Journal of Environmental Management 150 (2015) 288–298

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Evaluating the Sustainable Intensification of arable farms

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ARTICLE INFO

Article history:
Received 26 March 2014
Received in revised form
23 August 2014
Accepted 9 October 2014
Available online

Keywords:
Sustainable Intensification
Agriculture
Data Envelopment Analysis
Eco-Efficiency
Environmental pressures
Double bootstrapped truncated regression

ABSTRACT

Sustainable Intensification (SI) of agriculture has recently received widespread political attention, in both the UK and internationally. The concept recognises the need to simultaneously raise yields, increase input use efficiency and reduce the negative environmental impacts of farming systems to secure future food production and to sustainably use the limited resources for agriculture. The objective of this paper is to outline a policy-making tool to assess SI at a farm level. Based on the method introduced by Kuosmanen and Kortelainen (2005), we use an adapted Data Envelopment Analysis (DEA) to consider the substitution possibilities between economic value and environmental pressures generated by farming systems in an aggregated index of Eco-Efficiency. Farm level data, specifically General Cropping Farms (GCFs) from the East Anglian River Basin Catchment (EARBC), UK were used as the basis for this analysis. The assignment of weights to environmental pressures through linear programming techniques, when optimising the relative Eco-Efficiency score, allows the identification of appropriate production technologies and practices (integrating pest management, conservation farming, precision agriculture, etc.) for each farm and therefore indicates specific improvements that can be undertaken towards SI. Results are used to suggest strategies for the integration of farming practices and environmental policies in the framework of SI of agriculture. Paths for improving the index of Eco-Efficiency and therefore reducing environmental pressures are also outlined.

1. Introduction

Climate change and increased food demand are two of the most important challenges for the future growth of agricultural systems. The need for securing food supply, managing natural resources efficiently, building resilience to more frequent extreme weather phenomena and developing adaptation strategies for farmers has prioritised the need for a Sustainable Intensification (SI) of agriculture (FAO, 2011; Foresight Report, 2011).

Firbank et al. (2013), define SI at a farm level as the process of increasing agricultural production per unit of input whilst at the same time ensuring that environmental pressures generated at a farm level are minimised. SI of agriculture can therefore be considered not only as a practice but also as a mechanism of farm management that serves the balance between sustainability and intensification of production. This relies on the engagement of integrated methods and technologies to manage limited natural resources (soil and water), pests and nutrients (Pretty, 1997). Garnett et al. (2013) suggest that food security requires as much attention to be focussed on increasing environmental sustainability as to raising productivity. This means that, farmers, not only need to simultaneously increase yields to meet food demand, but also need to reduce environmental pressures generated by the production process. Therefore, from an environmental perspective this means reducing any additional conversion of land to agriculture (maintain existing land ecosystems and biodiversity), increasing productivity and improving input use efficiency (e.g. water, energy, agrochemicals) (Garnett et al., 2013; Garnett and Godfray, 2012).

Agriculture in the UK is a major contributor in determining and enhancing the viability of rural economies and preserving rural landscapes but also is the main source of degradation in a range of ecosystems services (Firbank et al., 2008). Sustainable farming systems therefore, are characterised as those that are able to be productive and to maintain their contribution to society in the long term. These agricultural systems by definition will be using natural resources efficiently, be competitive in the commercial market and environmentally protective (Rigby and Caceres, 1997).

For UK agriculture to meet the future challenges of food demand and climate change, SI can therefore be a management option especially for areas that are experiencing a stasis in productivity growth, where a more efficient use of natural resources, production

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http://dx.doi.org/10.1016/j.jenvman.2014.10.005

inputs and new technologies may be able to move production onto an upward trajectory and at the same time reduce the negative environmental impacts (Barnes and Thomson, 2014; Firbank et al., 2013; Garnett et al., 2013).

Recent research has sought evidence of SI among farming systems in the UK (Areal et al., 2012; Barnes and Poole, 2012; Barnes and Thomson, 2014; Firbank et al., 2013). Firbank et al. (2013) suggest that a farm is practising SI when it has managed to increase the food production per unit area in the study period and at the same time none of the environmental indicators selected has deteriorated.

1.1. *Using Eco-Efficiency to measure sustainable intensification*

One of the challenges in measuring SI is to find appropriate measures of the environmental dimensions. One variable that may give some indication of change in supply of ecosystem services is the level of rough grazing area to total area used, a criterion for identifying Higher Nature Value farming systems (Barnes et al., 2011), and also as a proxy for environmental outputs (Areal et al., 2012). Firbank et al. (2013) underlines the need for the development of metrics that can simultaneously account for both environmental pressures and economic output of farming systems in order to evaluate SI at farm level in temperate regions. As an example, composite indicators have been used to assess sustainability and production efficiency (Gomez-Limon and Riesgo, 2009) in the agricultural sector since it is possible, with the appropriate weighting of the different dimensions of the indicator, to assess progress on the three common dimensions of sustainability (economic, social and environmental) in order to produce an integrated performance output for evaluation. According to Barnes and Thomson (2014), most composite indicators have focused on country or regional level while only a few focus specifically on the agricultural sector. However, there is no evidence for the existence of an agreed set of indicators or a composite indicator for evaluating and measuring SI (Barnes and Thomson, 2014; Firbank et al., 2013; Westbury et al., 2011).

