Journal of Environmental Management 204 (2017) 594–604

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Assessing eco-efficiency and the determinants of horticultural family-farming in southeast Spain

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ARTICLE INFO

Article history:
Received 19 May 2017
Received in revised form
26 August 2017
Accepted 12 September 2017
Available online 21 September 2017

Keywords:
Eco-efficiency
Family farm
Horticulture
DEA
Socio-economic features

ABSTRACT

Eco-efficiency is currently receiving ever increasing interest as an indicator of sustainability, as it links environmental and economic performances in productive activities. In agriculture these indicators and their determinants prove relevant due to the close ties in this activity between the use of often limited natural resources and the provision of basic goods for society. The present paper analyzes eco-efficiency at micro-level, focusing on small-scale family farms as the principal decision-making units (DMUs) of horticulture in southeast Spain, which represents over 30% of fresh vegetables produced in the country. To this end, Data Envelopment Analysis (DEA) framework is applied, computing several combinations of environmental pressures (water usage, phytosanitary contamination, waste management, etc.) and economic value added. In a second stage we analyze the influence of family farms' socio-economic and environmental features on eco-efficiency indicators, as endogenous variables, by using truncated regression and bootstrapping techniques. The results show major inefficiency in aspects such as waste management, among others, while there is relatively minor inefficiency in water usage and nitrogen balance. On the other hand, features such as product specialization, adoption of quality certifications, and belonging to a cooperative all have a positive influence on eco-efficiency. These results are deemed to be of interest to agri-food systems structured on small-scale producers, and they may prove useful to policy-makers as regards managing public environmental programs in agriculture.

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1. Introduction

Humans have intervened in natural ecosystems to gather food in the most productive and efficient way possible for millennia. In recent decades, this activity has become extremely important due to an incessant population increase and the growing need to obtain basic goods amidst alarming scarcity of resources and greater pressure on the environment.

In this context, eco-efficiency, meaning the relationship between economic and ecological efficiency, is a useful indicator in relation to the capacity of companies, sectors and economies to produce goods and services with less consumption of natural resources and less impact on the environment. This concept emerged in the 1990s as an indicator of sustainability (Schaltegger and Sturm, 1996; Bleischwitz, 2003). The OECD (Organization for Economic Co-operation and Development) defined it as the efficiency with which ecological resources are used to meet human needs (OECD, 1998, 1999). While eco-efficiency has become a rather popular concept, it does have several limitations with regard to sustainability. On the one hand, it focuses on only two aspects of production processes and fails to consider social implications (Beltrán Esteve, 2012). On the other hand, the term efficient by no means implies that something is sustainable; the former is merely a necessary condition (or intermediate step) for the latter. This is essentially due to the fact that eco-efficiency is simply a relative indicator, and it does not provide information regarding effectiveness (Callens and Tyteca, 1999). For example, although the relative level of a particular environmental pressure may be low, which would be indicative of high efficiency, it might exceed the absorption capacity of the ecosystem itself. Moreover, the appearance of the so-called 'rebound effect', e.g. changes in consumption patterns (Holm and Englund, 2009), can compensate for or neutralize the efficiency achieved at any given moment. In short, achieving environmental efficiency at the micro level does not guarantee the

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http://dx.doi.org/10.1016/j.jenvman.2017.09.037
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achievement of environmental sustainability objectives in absolute terms at the macro level (Huppes, and Ishikawa, 2005).

Despite these shortcomings, eco-efficiency analyses have shown to be of particular interest for two reasons. Firstly, progress in environmental performance may represent the most cost-effective way to achieve a reduction in environmental degradation. Secondly, policymakers may find it easier to adopt policies aimed at achieving improvements in performance than other more radical policies that directly restrict the level of economic activity (Kousmanen and Kortelainen, 2005; Gómez-Limón et al., 2012).

In the field of microeconomics, this indicator has grown in popularity, particularly with the World Business Council for Sustainable Development (WBCSD, 2000); it serves as a means of stimulating productive organization to seek out environmental improvements that yield parallel economic benefits (Keating et al., 2010).

In agricultural production, measures of eco-efficiency not only allow pollutants to be tested but they can also incorporate the so-called balance principle (Coelli et al., 2007), which implies that nutrients not contained in good outputs return to the environment as potential pollutants (e.g. fertilizers, wastes, etc.). Hoang and Nguyen (2013) expand upon this analysis of agri-food activities by including nonmaterial inputs (e.g. labor, capital, farm services, etc.), offering a more general study (material balance and energy balance) of environmental problems (Oude Lansink and Wall, 2014). The most common measuring techniques in this context are production frontier models, DEA (Data Envelopment Analysis) and SFA (Stochastic Frontier Analysis), essentially because their operationalization relates environmental and economic outcomes rather than just conventional inputs and outputs (Callens and Tyteca, 1999; Lauwers, 2009). In keeping with this approach, Kousmanen and Kortelainen (2005) propose a definition of eco-efficiency based on what they refer to as 'a pressure-generating technology set', which represents all feasible combinations of economic value and environmental pressures (treated as conventional inputs). This particular definition has been applied in eco-efficiency analyses conducted in a variety of sectors, as well as in various agri-food production studies (see for a review e.g. Oude Lansink and Wall, 2014).

