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Improving productivity and water use efficiency: A case study of farms in England

Yiorgos Gadanakis*, Richard Bennett, Julian Park, Francisco Jose Areal

School of Agriculture, Policy and Development, University of Reading, Whiteknights, P.O. Box 237, Reading RG6 6AR, UK

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ABSTRACT

The idea of Sustainable Intensification comes as a response to the challenge of avoiding resources such as land, water and energy being overexploited while increasing food production for an increasing demand from a growing global population. Sustainable Intensification means that farmers need to simultaneously increase yields and sustainably use limited natural resources, such as water. Within the agricultural sector water has a number of uses including irrigation, spraying, drinking for livestock and washing (vegetables, livestock buildings). In order to achieve Sustainable Intensification measures are needed that enable policy makers and managers to inform them about the relative performance of farms as well as of possible ways to improve such performance. We provide a benchmarking tool to assess water use (relative) efficiency at a farm level, suggest pathways to improve farm level productivity by identifying best practices for reducing excessive use of water for irrigation. Data envelopment analysis techniques including analysis of returns to scale were used to evaluate any excess in agricultural water use of 66 horticulture farms based on different river basin catchments across England. We found that farms in the sample can reduce on average water requirements by 35% to achieve the same output (Gross Margin) when compared to their peers on the frontier. In addition, 47% of the farms operate under increasing returns to scale, indicating that farms will need to develop economies of scale to achieve input cost savings. Regarding the adoption of specific water use efficiency management practices, we found that the use of a decision support tool, recycling water and the installation of trickle/drip/spray lines irrigation system has a positive impact on water use efficiency at a farm level whereas the use of other irrigation systems such as the overhead irrigation system was found to have a negative effect on water use efficiency.

1. Introduction

Water is essential to agriculture production with uses comprising irrigation, spraying, drinking for livestock and washing (vegetables, livestock buildings). In the UK water for agriculture is obtained either directly from rivers and boreholes, or from the supply of mains waters as well as a combination of both (Defra, 2011). The effect of extreme weather phenomena associated with climate change on water availability has been studied (Chen et al., 2013; Daccache et al., 2011; Defra, 2009; Environment Agency, 2008; Jenkins et al., 2009). Most of these studies conclude that the availability of water for agriculture is under threat. The impacts for England in particular will be spatially and temporally variable (Defra, 2009). Therefore, future projections for reduced rainfall during spring and summer time and the increase in the average temperature will lead to more frequent and extensive drought[1] periods (Charlton et al., 2010). The recent dry periods of 2011 and 2012 caused increased pressures in UK water resources. In various catchments across the country, there was little or no water available for abstraction (FAS, 2013). Focusing on water use for irrigated root and vegetable crops, the continued production in the south and east of England will be dependent on the provision of adequate sources of water for irrigation. In addition, harvesting in wetter autumns could also be problematic (Charlton et al., 2010).

The main region within England for which water is crucial for agriculture production is the Anglian region where the main use of water is for irrigation, both for the production of cash crops as

* Corresponding author.
E-mail addresses: g.gadanakis@reading.ac.uk, grgadanakis@gmail.com (Y. Gadanakis).

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[1] "Drought is a nature produced but temporary imbalance of water availability, consisting of a persistent lower than average precipitation, of uncertain frequency, duration and severity, the occurrence of which is difficult to predict, resulting in diminished water resources availability and carrying capacity of the eco-systems" (Pereira et al., 2002).

well as for horticulture. The average abstraction of water (excluding tidal) in the Anglian region for spray irrigation between 2000 and 2012 was 50.5 million m^3 accounting for the 59% of the average total water used in agriculture for England. In terms of number of abstraction licences in force for spray irrigation in 2012, the Anglian region accounts for the 38% of total licences in England.[2] Irrigation in the East Anglian River Basin Catchment (EARBC) and in the South East of England is mainly concentrated on cash-crop production (potatoes and sugar beet) as well as horticulture and therefore it is considered as a major production input to secure yield and income for the farmers, especially during dry periods. Irrigated production delivers substantial economic benefits not only at the farm gate but also beyond that point since it supports a number of related businesses that provide equipment and farm supplies and are also responsible for the promotion and distribution of production. It can therefore be considered as an important factor for the development of the rural economy in East Anglia (Knox et al., 2009) and other regions of England with horticulture production like the South East, Thames, Humber, South West, etc. river basin catchment areas. The EARBC and England in general may face high pressures in future due to both (a) an increase in water abstraction rates for agriculture due to increased water demand and increased number of abstraction licences and (b) a decrease in water availability associated with changing weather conditions. The main climate threats are temperature increase and reduced precipitation (Defra, 2009; Environment Agency, 2008, 2011) with direct impacts on the hydrology structure of the area.