As such a composite indicator, the Economic-Ecological Efficiency, frequently known as Eco-Efficiency, emerged as a practical approach for evaluating progress towards sustainability and economic efficiency (Schaltegger et al., 1996). The OECD (1998) defines Eco-Efficiency as a ratio of an output (value of products) over the inputs used (the sum of environmental pressures generated by the firm, the sector or the economy) which measures the efficiency with which ecological resources are used to meet human needs. Using Eco-Efficiency as a measure of the economic value added over the environmental pressure generated is a potential method of evaluating progress towards the SI of agricultural systems. Therefore, an improvement in the Eco-Efficiency index can be translated as a decrease in environmental impact while the value of production is maintained or increased (de Jonge, 2004; European Environment Agency (EEA) 2010; Gomez-Limon et al., 2012) and the reverse in the case of deterioration.

However, as emphasised by the WBCSD (2000), improvements in the index of Eco-Efficiency do not automatically lead to improvements in sustainability. Given that sustainability is usually concerned with the absolute pressure that an economic activity is generating rather than the relative pressure, the main pitfall in the Eco-Efficiency ratio is that high levels of environmental pressures (e.g. soil erosion, pesticides risk, water use, fertiliser risk, CO_2 emissions) generated at a farm level can be compensated by high levels of Net Farm Income (Gomez-Limon et al., 2012; Kuosmanen and Kortelainen, 2005; Picazo-Tadeo et al., 2011).

These shortcomings however, do not invalidate the use of Eco-Efficiency as a concept to stimulate innovation and enhance the SI of farming systems. Kuosmanen and Kortelainen (2005) suggest at least two basic reasons for using an Eco-Efficiency index for assessing the impacts of production systems. First, in the context of attempting to reduce environmental pressures, improvements in Eco-Efficiency can be shown to be cost-effective and second, from a policy perspective, improvements in the efficient use of inputs are more attractive and easier to adopt than policies that directly restrict the level of economic activity. This win–win outcome of policies promoting efficient use of inputs encourages sustainable agriculture without the need for even greater environmental regulation as it leads to a reduction in the level of damaging inputs, such as fertilisers, pesticides, fossil fuels etc., will increase environmental efficiency and also improve net cost savings (de Jonge, 2004).

Therefore SI can be viewed as a trade-off between economic and ecological performance characterised by an Eco-Efficient frontier (Mahlberg and Luptacik, 2014) that aims to reduce environmental pressures in agriculture. In other words, a farm lying on the frontier cannot increase output without increasing the intensity of production which results in increasing waste and emissions. Eco-Efficiency frontiers can be estimated with the use of the Data Envelopment Analysis (DEA) method, a non-parametric frontier based modelling approach. A detailed literature review on integrated ecological-economic analysis in a production context is presented in Lauwers (2009).

One of the approaches suggested by Korhonen and Luptacik (2004) for modelling and assessing Eco-Efficiency in a DEA based modelling is to account simultaneously for economic and ecological performance given that the objective is to increase the desirable outputs and minimise the environmental pressure generated by the production process. According to Picazo-Tadeo et al. (2012) this provides a base for developing a broad range of models depending on the treatment of the economic output and/or the environmental pressures.

Various research papers have used DEA techniques to discuss the notion of Eco-Efficiency in different industries (Hua et al., 2007; Korhonen and Luptacik, 2004; Kuosmanen and Kortelainen, 2005; Lauwers, 2009; Zhang et al., 2008). Although DEA techniques have been widely used for the assessment of the environmental performance of farms (Asmild and Hougaard, 2006; Buckley and Carney, 2013; D'Haese et al., 2009; de Koeijer et al., 2002) and the agricultural sector (Barnes et al., 2009) only a few research papers have applied the method for the assessment of farming Eco-Efficiency (Gomez-Limon et al., 2012). Picazo-Tadeo et al. (2011) have used DEA techniques for the assessment of potential environmental pressure reductions in a set of 171 farms in rain-fed agriculture systems of Valencia, Spain. Further examples include Picazo-Tadeo et al. (2012), Gomez-Limon et al. (2012), and Iribarren et al. (2011).

Other alternatives are the integration of the Sustainable Value (SV) method in a production framework approach (Ang and Van Passel, 2010; Ang et al., 2011; Kuosmanen and Kuosmanen, 2009; Mondelaers et al., 2011; Van Passel et al., 2009). The method integrates the efficiency in respect to the triangular dimension of sustainability (i.e. economic, social and environmental) into a monetary value. However, a substantial debate has developed after its introduction as a measure of strong sustainability by Figge and Hahn (2004).

Here, it is suggested that environmental pressures generated at a farm level, as defined by Picazo-Tadeo et al. (2011), can be interpreted as an indication of the level of intensification of agricultural production in an effort to secure yields and maximise profit. Higher levels of inputs for individual farms in a benchmarked sample indicate that these farmers are using more intensive production methods when compared with others in the same sample. The objective of this paper is to measure the SI of farming systems,