moisture taken by crops) and grey water (defined as the amount of water needed to dilute pollutants discharged to water) (Hoekstra et al., 2011). This indicator will be reported as a volumetric amount of water, without considering water use impacts on the region, and therefore this paper presents a water footprint inventory analysis (ISO, 14046, 2014).

It was chosen to focus this study on the Ecuadorian banana production due to its economic relevance: Bananas represent 2.5% of the GDP of Ecuador, and the country is responsible for one third of the worldwide banana exportation. Having noted the economic significance of banana production in Ecuador, its environmental impacts are expected to be of comparable importance, as the agricultural sector is known to be a

major contributor to climate change, representing a 10%–12% of the global anthropogenic emissions of greenhouse gases (IPCC, 2014), and bears the greater responsibility for water consumption and pollution, since 92% of the global water footprint corresponds to agricultural production (Mekonnen and Hoekstra, 2011b).

Several studies have addressed the environmental impacts of banana production in tropical countries, both from a CF (Eitner et al., 2012; Luske, 2010; Svanes and Aronsson, 2013) and a WF point of view (LimnoTech, 2012; Mekonnen and Hoekstra, 2011a; Sikirica, 2011; Zarate and Kuiper, 2013). However, previous CF calculations were based in data from smaller samples (Eitner et al. (2012) considered one cooperative of conventional farmers and one of organic farmers in El Oro Region in Ecuador, and for each category only one set of common farming practices were analysed; Luske (2010) and Svanes and Aronsson (2013) studied only two farms located in Costa Rica), and their calculation procedures had not been as adapted to the real conditions of the Ecuadorian banana farming (N₂O emissions from managed soils were determined using emission factors for temperate climates, instead of taking into account tropical conditions and different soil textures, and secondary data were used for the production of packaging material production). Regarding WF previous studies, the number of inventoried farms was also lower (LimnoTech (2012) and Sikirica (2011) considered, respectively, four and three farms in tropical countries – none of them Ecuador –, Mekonnen and Hoekstra (2011a) base their results in national statistics for Ecuador, while only Zarate and Kuiper (2013) considered 15 farms in the Ecuadorian country), and none of them consider real irrigation volumes, but those obtained from calculation software, meaning that water requirements of the fruit are always fully met. Besides, both indicators have not been reported so far for the same farms, and extended to the whole Ecuadorian banana value chain.

The CF of the Ecuadorian banana production has been determined from a cradle-to-grave perspective (Roibás et al., under revision), and that analysis is completed here with a WF inventory analysis, also focusing on primary data from the farming stage but including secondary data to characterize the remaining stages of the banana value chain, thus completing a cradle-to-grave WF.

Both indicators have now been quantified in parallel for the different stages of the value chain, in order to see the similarities and divergences between them, and along with economic data obtained for each stage. This way, the three vertex of sustainability triangle have been taken into account for the banana distribution chain: the environmental point of view, the economic approach (the fruit price has been determined at each stage of the value chain, identifying the wealth generated in each stage along fruit distribution) and the social point of view (analysing the relationship between the prices paid to Ecuadorian producers and the final price paid by consumers, and its evolution through time).

2. Materials and methods

2.1. Environmental footprints

An environmental evaluation of the whole banana value chain has been carried out, from fruit production in Ecuador to consumption in Spain, through carbon and water footprint indicators. The area of consumption was placed in a southern

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