Journal of Environmental Management 128 (2013) 400–412

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Participatory modelling to support decision making in water management under uncertainty: Two comparative case studies in the Guadiana river basin, Spain

Gema Carmona [a,*], Consuelo Varela-Ortega [a,1], John Bromley [b,2]

[a] Universidad Politécnica de Madrid, ETSI Agrónomos, Dept. Economía y CC. Sociales Agrarias, Avda. Complutense s/n, 28040 Madrid, Spain
[b] Oxford University, School of Geography and the Environment, Oxford Water Futures Programme, South Parks Road, Oxford OX1 3QY, United Kingdom

ARTICLE INFO

Article history:
Received 15 March 2011
Received in revised form
28 April 2013
Accepted 8 May 2013
Available online 19 June 2013

Keywords:
Participatory modelling
Bayesian networks
Water management
IWRM

ABSTRACT

A participatory modelling process has been conducted in two areas of the Guadiana river (the upper and the middle sub-basins), in Spain, with the aim of providing support for decision making in the water management field. The area has a semi-arid climate where irrigated agriculture plays a key role in the economic development of the region and accounts for around 90% of water use. Following the guidelines of the European Water Framework Directive, we promote stakeholder involvement in water management with the aim to achieve an improved understanding of the water system and to encourage the exchange of knowledge and views between stakeholders in order to help building a shared vision of the system. At the same time, the resulting models, which integrate the different sectors and views, provide some insight of the impacts that different management options and possible future scenarios could have. The methodology is based on a Bayesian network combined with an economic model and, in the middle Guadiana sub-basin, with a crop model. The resulting integrated modelling framework is used to simulate possible water policy, market and climate scenarios to find out the impacts of those scenarios on farm income and on the environment. At the end of the modelling process, an evaluation questionnaire was filled by participants in both sub-basins. Results show that this type of processes are found very helpful by stakeholders to improve the system understanding, to understand each other's views and to reduce conflict when it exists. In addition, they found the model an extremely useful tool to support management. The graphical interface, the quantitative output and the explicit representation of uncertainty helped stakeholders to better understand the implications of the scenario tested. Finally, the combination of different types of models was also found very useful, as it allowed exploring in detail specific aspects of the water management problems.

1. Introduction

For management problems, especially in the field of natural resources, the current trend is to develop integrated policies that are sustainable in the long term and take into account all the factors related to resource use. To support this approach the European Union has developed the Water Framework Directive (WFD), which establishes general guidelines for water management in EU countries. This framework represents a new perspective on water management, as it includes a shift from supply to demand management, an obligation to consider the cost-effectiveness of measures and the requirement to include stakeholders in the design of river-basin management plans. The WFD is based on the concept of Integrated Water Resources Management (IWRM), which was developed during the 1990s and was defined by the Global Water Partnership as "a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000). There are other definitions of the concept, but all of them involve the need to consider the complexity of water systems, involving multiple factors and actors in multiple spatial and time scales, and the need to involve stakeholders in the resource management (Biswas, 2004; Pahl-Wostl, 2007; Rault and Jeffrey, 2008).

* Corresponding author. Tel.: +39 0332 78 6505; fax: +39 0332 78 5162.
E-mail addresses: gema.carmona@gmail.com (G. Carmona), consuelo.varela@upm.es (C. Varela-Ortega), john.bromley@ouce.ox.ac.uk (J. Bromley).
[1] Tel.: +34 913365790; fax: +34 913365797.
[2] Tel.: +44 (0) 1865 285539; fax: +44 (0) 1865 275885.

0301-4797/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jenvman.2013.05.019

The WFD stresses the importance of stakeholder participation in decision making, being one of the main principles and a compulsory feature of water management in the European legal framework (De Stefano, 2010; European Commission, 2000; European Commission, 2003). Participation is understood as the involvement of members of the general public in policy-forming activities, by means of several mechanisms intentionally created for that purpose (Beierle and Cayford, 2002; Rowe and Frewer, 2004). Three major justifications for stakeholder involvement proposed in the literature (Johnson, 2009; Smith Korfmacher, 2001; Webler and Tuler, 2001) are:

- Democratic rationale: the public should be involved in decisions that affect them.
- Substantive rationale: citizens can provide scientists with their specialised knowledge, for better understanding of facts and values.
- Pragmatic rationale: an involved and educated public is more likely to support implementation of resulting policies.

These motivations form the basis of the WFD participatory requirements. First, stakeholder participation enables information to be shared by those holding different points of view and, as a result, helps build a common understanding of the system. In addition, stakeholder involvement in decision making improves public acceptance of water-management plans, which become more likely to be successful when stakeholders have participated in the design of those plans.

The design of the participatory process has to be carefully planned if the desired results are to be obtained. The process should ideally be iterative, taking into account perception of uncertainty and including a stage of group validation and verification (Johnson, 2009; Smith Korfmacher, 2001; Webler and Tuler, 2001).

