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An integrated decision support system for irrigation and water policy design: DSIRR

G.M. Bazzani*

National Research Council IBIMET, V.Gobetti 101, 40129 Bologna, Italy

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Abstract

The Decision Support System for Irrigation (DSIRR) is a DSS for the economic-environmental assessment of agricultural activity focusing on irrigation, designed to answer both public and private needs. The program simulates the economically driven decision processes of farmers, permitting an accurate description of production and irrigation in terms of technology and agronomics. Distinct farm models can be constructed to describe the relevant production system in the catchment. Short and long term analyses can be conducted, the latter with endogenous investment choices. Solutions are found by applying multicriterial mathematical programming techniques. Farm models run under a graphical interface, which allows the user to quantify, by farm type, the utilization of water, labour and machinery, considering different types of soils, irrigation systems, water-yield functions and seasonality. Data are aggregated at catchment scale. Richness of information produced, flexibility and simplicity of use make DSIRR a useful tool for more sustainable agriculture and the definition of a sound water policy.

Keywords: Decision support system; Economic modelling; Multicriteria modelling; Agriculture; Water; Irrigation; Agriculture policy; Water policy

1. Introduction

The definition of a suitable policy for water is assuming increasing relevance in a context of growing scarcity and competing uses. The fact that in most countries agricultural demand for water ranges from 40% to 80% of total consumption gives us an idea of the dimension of the relevance of irrigation. The strategy adopted at the global level is known as integrated water resources management (IWRM), "a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2002).

In the EU the Water Framework Directive 2000/60 (WFD) defines criteria for water management, regulations and pricing (European Council Directive 2000/60). For a review of pricing irrigation water see Johansson et al. (2002). Economic instruments are recommended to put into action the *cost recovery* and *polluter-pays* principles adopted by the WFD: water price should be set so as to cover the costs of the provision, the opportunity cost of the resource and the environmental cost induced, and it should provide incentives in the direction of a reduction of both water use and pollution. WFD implementation at catchment scale requires the definition of river basin plans and long term forecasts of supply and demand for water.

According to IWRM, key variables for water policy definition are not only collected revenue and welfare losses but also water saving and environmental impacts, which could be negative like pollution, or positive, like soil protection, landscape creation and biodiversity preservation. Therefore, a lot of information should be made available to policy makers and stakeholders but the problem becomes how to obtain it.

2. Modelling irrigation

Modelling and decision support systems (DSS) represent tools which can offer positive contributions

* Tel./fax: +39-051-6398016.
E-mail address: g.bazzani@ibimet.cnr.it.

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to the decision process and many efforts in this direction have been made (a good review is given by McKinney et al., 1999). Since then, Mateos et al. (2002) have presented SIMIS, a DSS for irrigation scheme management adopted by FAO. This is not an optimizing tool so it does not allow water demand estimation. Ragab (2002) has developed SALTMED, a model which adopts an holistic approach with great attention to the agronomic aspects but little consideration of the farmers' decision process. The IWRAM project (Letcher et al., 2002) represents another interesting experience which integrates GIS, hydrological and producer models. At present the main limitation seems to be an inadequate representation of the farmers' (stakeholders) decision and the production process. This is a common situation. As stated by Global Water Partnership (2002) "presently hydrological models simulating water balance elements (such as run-off, groundwater and evapotraspiration) are quite well developed. So are water quality models for rivers, groundwater and lakes. However, models for most other water aspects (ecological, environmental, economic, social, institutional and legal) need significant improvement".

Farmers' decisions and their policy implication seem well represented and analyzed by economic models. Economic theory shows that *demand curves*[1] are relevant and permit the estimation of water consumption, farmers' income and Water Agency revenue at different water rates, and show their variation in response to price changes (Howitt et al., 1980). Since real data for water demand are at best available only for the range close to the existing consumption level, the curve estimate can be obtained via model simulation using mathematical programming techniques (MPT). A body of economic literature exists on models based on MPT focusing on irrigation (Amir and Fisher, 1999; Doppler et al., 2002; Moore et al., 1994; Schaible, 1997; Varela-Ortega et al., 1998). The literature also indicates that farmers' behaviour can be better understood and represented via multicriteria analysis (MC) than by the simple profit-maximizing hypothesis which the standard economic model adopts (Romero and Rehman, 1989; Berbel and Rodriguez, 1998; Gómez-Limón and Arriaza, 2000). Most economic models at present however suffer from a severe drawback in their representation of agronomic and environmental aspects.

The integration of the two faces of the problem, socio-economic and environmental, seems therefore the real issue at hand. The work of Mimoumi et al. (2000) leans very much in this direction. They have analyzed the trade-offs between farm income and the reduction of erosion and nitrate pollution in an MC framework adopting a multi-objective programming model. At territorial level Garrido (2000) presents a model that includes the crop yield response to water and nitrates at farm level to evaluate water markets in the agricultural sector.

Furthermore, nearly all economic models have severe limits in applicability for two main reasons: firstly, they have been created for specific purposes and therefore are not easily accessible for further application; secondly, they cannot be used directly by the final users, if they are not experts in modelling, for the absence of a user friendly interface.

DSIRR represents a step to fill the previous gap, in the direction of integrating agronomic, technical and environmental aspects with economic theory in a MC framework using MPT. Fig. 1 represents a logical flow chart of the DSS.

The main characteristics of DSIRR are:

- the capacity to accurately describe the irrigation process at farm level, in terms of technologies (furrow, sprinkler, drip, etc.), irrigation needs by crop and type of soil, and climate (rain), both in physical and economical dimensions;
- an explicit consideration of agronomic aspects, like water-yield functions and rotations;
- a good capacity to represent farmers' behaviour, because of the MC approach adopted;
- the integration of different types of farms at catchment level;
- an internal archive of models suitable for different analysis;
- a modular architecture, which enables further development to cope with new needs;
- an open structure to exchange data with other applications and models.

DSIRR could be easily joined to other packages to create a more comprehensive tool, in which it could represent the production and irrigation module, defining land allocation and quantifying multidimensional indexes.

3. The scale problem

The definition of the proper scale on which to conduct the analysis is one of the major issues to be solved in the modelling process. As is well known, catchment is the correct scale to deal with the environment and to define policy. But the design of suitable policy should also be verified in terms of cost and benefit for the stakeholders among which farmers are a relevant component. Choices regarding the use of water, the allocation of land for different uses, the adoption of technology, in other words all the actions which in their interaction determine the state of the environment, are taken at farm level by actors pursuing their private

[1] Water demand is a function describing the price/quantity relation of the resource. Such a relation is inverse since when rising the price the consumption decreases.