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Coupling real-time control and socio-economic issues in participatory river basin planning

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Abstract

In this paper an approach for coupling real-time control and socio-economic issues in participatory river basin planning is presented through a case study. It relies on the use of Bayesian Networks (Bns) to describe in a probabilistic way the behaviour of farmers within an irrigation district in response to some planning actions. Bayesian Networks are coupled with classical stochastic hydrological models in a decision-making framework concerning the real-time control of a water reservoir network. The approach is embedded within the framework of the Participatory and Integrated Planning (PIP) procedure.

Keywords: Integrated Water Resource Management; Model integration; Bayesian Networks; Reservoir operation; Participation

1. Introduction

Reservoir network management is a key component of Integrated Water Resource Management (IWRM) and plays a central role in the implementation of the Water Framework Directive, as the alteration of the natural water regime it produces may have a direct influence on the quality status of the downstream ecosystem.

The wise and sustainable management of the water stored in a reservoir requires consideration of a large number of complex and inter-related issues and poses intricate technical and political problems (McCartney and Acreman, 2001). It must take account of water uses upstream and downstream of the dam, including water supply, agriculture and power generation, as well as the needs of aquatic habitats. As such, reservoir management has to be considered within the wider framework of river basin management and planning (World Commission on Dams, 2000).

Making balanced and fair decisions in river basin planning requires an integrated and participatory assessment procedure:

Integrated, because it has to evaluate all the positive and adverse effects of the actions on the table, among which reservoir management policies have to be included (Soncini-Sessa et al., 2003). This is far from being a trivial task, since is complicated by the uncertainty arising from incomplete knowledge on both the physical and socio-economic components of the river basin system. Indeed, it may happen that the physical and socio-economic processes that occur in a component of a water system are poorly known and/or that it is not practicable to obtain raw data to characterize them better. In these cases, it would obviously be problematic for the analyst to describe that component by means of a type of model that requires a good knowledge of its internal processes or many data to be calibrated, as is the case with common mechanistic, empirical and Markovian models. For this reason, these components are often ignored or are drastically simplified when they are described with the same type of models used for the other components of the water system.

Participatory, since the stakeholders must be involved in every phase of the decision-making process (see, among others, Delli Priscoli (2004), Soncini Sessa et al. (in press-a-b) and

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the references therein), from the recognition of the need for the process itself to the choice of the alternative to be implemented. Participation should neither be limited to providing the stakeholders with information (Informative Participation), nor to just asking them for information (Consultation), but should also involve the stakeholders in the design and evaluation of the alternatives (Co-designing). As explained in Castelletti and Soncini-Sessa (2007), the computational burden for the alternative design increases exponentially with the dimension (i.e. the number of state variables) of the water system model. Therefore, the type of model adopted should be able to capture concisely the essence of the component's complexity, without losing transparency and reliability for the stakeholders owing to the many simplifications that are introduced. One first has to build a model (*evaluation model*) for the alternative evaluation, and then to obtain a *parsimonious* version of it (*screening model*) for designing the alternatives.

Through a real world case study, the paper illustrates how the above key points can be addressed in practice. First, it shows how Bayesian Networks (Bns) (Pearl, 1988; Jensen, 2001) can be integrated with the other types of models commonly used in river basin modelling (Castelletti and Soncini-Sessa, 2007) to build an evaluation model of the entire water system. Then, it demonstrates how the evaluation model so obtained can be reduced to a screening model for the alternative design. The key idea of the approach is to use Bns to model the system components for which knowledge is limited or unstructured (e.g. farmers' behaviour in the irrigation districts), while mechanistic and empirical models are used to describe the components about which knowledge is well structured or many data are available (e.g. power stations and catchments).

The modelling approach proposed is embedded within the framework of the Participatory and Integrated Planning (PIP) procedure proposed in Castelletti and Soncini-Sessa (in press): therefore the paper is organized following the framework of that procedure. The second section is devoted to a brief description of the physical system, the stakeholders, the conflicting issues and the planning actions proposed (Phases 0–1 of the PIP procedure) for the planning of the Vomano water system, in central Italy. The third is devoted to the identification of the stakeholders' criteria and indicators (Phase 2), while the fourth discusses the decomposition of the water system into single components and the identification of the models of those components about which knowledge is well structured (Phase 3). The BN that describes the farmers' behaviour in response to the considered planning actions is described in the fifth section. In the sixth, the global model of the system is presented, while in the seventh it is simplified for the purpose of designing the alternatives. In the last two sections the main results of the project are discussed and the conclusions drawn.

2. The Vomano water system

The Vomano water system (Fig. 1) is one of the four chief river basins of Abruzzo, the central Italian region richest in water. It extends for about 785 km^2 from the easternmost slopes of the Appennines (Gran Sasso) to the Adriatic Sea. Its waters are heavily used for hydropower generation, to cover power demand during peak hours (from 11:30 a.m. to 03:00 p.m.) and, to a lesser extent, for agricultural production and drinking water supply.

Three barrages dam the river course, forming as many water reservoirs (Campotosto, Provvidenza and Piaganini) with a total storage capacity of 220 Mm^3 (217 of which are in the Campotosto reservoir only). Each reservoir supplies water to a downstream power station (Provvidenza, S. Giacomo and Montorio, respectively, for a total installed capacity of 700 MW) and is fed, besides by its own catchment, by one or two interceptor canals cutting across the basin slopes, respectively, at 1350, 1100 and 400 m a.s.l., and draining a number of relatively small rivers that otherwise would flow directly to the sea. The flow rate of the Eastern interceptor at 400 m is partially reduced, before it feeds the Piaganini reservoir, by the Ruzzo Aqueduct withdrawal, which supplies drinking water to Teramo and all the coastal towns. Provvidenza and

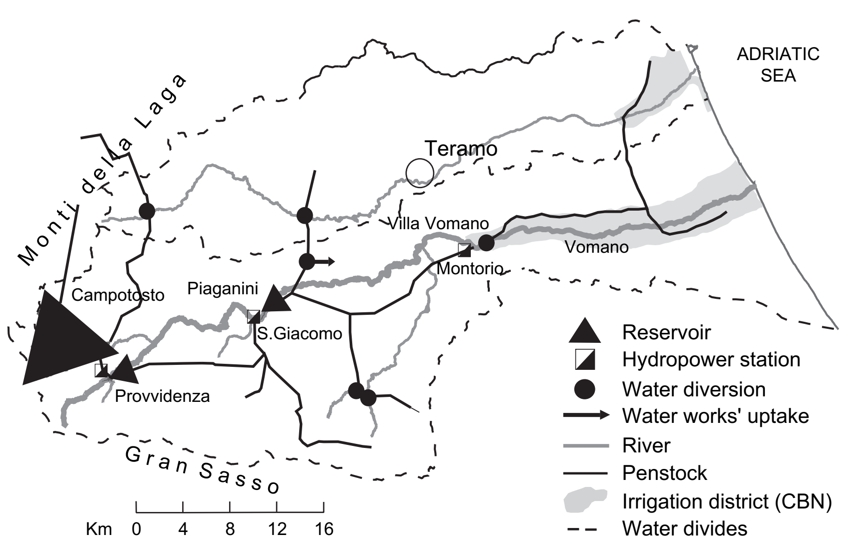

Fig. 1. The physical scheme of the Vomano water system.