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The environmental footprint of an organic peri-urban orchard network

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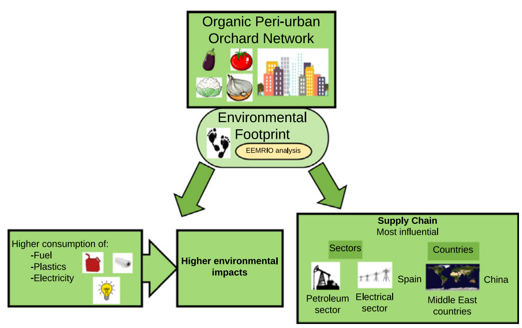
HIGHLIGHTS

- The Environmental Footprint of an organic peri-urban orchard network was assessed.
- Higher impacts were due to a higher consumption of fuel, plastics and electricity.
- Petroleum and electrical sector in Spain, China and Middle East countries were identified in the supply chain as the most influential.
- Favorable environmental impacts were obtained.

GRAPHICAL ABSTRACT



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ABSTRACT

Over the past years, the implementation of urban and peri-urban orchards in cities has increased and so has the environmental awareness regarding these systems. This study applied the environmental extended multi-regional input-output analysis to obtain the Environmental Footprint associated with an organic peri-urban orchard network in Spain. The total environmental impacts were calculated for seven organic peri-urban orchards identified as PUO1 to PUO7. PUO1, PUO4 and PUO6 presented the highest environmental impacts due to a higher consumption of (1) fuel, (2) plastics and (3) electricity in comparison to the other orchards. Approximately 70% of the overall impacts were indirect impacts generated in the supply chain. A more in-depth study of climate change impacts in the supply chain of the organic peri-urban orchard network revealed that the major hotspots were the sectors "extraction of crude petroleum" (29%) and "production of electricity by gas and coal" (31%) located in Spain, China and Middle East countries. The Environmental Footprint serves as a useful indicator to provide the environmental performance of an organic peri-urban orchard network and foster greener and more sustainable cities.

1. Introduction

The world's population has experienced an extremely rapid growth. Over the past twelve years, there has been an addition of one billion people. It has been predicted that the total population will be between 8.4 and 8.7 billion in 2030 and between 9.4 and 10.2 billion in 2050 (UNPD, 2017). The increasing demographic and economic growth have led to an urban transition. The population has shifted from rural areas to cities. In 2016 it was reported that urban population

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represented approximately 54.5% and it has been estimated that by 2050 66% of the world's population will be urban (United Nations, 2016). Urbanization can have some positive impacts on economic growth. However, sustainable development can also be threatened by an unplanned urban growth. The uncontrolled urban expansion could entail the risk of destroying ecosystems, deforestation and contribute to climate change (United Nations, 2014). The issue of urban sustainability was first addressed in Rio with Agenda 21 and was followed by United Nations City Summit in Istanbul in 1996 (Deelstra and Girardet, 2001). Nowadays, it is a fact that cities exert high pressures on the environment and also generate a high amount of waste (European Commission, 2010).

One of the challenges presented by urbanization is to promote sustainable cities. In doing so, urban and peri-urban agriculture has been implemented as a way of integrating plant growth and animal breeding within and around cities (Duzí et al., 2017). This type of agriculture can be expressed in different forms and spatial structures, such as green roofs, hydroponic greenhouses, community and backyard gardens, school farms and food cooperatives (Kontothanasis, 2017). Research on different cities report that 500 ha are used in London to produce 8400 t of fruit and vegetables, in Berlin there are 80,000 local gardeners and in Paris, several experimental rooftop gardens have been opened testing the level of pollution generated to produce fruit and vegetables (Deelstra and Girardet, 2001; Grard et al., 2017; Petts, 2001).

In order to measure and communicate in a transparent way the environmental pressures of products and organizations, the Environmental Footprint (EF) was proposed by the European Commission (European Commission, 2010). By modeling fourteen impact categories, which include the emissions, wastes, energy and material flows, the environmental performance is obtained (He et al., 2017). Kulak et al. (2013) studied the possibility of reducing the global warming potential with urban agriculture. By integrating this type of agriculture in urban areas, together with a specific selection of crops and techniques, greenhouse gas emissions could be reduced. However, greenhouse gas emissions only provide a limited perspective as it only focuses on a single environmental impact. On the other hand, Rothwell et al. (2016) investigated a range of environmental indicators, such as global warming potential, land use, water use and eutrophication, to compare the trade-offs of local peri-urban production of lettuce with field production through life cycle assessment. This research proved the importance of emphasizing in other impact categories and showed the potential of peri-urban horticulture to improve the environment. Following this path, it was also tested the efficacy of urban agriculture as an environmentally superior production over conventional agriculture. However, environmental impacts may vary depending on the region. Goldstein et al. (2016) found that the overall environmental reduction by urban agriculture appeared to be limited in northern cities.