Following this methodology, numerous analyses in the agri-food sector have focused on eco-efficiency at farm level, using individual farms as the basic production units (e.g. De Koeijer et al., 2002; Picazo-Tadeo et al., 2011; Hoang and Nguyen, 2013; Beltrán-Esteve et al., 2014). This has been done so fundamentally because it is believed that individual farmers are responsible for making the most important decisions concerning the use of resources and the implementation of greener technologies (Webster, 1999). In addition, and perhaps more importantly, when conducting specific analyses on farming activity, it must be taken into account that there are factors determined by issues of agricultural policy and others influenced by socioeconomic features, e.g. farmers' attitudes, organization structures, environmental concerns, etc. (Keating et al., 2010). In effect, although business people, policy makers and society in general are always interested in indicators, the study of determinants of eco-efficiency is no less important, yet it has been addressed to a lesser extent in the literature (Oude Lansink and Wall, 2014).

This work presents an eco-efficiency analysis of the horticultural farming system in southeast Spain, which is characterized by a structure consisting of small-scale family farms. This farming sector represents about 30% of Spanish fresh vegetables produced and about 18% consumed in Europe (Cajamar, 2016). Over the course of decades, the growers in this region have progressively incorporated technologies adapted to the environmental conditions of the area, such as limited basic resources (mainly water and land), as well as various techniques to reduce negative externalities resulting from the increasing intensification of farming methods (e.g. water scarcity, chemical contamination, waste, etc.), although not always with homogeneous results (Piedra-Muñoz et al., 2016). This agricultural development has been greatly influenced by a series of socio-economic components of farming itself (e.g. family, cooperative organization, education, etc.) as well as interrelationships with the agri-food cluster surrounding said activity, such as auxiliary and service companies (Aznar-Sánchez et al., 2011).

The aims of this paper are: i) to obtain a series of indicators for eco-efficiency by computing several ratios for environmental pressures and economic value added in this farming activity; ii) and to analyze their socioeconomic and environmental influences on these indicators. The methodology followed is the Data Envelopment Analysis, DEA, framework on a sample of horticultural family farms as decision-making units (DMUs). In a second stage, by using a truncated regression and bootstrapping techniques, the determinants of eco-efficiency scores in this farming system are analyzed. Unlike other research papers along this line, the present study identifies both aggregate and specific individual environmental pressures as well as the determinants that influence them. Such information is important for intensive horticultural sectors, especially those in semiarid regions with specific environmental characteristics. In the present case, examples of these features include the concentration of crops in the study area and the traditional pressures exerted on its natural surroundings. Moreover, as we are dealing with family farms, this study is of particular interest at the micro-level given the determinants being analyzed, i.e. social, economic and environmental. The former are the most relevant in this regard due to the sector's family orientation (e.g. the role of farm succession to the next generation) and organizations (cooperatives). These aspects, related to the type of farm managers and their behavior, are of considerable importance as well. In addition, while one of the main objectives of other eco-efficiency studies is usually to focus on the assessment of environmental programs or the support to farming, in the present case, such initiatives are traditionally of little relevance. As a result, in this context, the influence of the specific characteristics of the sector, e.g. type of manager, become even more important. The results of the present study can provide a wide overall perspective on ecological-economic relationships and orientations. This can be of great help for the drafting of agri-environmental policies in the horticultural sector under study, as well as a contribution to methodological applications in other similar farming systems.

The rest of the paper is structured as follows. In the second section a description of the sector under study is outlined. In the third section, methods and data are expounded. In the fourth section the estimations and results are presented. Finally, the conclusions and policy implications are detailed in the fifth section.

2. Description of horticulture in southeast Spain

The current agricultural system had its beginnings some five decades ago, initially cultivating fresh vegetables out in the open and later in greenhouses. With some 30,000 ha of crops at present, located in the coastal area of the provinces of Almería and Granada, this system accounts for approximately one third of all vegetables grown in Spain and this produce is destined for both the domestic and foreign markets (Cajamar, 2016). The evolution of this horticultural system has been particularly characterized by a process of adaptation to environmental conditions and challenges of resource efficiency (Figs. 1 and 2).

This agricultural area is semi-arid with scarce precipitation, but

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