The Environment Agency (EA) is the water regulatory authority for England and is also responsible for the authorisation of abstraction licences (Environment Agency, 2013). Its primary responsibility is to balance the water needs of all abstractors (all industries involved in water abstraction including agriculture) with that of the natural environment. The EA considers water use efficiency as a need to save and manage water efficiently whilst at the same time promoting environmental sustainability.

Irrigated agriculture in England has therefore to achieve two goals in order to secure the future growth and the economic sustainability of the sector. The first objective is to maintain and improve productivity in order to meet increasing future food demand (FAO, 2011) but at the same time to preserve the associated natural environment. Intensive agricultural practices combined with the probability of more frequent dry periods in the area may increase the competition for water resources in an already over-abstracted and over-licensed catchment (Knox et al., 2009). The Sustainable Intensification (SI) of agricultural production is promoted as a mechanism that can balance the two objectives and at the same time mitigate any conflicts between these two objectives. More specifically, the SI of agriculture requires farmers to simultaneously increase their yields in order to meet the future demand for food, but also to reduce environmental pressures generated by the production process (Garnett and Godfray, 2012).

In this sense, agricultural productivity and water use efficiency should be considered together when evaluating the sustainability of farming systems. However, the social aim of sustainable farming systems (i.e. increase productivity, being water use efficient) does not necessarily match with farmers business aims (i.e. increase profitability). In order to close this gap between social and business objectives, farmers, need to demonstrate efficient water use for renewing an irrigation abstraction licence (Knox et al., 2012). For instance, a farmer may seek to maximise production and profit per unit of water (financial sustainability) while the goal of an environmentally sustainable system could be to minimise the use of water per value or volume of production (Knox et al., 2012). These contrasting approaches to efficiency and also between increasing agricultural productivity and environmental preservation require a management approach that simultaneously takes into consideration sustainability, productivity, and profitability (Vico and Porporato, 2011).

For most farmers in England involved in high value crop production water use for irrigation is driven by the need to produce a high quality product and hence obtain contracts and high prices from their customers, particularly supermarkets (Knox et al., 2012). Therefore, economic incentives can play a critical role in irrigation decisions (Oster and Wichelns, 2003). Knox et al. (2012) suggests that an economically rational farmer, when there are unlimited water resources, would aim to use water until the marginal benefit no longer exceeded the marginal cost. If the farmer fears that the water resources may be inadequate, irrigation is restricted to the most (financially) responsive crops. Water use efficiency is therefore considered as an economically driven parameter strongly related to the production and marginal profit of a farm. The Farm Business Survey in England 2009/2010 also recorded financial or customer reasons as the primary reasons (55%) for farmers carrying out management practices for efficient water use in irrigation (Defra, 2011).

In addition, Knox et al. (2012) suggest that excess irrigation is avoided when the farmer is aware of the risk of increased crop disease, has difficult land access and/or has concerns about the risk of fertiliser leaching. Most farmers therefore sensibly aim for best (or reasonable) use of a potentially limited water supply, aiming not to over or under irrigate (especially in the case of dry summers), whilst minimising any non-beneficial losses (e.g. run-off, leaching). This is often described as “applying the right amount of water at the right time in the right place”.

Water demanded for irrigation at a farm level depends on farmers’ decisions on when and which crop to produce, the volume and the frequency of irrigation and also the selection of irrigation method and technology (Marques et al., 2005). It is therefore a decision related to the production technology and the management ability of the farmer. Vico and Porporato (2011), note that there are a number of uncertainties in relation to both the economic and productivity goals of a farmer that increase the complexity of the choice of a sustainable and efficient water management strategy. These uncertainties are related to pests and diseases, temperature extremes, rainfall variability and timing in relation to crop growth stages, crop physiological properties and response to water availability. Further, they are confounded by differences in soil properties that determine water runoff and percolation (English et al., 2002). Among the above, rainfall variability (especially increased frequency of drought periods during the growing season) can significantly impact productivity and profitability (Vico and Porporato, 2011).

1.1. Measuring water use efficiency at a farm level

The vast majority of published research papers and reports on measuring water use efficiency focus on engineering and agronomic techniques. Under this framework, water use efficiency can be defined as the yield of harvested crop product achieved from the water available to the crop through rainfall, irrigation and the contribution of soil storage (Singh et al., 2010).

However, these approaches do not consider water as an economic good and therefore they do not allow the evaluation of the economic level of water use efficiency (Wang, 2010). The economic approach to defining and measuring water use efficiency is based on the concept of input specific technical efficiency (Kaneko et al.,

[2] Data comes from the “Water quality and abstraction statistics” published in the DEFRA website. The source of data is the Environment Agency. Available online at: https://www.gov.uk/government/statistical-data-sets/env15-water-abstraction-tables: Accessed on 26.12.2013