This article describes the implementation of a participatory process developed as a tool to support decision making in water management. The process aims to achieve an improved understanding of the water system and to encourage the exchange of knowledge and views between stakeholders in order to help build a shared vision of the system. The process also identifies the impacts of different solutions to water-system problems in order to provide information regarding which solution a final decision should be based on. This research has been applied in the Guadiana river basin, which is located in the centre of the Iberian Peninsula and covers an area of 67,000 km^2. The area has a semi-arid climate, with high variable precipitation leading to irregular water recharge throughout the year. The Spanish part of the Guadiana basin (83% of the total) is divided into 3 sub-basins: the upper Guadiana (UG), the middle Guadiana (MG) and the lower Guadiana in Huelva Province. Our study focuses on the upper and middle sub-basins (see Fig. 1).

These two sub-basins sustain an economically important agricultural sector, which consumes large quantities of water. However, the two catchments draw most of their water supplies from different sources. In the UG groundwater provides the bulk of the supply, while in the MG surface water is the main source. The development of irrigation in the upper part of the basin has been accomplished through private initiatives, which produced highly efficient irrigation systems. However, over-exploitation of groundwater for irrigation in the upper part of the basin led to the depletion of aquifers, together with serious environmental deterioration and conflicts between water users (Llamas and Martínez-Santos, 2005). Management and control measures, such as water transfers from the Tagus river, the EU funded Agri-Environmental plan or the enforcement of legal restrictions in pumping volume and wells' drilling, have been costly but ineffective (Llamas et al., 2010). In contrast, the middle part of the basin has benefited from public plans for the development of irrigation; however irrigation efficiency is low and large volumes of water are used. The modernisation of irrigation systems and water governance is a major challenge for the area.

To define the various complexities and uncertainties in the area and provide the opportunity to involve stakeholders in the decision making process, a decision-support system based on Bayesian

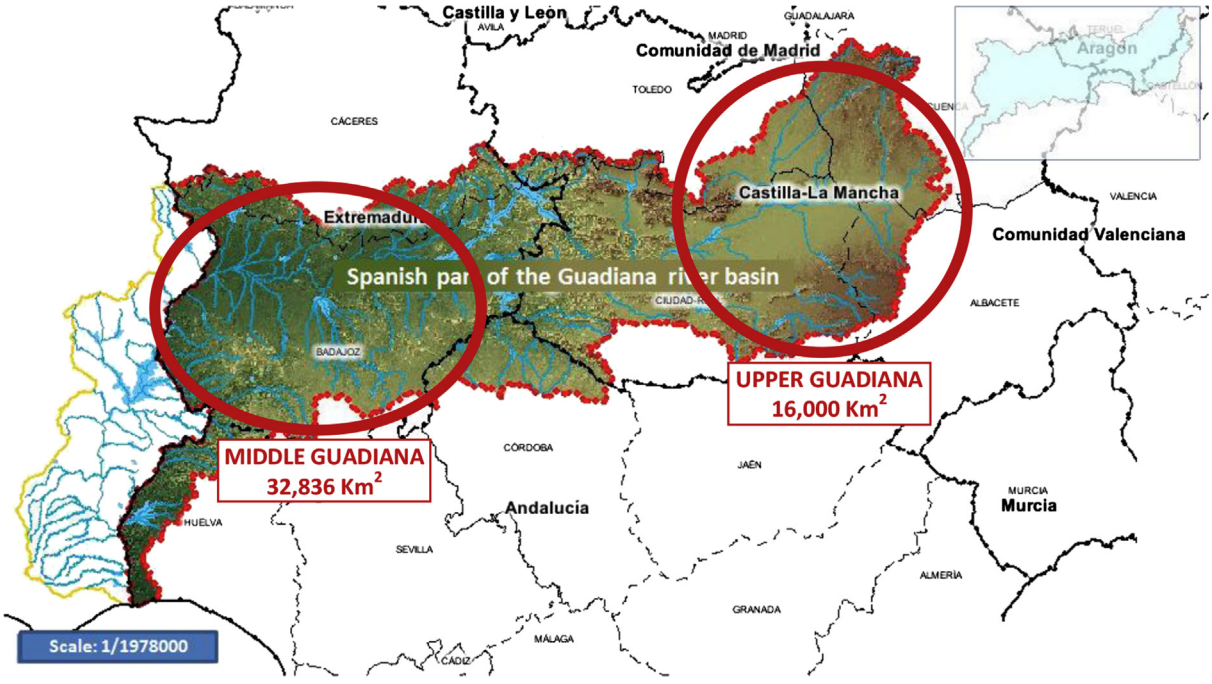

Fig. 1. Location of the Guadiana Basin in Spain. Source: Adapted from CHG, 2010 CHG (Confederación Hidrográfica del Guadiana), 2010. URL: http://www.chguadiana.es/consultas/sigchgweb/SIGCHGWEB_pub.jsp. Last viewed: March 2011