Chapter 4.7
Estimation of Irrigation Water Demand on a Regional Scale: Combining Positive Mathematical Programming and Cluster Analysis in Model Calibration

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ABSTRACT

Mathematical programming tools are widely used to simulate agriculture water use thanks to their ability to provide a detailed technical and economic representation of farm choices. However, they also require a significant amount of basic information and appropriate methods for the organization of such information. The objective of the paper is to test a methodology for the estimation of irrigation water demand using a combination of Positive Mathematical Programming (PMP) at farm level, and a cluster analysis. The methodology is applied in an area of Northern Italy. The main outcome of our empirical application is the variety and complexity of reactions of different farms. The scenarios considered highlight the potential importance of the effects of price and cost variables, while the changes in the (area-based) tariff system appear less significant. The change in water cost/pricing appears somehow relevant, but does not motivate major changes in present water management policy, at least in the range of scenarios considered.

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INTRODUCTION AND OBJECTIVES

The attention to natural resource management, the threat of climate change and the augmented frequent phenomenon of water scarcity, have brought increased attention to the modeling of water use. This is a major issue for agricultural water management for several reasons. First, agriculture is one of the most important sectors in terms of water use worldwide, and this is particularly the case in water poor countries. Second, agricultural water use is connected to irrigation, which is performed on a number of different types of farms, through a variety of technologies. Finally, the drivers of agricultural water use are to a certain extent the same as the drivers of other developments in the agricultural sector, which is undergoing significant change worldwide in terms of both the structural characteristics of farms and cultivated crops.

These phenomena specifically affect Mediterranean agriculture, including Italian agriculture, where the empirical application illustrated in this paper is situated. Italian agriculture is facing rapid structural change in response to market trends and Common Agricultural Policy (CAP) reforms. Irrigated agriculture is directly affected by such changes and engaged in making sense of the interaction between agricultural policy and other policies. Among these, the Water Framework Directive (60/2000, WFD) is particularly important in contributing to shape future water management through increased attention to environmental issues, cost recovery, the application of the Polluter Pays Principle (PPP) and the provision of incentives to users through volumetric pricing.

In recent years many economic modeling exercises have been performed in order to evaluate the mechanisms of both agriculture and water policies, and their effects on irrigated farming systems. The common piece of information behind the simulation of such scenarios is provided by the 'water demand function', (or 'marginal willingness to pay') of farms for water availability. Hence, many modeling exercises focus, either as an intermediate or final step, on the estimation of such a demand curve.

These modeling exercises have widely used mathematical programming (MP) tools. MP provides a good basis for a detailed technical and economic representation of farm choices. However, it also requires a significant amount of basic information (e.g. gross margins, technical coefficients) and appropriate methods for the organization of this basic information for modeling purposes. In addition, different MP techniques can be used, resulting in differing degrees of accuracy as well as varying information burdens.

The objective of this paper is to test a methodology for the estimation of irrigation water demand using a combination of Positive Mathematical Programming (PMP) at farm level, and a cluster analysis. The methodology is applied in an area of Northern Italy.

The structure of the paper is the following: in the next section we provide a short review of the main issues involved in modeling water use by irrigated farming. Then, we describe the case study area, followed by the methodology. The results of the application to the case study area are illustrated in the following section. The final section offers some discussions and draws conclusions.

RELATED WORKS

The literature on simulation of irrigation system behavior provides a number of different applications including different scales and different timing for simulation. The scale of application ranges from single plants/plot models to regional scale. The timing of simulation ranges from daily water use to multiannual water use simulation.

The range of modeling approaches is also very broad, with each approach requiring different information sources and having differing capabilities with respect to decision-making processes.

An extreme example is provided by Pulido-Calvo & Gutiérrez-Estrada (2009) who use a