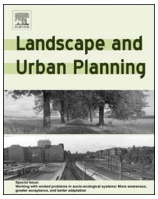
Landscape and Urban Planning 172 (2018) 60–68

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan



Life-cycle energy assessment and carbon footprint of peri-urban horticulture. A comparative case study of local food systems in Spain

David Pérez-Neira[a,*], Anibal Grollmus-Venegas[b]

[a] Department of Applied Economy, University of Leon, Spain
[b] Environmental Engineer, University of Concepcion, Chile

ARTICLE INFO

Keywords:
Sustainability
Agrifood system
Local food
Peri-urban horticulture
Organic farming
Community-supported agriculture

ABSTRACT

In a context of oil depletion and urban population growth, the development of peri-urban agriculture is of special socio-environmental and economic interest in the articulation of local food systems. The quantification and analysis of the environmental impact of peri-urban agriculture is a fundamental element for the design of policies aimed at agrifood and urban sustainability. Based on primary data, the life-cycle assessment of the energy and carbon footprint of peri-urban horticulture in Seville (Andalusia, Spain) was carried out from a cradle-to-consumption approach. Three cases were analyzed taking into consideration their differences in terms of farm management and local supply chain: two conventional farms that sell their output through a local distribution system, and a community-supported agricultural initiative that sells its organic vegetables directly to the consumers. The cumulative energy demand for the production, transport and distribution of 1 kg of fresh vegetables to the consumer in those three cases was estimated at between 2.22 and 5.13 MJ kg^{-1} with a carbon footprint of between 0.117 and 0.271 kg CO_2-eq kg^{-1}. Organic farming consumed approximately 42.5% less non-renewable energy per kilogram than conventional methods, whereas direct distribution reduces greenhouse gas emissions between 63.8 and 91.3% than local supply chains. The results of this work show how the combination of low-input production systems in the peri-urban area of Seville and local supply chains is an economically viable and low energy-impact option for the production and supply of fresh vegetables in the city, especially when the output is organic and the distribution direct.

1. Introduction

The intensification of agriculture (Pimentel & Pimentel, 2008), added to industrialization and the insertion of agricultural goods into global distribution chains, has increased the energy dependence of food production (O'Rourke, 2014). In a context characterized by oil depletion (Murray & King, 2012), the increase in the dependence of food on non-renewable energy has reopened the debate on food insecurity (Arizpe, Giampietro, & Ramos-Martin, 2011). Guaranteeing sufficient food production for a growing population ever more concentrated in the cities (UN, 2012) is among the most significant future challenges (Freibauer et al., 2011). In this sense, the development of urban agriculture is especially interesting, given the possibilities of producing proximity food, improving the resilience of food and energy systems through the diversification of supply (Hodgson, Campbell, & Bailkey, 2011), and increasing the degree of food self-sufficiency in cities, communities or neighborhoods while meeting the demands of a diversity of cultural and geographical environments (Bellwood-Howard, Shakyab, Korbeogoc, & Schlesinger, 2018; Block, Chávez, Allen, & Ramirez, 2012; Saha & Eckelman, 2017). In addition, the reinforcement of urban and peri-urban agriculture may generate important socio-economic (income, employment, food diversity, leisure time, etc.) and environmental (carbon sequestration, reuse of waste, etc.) benefits (Pearson, Pearson, & Pearson, 2010; Specht et al., 2014), and produce a range of non-food and non-market goods related to ecosystemic services with a positive impact on the urban setting (Langemeyer, Camps-Calvet, Calvet-Mira, Barthel, & Gómez-Baggethun, 2018).