In Spain, urban and peri-urban agriculture has experienced an increasing interest over the past years. In 2000, 148,542 m^2 of the urban area was dedicated to agriculture in this country, whereas in 2015 the area highly increased to 2,190,233 m^2 (Ballesteros, 2014). A growing interest in urban and peri-urban agriculture has emerged prompted by the environmental deterioration of cities. This type of agriculture appears as one of the possible solutions to cities' environmental issues, such as the increasing levels of pollution and waste disposal (Mougeot, 2006).

In order to be able to confirm the benefits this agriculture claims, specific tools are required. The Environmental Extended Multi-Regional Input-Output (EEMRIO) analysis is a well-known technique applied to obtain the footprints of nations, sub-national entities, socio-economic groups and organizations or companies (Wiedmann, 2009). By applying this method, the incompleteness presented by the process-based method due to the truncation effect is overcome (Suh et al., 2006). It was applied by Weber and Matthews (2008) to estimate the climate impacts of local food considering all the environmental emissions along the entire supply chain and concluded that buying local food could reduce a 4% the overall greenhouse emissions.

Within the environmental impacts of urban and peri-urban agriculture found in the existing literature, these are usually restricted to carbon emissions. In this paper, we propose the EF as a complete indicator to evaluate the environmental performance of this type of agriculture. In addition, while previous investigations have limited their boundaries to study the peri-urban systems, we have also included all upstream impacts by using the EEMRIO analysis. Our contention presented here is that the calculation of the EF could serve as evidence to support the implementation of more peri-urban orchards. Furthermore, the EEMRIO analysis could provide a comprehensive assessment assisting consumers and policy-makers by identifying areas for improvement of their environmental performance. In order to do so, our objectives were to: (1) assess the EF of a network of organic peri-urban orchards, (2) Identify the carbon emission hotspots with regards to the sectors and countries involved in the supply chain, and (3) establish the implications of urban and peri-urban agriculture.

2. Material and methods

2.1. Organic peri-urban orchard network

The organic peri-urban orchard network studied in this research consists of seven peri-urban orchards located in the Spanish city of Zaragoza (Fig. 1 and Table 1). They are located near the Ebro River, where the soil is classified as Haplic Gypsisol (GY) and the climate is characterized as continental Mediterranean climate (IUSS Working Group WRB, 2014). With regards to the management practices, the orchard's areas were managed according to organic agriculture practices (FAO, 2015). In general, the agronomic field operations included plowing, fertilizing, sowing, mulching, irrigation carried out by drip irrigation and harvesting (Fig. 2). The specific characteristics of an organic management included the substitution of synthetic chemicals by natural fertilizers, such as manure and other organic composted substances, and the prevention of pest and disease by weeding and using natural pesticides.

2.2. Methodology

In order to calculate the Environmental Footprint (EF), three steps were followed. In the first place, the inventory phase consisted of collecting all the necessary information related to the orchards' activities (Fig. 3). The municipal government was in charge of requesting and facilitating the economic inputs for the assessment. The information required for the calculation of the total impacts is expressed in monetary terms and includes the accounting records of the goods and services needed for the vegetable production. Capital expenditure has been considered as direct expenses (executed in 2016). Consequently, no amortization period has been considered. In the same way, depreciation costs and amortization expenses related to investments from previous years have not been included in the study. The boundaries of the system refer to the organizational and operational boundaries which include the expenditure involved in energy consumption, water consumption, fuel consumption and other expenses incurred to obtain the total production of each orchard. They were then allocated in the 163 sectors included in the multi-regional input-output database of EXIOBASE (Wood et al., 2015). The soil and crop preparation, the harvesting and transport to consumer phases have all been considered as the production phase comprised in the orchard network.

In the second phase, the calculation of the EF was carried out. Applying an EEMRIO analysis, the total impacts of fourteen impact categories can be obtained using the expenditure as inputs for this method. The impact categories studied were climate change, ozone depletion, human toxicity cancer effects, human toxicity non-cancer effects, particulate matter, photochemical oxidation, acidification, eutrophication-