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Integrated modelling for agricultural policies and water resources planning coordination

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Pressures due to agricultural activities play a major role in the status of water resources systems. The evaluation of the effects of agricultural policies is therefore a key problem in water resource planning and management. The work presented in this paper is an attempt to include the predictable effects of the Common Agricultural Policy (CAP) of the European Union (EU) in the process of water resources planning at the basin scale prescribed by the EU Water Framework Directive (WFD). The approach is based on the combined use of three models: (i) an economic model used to predict the likely land use scenarios at the basin scale following CAP reform; (ii) a spatially distributed hydrological model for the assessment of the related irrigation water requirements; and (iii) a decision model supporting stakeholders and decision makers in the process of water resources planning. The paper presents an application to a pilot study area in Northern Italy. The results highlight how the CAP may produce an adjustment in the agricultural sector, with a shift towards more extensive land use and to a greater diversification of production. The predicted changes in land use type and distribution are shown to have significant influence on water requirements, with a generalised decrease of their amount, which may exceed 10% in some areas. In turn, the decrease of irrigation demand can be exploited to achieve a higher degree of satisfaction of other water users in the basin and can improve the attainment of the WFD objectives.

1. Introduction

The European Union has introduced new water directives over recent years: the Water Framework Directive (WFD, 2000/60/EC) is the foundation for a modern, holistic and ambitious water policy for the European Union. The Groundwater Directive and the Flood Water Directive were put into place in 2006 and 2007, respectively. These directives establish a legal

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framework to protect and restore clean water in sufficient quantity and reduce flood risks across Europe by defining new objectives (achieving *good ecological status* of all water bodies by 2015), new principles (like the Full Cost Recovery, the Polluter Pays Principle and the use of pricing policies in order to promote water use efficiency and reduce water pollution) and new paradigms (Integrated Water Resources Management, IWRM).

After only a few years since the delivery of the WFD CIS (2004), a clear message emerged from the analysis of pressures and impacts on water resources across the EU countries: agricultural activities, including water consumption and pollution, were often an important obstacle to the achievement of the WFD objectives. The 2010–2012 WFD CIS work program confirmed agriculture as one of the major priorities to address to achieve the objective of good status of European waters in 2015. Therefore, the link between agriculture and WFD is one of the highest priorities, and it is important to discuss how agricultural policies can contribute to the achievements of the WFD objectives. The 10 years execution of the single farm payment scheme introduced by the Fischler Reform has increased the opportunities to support farmers in addressing some environmental issues: Cross-Compliance and the strengthening of the Rural Development policy are at the moment important tools to merge agricultural and environmental policies better. These new elements affect the farmers' behaviour, addressing their production choices, which, in turn, may have consequences on the water demand for agriculture.

From the water quantity viewpoint, agriculture is a large consumer and improving water use efficiency is one of the main issues at stake, following the increasing impacts of water scarcity and droughts across Europe in a context of climate change. This is particularly true for Southern European countries, where irrigation is an essential element of agricultural production and agricultural abstractions accounts for more than 60% of total abstractions, and climate change is expected to intensify problems of water scarcity and irrigation requirements (Wriedt, van der Velde, Aloe, & Bouraoui, 2009). A recent study carried out in Spain assessed that more than 70% of total water abstractions were addressed to agricultural use, supplying more than 3.4 million ha of irrigated land (ESYRCE, 2013).

Due to the importance of these issues, much research has been done and many models have been developed to forecast farmers' behaviour as a consequence of agricultural policies, such as, among others, CAPRI (Britz, Pérez, & Wieck, 2003; Heckelei & Britz, 1999, 2001), INRA-Nancy model (Barkaoui & Butault, 2000; Barkaoui, Butault, & Rousselle, 1999), PROMAPA (Júdez, Chaya, Martínez, & González, 2001; Júdez, De Miguel, Mas, & Bru, 2002; Júdez et al., 2008), FARMIS (Offermann, Kleinhanss, & Bertelsmeier, 2003; Offermann, Kleinhanss, Huettel, & Kuepker, 2005), AGRISP (Arfini, Donati, & Zuppiroli, 2005).These models use Positive Mathematical Programming (PMP) (Howitt, 1995) to forecast the adaptation of the production system to changes in agricultural or environmental policies. Using PMP, Cortignani and Severini (2009) assessed responses at the farm level of a reduction in water availability.

A wide literature has also been produced on the assessment of irrigation water requirements at large scale, and in the last decade various methods have been developed to simulate crop water and irrigation requirements ranging from simple calculation schemes to integrated modelling approaches based on soil water balance calculations (e.g., Döll & Siebert, 2003; Facchi, Ortuani, Maggi, & Gandolfi, 2004; Fortes, Platonov, & Pereira, 2005; Heinemann, Hoogenboom, & de Faria, 2002; Ishigooka et al. 2008; Todorovic & Steduto, 2003; Vassena et al., 2012; Wriedt et al., 2009).

However, the examples of conjunctive modelling of the two aspects (forecasting farmers' behaviour and assessing irrigation water requirements) are more limited. For instance, Ahrends, Masy, Rodgers, and Kunstmann (2008) presented a coupled distributed hydrological–economic model system for the investigation of interdependencies between irrigated agriculture and regional water balance and for identification of optimised cultivation strategies; Lin, Hong, Wu, Wu, and Verburg (2007) combined a land use change model, landscape metrics and a watershed hydrological model for the analysis of impacts of land use scenarios on land use pattern and hydrology; and more recently, Barthel et al. (2012) developed an integrated simulation system to simulate water-related influences of global change effects on agricultural and groundwater, including, among others, also a regional economic production model.

The main novelty in the approach presented in this paper is that it not only combines an economic model and a spatially distributed hydrological model, but also includes a further component, for the optimisation of water resources allocation at the basin scale. In practice, the economic model defines different land use scenarios deriving from the effects of the CAP on farmers' production choices; the hydrological model assesses crop water requirements and determines the consequent variations of irrigation water demand at the basin scale; finally, the modified pattern of irrigation demand of each land use scenario feeds into a multi-objective optimisation model, which generates a set of water management policies that are efficient, in the Pareto sense, with respect to the satisfaction of the irrigation demand and to the other objectives of water resources management in the basin (Soncini Sessa, Castelletti, & Weber, 2007). The paper focuses mainly on the economic and hydrological models and on their integrated use, presenting the results of an application to a pilot study basin in Northern Italy, the Adda river basin.

2. Materials and methods

Integrated Water Resources Management (IWRM; see Global Water Partnership, 2000) has been adopted as a guiding principle for the development of River Basin Management Plans (RBMP) by the Water Framework Directive. RBMP design implies therefore dealing with large scale participatory decision processes and calls for formalised procedures to drive and support the planning process.

The methodological approach proposed in this paper addresses a specific issue in the development of River Basin Management Plans (RBMP), which is accounting for the effects on water resources of land use changes due to the implementation of specific agricultural policies. The approach is based on the combined use of three different models: