Renewable and Sustainable Energy Reviews 76 (2017) 155–162

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Assess and prognosticate green house gas emissions from agricultural production of EU countries, by implementing, DEA Window analysis and artificial neural networks

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ARTICLE INFO

Keywords:
DEA Window analysis
Artificial Neural Networks
Environmental efficiency
Greenhouse gas emissions

ABSTRACT

One of the most important policy reforms for the European Union (EU) agriculture was the implementation of the Agenda 2000, which establishes a new framework for subsidies management, decoupled from both crop and animal production for the vast majority of products. One of the main goals of this new policy framework is the improvement of its environmental impact. Additionally, there is a need for the implementation of new efficiency assessment and prognostication tools for the evaluation of EU farming, because the influence of market forces has been increased substantially. Having in mind the efficacy of Data Envelopment Analysis (DEA) methodology, it is used to calculate and quantify the environmental efficiency of EU countries' primary sectors. In this paper, the DEA Window methodology is used to assess GHG emissions efficiency and identify efficiency change of EU countries' primary sectors, under the strong influence of Common Agricultural Policy (CAP), quantifying by this way its positive or negative impact on a national basis, providing at the same time hints for counteractive actions. The main results provide the significant differences among EU countries, with the less developed ones to perform low environmental efficiency rates. Moreover, countries which their output depends to a large extend on arable crops achieve low efficiency rates too. Finally, Artificial Neural Networks (ANNs) are being used as a tool to estimate future performance of EU countries primary sectors on the topic of Greenhouse Gas (GHG) emissions as an undesirable output of agricultural production process. The validation performance characteristics, as well as the linear fit to this output-target relationship, closely intersect the bottom-left and top-right corners of the plot. The combination of these methodologies provides a new methodological approach for CAP evaluation and prognostication, appropriately adjusted to the new market oriented framework for EU agricultural production.

1. Introduction

The recent reforms of the Common Agricultural Policy (CAP) of the European Union (EU) aim to improve the environmental profile of agricultural production process. One of the most important policy reforms for the EU agriculture was the implementation of the Agenda 2000, with the establishment of a totally new framework for subsidies management, decoupled from both crop and animal production for the vast majority of products. Since the year 2005 the new subsidy scheme has come into force, providing by this way the ability to the EU to fully comply with the last World Trade Organization (WTO) agreement of the Uruguay Round [1].

Up to now, Data Envelopment Analysis (DEA) has been used to assess efficiency of agricultural production processes. The non-parametric approach of this methodology, in accordance with the absence of a priori assumptions, formulates a framework where it is easily applicable. Another quite important advantage of it is the ability to use multiple inputs and outputs for efficiency assessment, increasing by this way the objectivity of the results being obtained when handling real life tasks. Therefore, it has been used for efficiency assessment of very important sectors of the economy, like banking, health care, schools, and several industrial sectors quite important for national economies globally [2]. Nevertheless, it has also been used in various cases in agriculture, as well as in the food industry, trying to evaluate the efficiency rates of inputs used, as well as the outputs achieved [3]. For almost every sector of the economy there is a variation of efficiency goals, beyond the typical economic ones. Consumers demand for adopting environmentally friendly production methods by the produ-

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http://dx.doi.org/10.1016/j.rser.2017.03.054
Received 21 July 2016; Received in revised form 14 December 2016; Accepted 8 March 2017
1364-0321/

cers, in addition with the need for a continuous increase of energy efficiency, outlined new perspectives for the use of DEA with fairly successive research results. The European primary sector, especially after the implementation of the Agenda 2000, has put a lot of effort to meet these goals. Due to the fact that it is important for policy makers to detect efficiency trends overtime, the DEA Window analysis and the Malmquist productivity index are suitable tools for such assessments. It has been used for rather diversified economic activities, verifying by this way the validity of these methods and their acceptance as research tools [4,5]. In this paper, the DEA Window methodology is used to assess GHG emissions efficiency and identify efficiency change of EU countries primary sectors, under the strong influence of CAP, quantifying by this way its positive or negative impact on a national basis, providing at the same time hints for counteractive actions.

Quite important is also the ability of policy makers to assess the level of impact and success of policies being planned. In many cases this is not an easy task, due to the fact that this level of success is heavily depended on the assumptions being made as well as the suitability of the models being used for such estimations. Regarding agriculture, there are models focusing on the impact of policies on agricultural trade and development, as well as other tasks like biophysical and environmental ones. All these widely recognised models are based on various mathematical methodologies, providing useful information for significant issues of agriculture, like land management, agricultural trade and agricultural income. There are though other prognostication methodologies, being already used in many scientific fields with significant success, like the Artificial Neural Networks (ANNs). In this paper ANNs are being used as a tool to estimate future performance of EU countries primary sectors on the topic of Green House Gas (GHG) emissions as an undesirable output of agricultural production process.