One of the most important debates around "local food" has focused on analyzing to what extent the delocalization of production can reduce energy consumption and greenhouse gas (GHG) emissions. Using the concept of "food miles", some authors have argued that a decrease in the distance travelled by food constitutes a fundamental factor of agrifood sustainability (Morgan, Marsden, & Murdoch, 2006; Paxton, 1994). However, others have criticized the reductionism of this concept and have underlined the role of other factors and agrifood phases (e.g., packing, storage, vehicle efficiency, refrigeration, infrastructure, etc.) in the supply chain rendering the analysis more complex (Almeida et al., 2014; Coley, Howard, & Winter, 2009; Mundler & Rumpus, 2012). From the fields of

---

[*] Corresponding author. Present address: Department of Applied Economy and Statistics, Leon University, Campus de Vegazana s/n, CP 24071 León, Spain.
E-mail addresses: dpern@unileon.es, dapeneira@uvigo.es (D. Pérez-Neira), anibal.grollmus@gmail.com (A. Grollmus-Venegas).

https://doi.org/10.1016/j.landurbplan.2018.01.001
Received 18 April 2016; Received in revised form 23 December 2017; Accepted 2 January 2018

political economics and geography, Born and Purcell (2006) have argued that environmental (and/or social) outcomes are not inherent to scale, but are produced, or not, within a specific context and according to the particular actors and interrelationships of the given food system. Therefore, the potential of local food and peri-urban agriculture for reducing the system's environmental impact needs to be assessed from a broad perspective, taking into consideration their whole life cycle and incorporating other socioeconomic factors in relation to their contexts (Edwards-Jones et al., 2008).

Based on life-cycle assessment (LCA), many studies have quantified the environmental impact of food (Roy et al., 2009). For instance, Milà i Canals, Burnip, and Cowell (2006) evaluated apples for a case study in New Zealand and Pérez-Neira (2016) did the same with export cocoa in Ecuador, whereas other works like those by Carlsson-Kanyama, Ekstrom, and Shanahan (2003) or Notarnicola, Tassielli, Renzulli, Castellani, and Sala (2017) analyzed a large number of foods associated to Swedish and European diets. In relation to the debate on local food, some studies have reported that local production can be energetically more efficient than non-local production (Jones, 2002; Stadig, 1997) while other researches have presented contradictory results depending on the context and products analyzed (Saunders, Barber, & Taylor, 2006; Webb, Williams, Hope, Evans, & Moorhouse, 2013). For fresh vegetables, Wallgren (2006) obtained a much lower transport-related energy use in local food systems in Sweden, though she underlined the fact that the analyzed products are restricted to two or three summer months. Stoessel, Juraske, Pfister, and Hellweg (2012) concluded that sourcing vegetables locally is a good strategy in relation to GHG emissions insofar as the vegetables are not cultivated in heated greenhouses within the same territory (Sweden).

With regard to urban agriculture and local food, it is important to consider some precedents. Lee, Lee, and Lee (2015) estimated the expected GHG reduction effect in the case of a revitalization of urban agriculture in the city of Seoul. Kulak, Gravesb, and Chatterton (2013) quantified the potential savings associated with food production in urban community farms in the United Kingdom. Sanyé-Mengual, Cerón-Palma, Oliver-Sol, Montero, and Rieradevalla (2013) showed how producing tomatoes in roof-top greenhouses in Barcelona leads to lower energy dependence and reduces other LCA impact categories in contrast with the current linear system in Spain. He et al. (2016) used a LCA to quantify the environmental advantages of producing organic tomatoes in greenhouses as compared to conventional practices in the city of Beijing (China). Within this analytical framework, it is essential to continue researching on the role of urban agriculture, as well as to make diversity visible, especially in relation to food production management and distribution systems.