2. Background

DEA has been used for many decades, when Farrell [6] stated the problem of measurement of productive efficiency. Based on these ideas Charnes et al. [7] introduced DEA as an adequate methodology for quantifying relative deficiencies of multi-input and multi-output production units. The great acceptance and usefulness of DEA is proved by the use of it for efficiency assessment of very important production sectors of the economy, even nowadays [8]. The most important utilities of DEA are the use of peer groups, the identification of efficient operating practices, the setting of targets, the identification of efficient strategies, the monitoring of efficiency changes over time, and resource allocation [9]. One of the first implementations of this was for the banking sector [7,10]. Similar approaches there were for efficiency evaluation for schools [11,12] with satisfactory results. Another very important sector for economies is the energy production one. Special research focus has been given on the electric power plants efficiency on both operational and environmental terms [13,14]. Additionally, DEA has been used for evaluation of ports, prevailing by this way best management practices in a highly competitive sector of international economy [15].

The increasing awareness for environmental protection has driven research towards assessing the impact of inputs being used in agriculture on eco-efficiency. Several studies on specific crops assessed eco-efficiency and presented the linkages between eco-inefficiency and input management. Spanish olive growers were proven to be quite eco-efficient with inefficiencies to be closely related with technical inefficiencies. Eco-efficiency was boosted via implementation of agri-environmental projects like university education [16,17]. Eco-efficiency is closely related with land use management too [18]. Application of DEA on citrus cultivation lead to specific alternatives focusing on efficiency improvement in areas where small size of agricultural holdings is a major issue, which is the case in many Mediterranean countries [19]. The use of DEA for olive trees cultivation provided the ability to measure inefficiencies related with resources management like land and water, in Andalusia were especially water availability is a crucial issue for both inhabitants and cultivations [20]. Quite vital issue for farming is labour management too. On the same trend for assessing environmental efficiency, a combination of Life Cycle Assessment (LCA) and DEA has been used by researchers regarding agricultural production. LCA is a tool for estimating the environmental impacts of a process or a product. DEA implementation by using LCA results can lead to super efficiency analysis to simplify the selection process of reference performers, which is essential in a benchmarking process. Additionally, there is the ability for inter- and intra- assessment of multiple data sets, because for every process the energy impact has been calculated and used. Furthermore, sustainability issues can be correlated with the economic dimension of every activity being incorporated in these models and the application of DEA Window analysis provide the ability to quantify environmental efficiency variation for a specific time period [21]. Applications of this methodology can be found for mussel production, where the DEA targets being obtained can be utilised as virtual cultivation sites with less input use and more output production achieved simultaneously [22]. Interesting findings were attained when this methodology was used to assess both operational and environmental efficiency for fisheries. This combination is suitable in such cases were multiple input/output data should be used, providing at the same time the ability of not using standard deviations which is usually the case when working with average inventories [23]. One of the most competitive sectors in animal production is the cow milk one [24]. The application of LCA and DEA provided very useful and applicable results, focusing on reducing the operational cost of dairy farms, as well as improving their environmental footprint [25]. There are though successful applications in crop production too. LCA and DEA of grape production and vinification presented quantified inefficiencies on both operational and environmental level. In NW Spain a necessity for 30% on average on inputs reduction was assessed, leading to an increase of 28–39% of environmental gains depending on the impact category [26]. The applicability of this methodology was verified for arable crops cultivation too. Regarding soybean farming in Iran 46% farms of the sample were found as efficient. The most important contributors to global warming were irrigation and fertilization by 63% and 34% respectively, providing a road map for both efficiency improvement and minimization of environmental footprint [27]. It has been proved though that DEA methodology autonomously implemented to assess environmental efficiency is a widely accepted approach. Significant advantages of it are the accuracy of results for small data sets and the ability to include undesirable outputs and inputs [28]. The continuous focus of both agricultural policies and consumers on environmental issues and the impact of production procedures on them motivate all the participating parties to assess this impact and put serious effort on improving environmental efficiency. Following this approach, DEA was used to assess energy efficiency of wheat farms, by separating efficient from inefficient farmers and calculate quantities of inputs being used in a wasteful way. The most important findings originated that only 18% of growers were technically efficient, with the overall technical efficiency to be 0.82. It has been observed also that by implementing energy optimization the total GHG emissions can be reduced substantially [29]. A similar case is the alfalfa production. In this, 46% of growers were found technically efficient, with the average technical efficiency to be 0.84. Optimization of energy use improved the energy use efficiency by 10.6% [30]. The energy cost of greenhouse vegetable production is the most important one, affecting directly feasibility and competitiveness of agricultural holdings. An integrated input-output analysis measured the energy efficiency of greenhouses producing vegetables like tomatoes and cucumbers. Inputs substantially affecting energy costs are diesel fuel and fertilizers. Quite important is also the energy ratio for the two cultivations, which is 0.69 and 1.48 respectively. In pure economic terms it is indicated that tomato cultivation is more