Since the 1990s, different community-supported peri-urban agriculture initiatives have emerged in Spain that are committed to organic farming and the construction of alternative agrifood systems (Simón-Fernández, Copena-Rodríguez, & Rodriguez, 2010). The most extended community-supported agriculture (CSA) model is that of food cooperatives, which bring together consumers and farmers within the sphere of alternative and solidarity economy (ECSARG, 2016). According to the European Community-Supported Agriculture Research Group (ibid.), there are 75 CSA initiatives in Spain feeding around 7000 persons. Vegetables are the most common type of food available (96%), followed by bread (67%) and fruit (52%). Urban planning in Seville (Andalusia, Spain) has ignored urban and peri-urban agriculture (Dimuro-Peter, Soler-Montiel, & Jerez, 2013), but, in spite of it, agriculture is still alive in the city and, in the last decades, new CSA initiatives and citizen projects linked to agroecology and food sovereignty have emerged (Dimuro-Peter et al., 2013). CSA initiatives are focused on the organic production of seasonal fruits and vegetables distributed through alternative consumption networks that avoid intermediaries. Following Hardmana et al. (2018), this type of initiative may be considered to lie at the more informal end of the urban food growing movement and green activism.

Consequently, the main objective of this work is to analyze the energy metabolism and carbon footprint of peri-urban agriculture in the city of Seville taking into consideration the differences between production models and supply chains. For this purpose, LCA methodology (cradle-to-consumption approach) has been applied to three cases: two conventional farms that distribute their products through the local supply chain (wholesaler-retailer-store) and one CSA initiative that grows organic vegetables and sells them directly to the consumer through alternative distribution networks. As an additional secondary objective, this work analyses the economic profitability of peri-urban farms. The results presented in this paper, in addition to being a novelty in Andalusia and Spain, provide scientific information that, within the limits of the study and in accordance with the methodology applied, can contribute to the design of agricultural policies and practices aimed at agrifood sustainability.

2. Materials and methods

2.1. LCA, system boundaries and functional unit

The methodology used in this work is the life-cycle assessment (LCA) focused on the energy metabolism and carbon footprint. The LCA of peri-urban horticulture in Seville has been divided into 5 phases. Phase 0 calculated the energy costs associated with the agricultural inputs and capital used on the farms. Phase 1 quantified the energy consumption required to produce vegetables. In phases 2 and 3, the energy use associated with wholesale, packing, and retail storage was also quantified. The energy cost associated with the sale of vegetables was measured in phase 4. Phase 5 considered the energy consumption of transporting the products from the farm to the consumer (Fig. 1). The cradle-to-consumption analysis has been divided into two LCA stages: (a) the cradle-to-farm gate approach, including phases 0 and 1 (functional unit: hectares and kilograms) and (b) the farm gate-to-consumption approach, encompassing phases 2, 3, 4 and 5 (functional unit: kilograms).

2.2. Case studies and elaboration of an inventory

The cases were selected with the intention of obtaining a non-statistical representation of conventional and organic horticulture, as well as of the local commercial strategies of *peri*-urban horticulture in Seville (Andalusia, Spain) (Fig. 2). The farms under study represented approximately 1.25% of the cultivated area in *peri*-urban Seville (OPS, 2006) and were situated in the following locations: Farm 1: 37°25′51.3″N 5°57′47.5″W; Farm 2: 37°25′54.3″N 5°57′44.4″W, and Farm 3: 37°25′44.9″N 5°57′30.5″W. The information required to make the environmental and economic estimates was gathered through face-to-face questionnaires during 2012. The data set used in the analysis was collected and organized in the inventory summarized in Tables 1a, 1b and 1c.

The first two cases analyzed (C1 and C2) correspond to two small family farms (F1 and F2) that cultivate conventional vegetables and commercialize their products through a wholesaler. The products reach the consumers through local distribution chains (retailer-store) in Seville and the surrounding areas (Table 1c). The third case (C3) is that of a community-supported agriculture (CSA) initiative that comprises a small organic family farm (F3) and a group of consumers. The farm grows a medium to high diversity of seasonal vegetables that are directly sold to consumers in the city. The consumers are organized into "consumer groups" and undertake to purchase (pre-payment) a weekly basket of vegetables and to actively participate in the logistics of distribution.

The two methods of distribution used by the CSA initiative were analyzed (ECSARG, 2016). In the first one, distribution is organized autonomously by each consumer group (1 group = 1 delivery). Someone from each group collects the baskets at the farm and takes