Environmental Modelling & Software 79 (2016) 22–34

Contents lists available at ScienceDirect

Environmental Modelling & Software

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

An integrative modelling approach for linking environmental flow management, ecosystem service provision and inter-stakeholder conflict

Dídac Jorda-Capdevila [a, *], Beatriz Rodríguez-Labajos [a], Mònica Bardina [b]

[a] Institute for Environmental Science and Technology (ICTA), Autonomous University of Barcelona (UAB), Spain
[b] Catalan Water Agency (ACA), Government of Catalonia, Spain

ARTICLE INFO

Article history:
Received 22 April 2015
Received in revised form
14 December 2015
Accepted 26 January 2016
Available online xxx

Keywords:
Biophysical valuation
Environmental flows
Integrated valuation
Participatory modelling
River ecosystem services
Water conflicts

ABSTRACT

Fifteen water flow-dependent ecosystem services (ES) are modelled for the case of the Ter (Catalonia, Spain), a river with persisting intra- and inter-basin conflicts on water flows. The aim is to analyse ES response (and ensuing social reaction) to changes in water flow management, in a context of several tradeoffs and synergies driven by access to water use.

We argue for a new modelling approach to integrate diverse values and perspectives through engaging with stakeholders' concerns and claims. This is done under different conditions, including droughts, wet years, and different options for managing flows. Our approach involves two stages, namely water allocation modelling, including scenario development, and ES provision modelling, including participatory design of service suitability curves. The method presented allows analysing spatial/temporal patterns and ES performance. The paper explains methodological innovation and its application to highlight the role of recurrent socio-environmental conflicts in water management decisions.

1. Introduction

Humans have benefited from rivers for millennia (Fagan, 2011). The development of water infrastructure (e.g., dams and weirs) for the control and distribution of water flows has altered the normal functioning of river ecosystems worldwide (Bunn and Arthington, 2002; Poff et al., 1997; World Commission on Dams, 2000). While enhancing the delivery of provisioning services such as hydropower and water supply for industry and irrigation, such changes have had an impact on freshwater habitats and biodiversity (Vörösmarty et al., 2010). Thus, the provision of services are strongly dependent on an ecosystem's health, such as fish production or the beauty of the waterscape (Auerbach et al., 2014; Brisbane Declaration, 2007).

In a global perspective, the drainage basin of the Mediterranean Sea is particularly threatened. Being subject to dramatic changes in temperature and precipitation, the quantity of water will be impaired (García-Ruiz et al., 2011). Costs of climate change express themselves also through unwanted changes in ecosystem services (ES) provision (Rodríguez-Labajos, 2013). Likewise, the Mediterranean countries are not exempt from conflicts related to rivers and lakes being drained (Environmental Justice Atlas; Selby and Hoffmann, 2011).

The socioeconomic relevance of water-related ES is widely acknowledged at the global level (Costanza et al., 1997; MA, 2003; Postel and Carpenter, 1997; Russi et al., 2013). Over recent decades, the notion of 'ecosystem service' has been used by economists and conservation scientists to evaluate the broader benefit associated with ecosystems (Brown, 1991; Wilson and Carpenter, 1999). More recently, Martin-Ortega et al. (2015), Nahlik et al. (2012) and Seppelt et al. (2011) insist on the need to reconnect this socioeconomic relevance of ES with their biophysical underpinning.

Approximately 6280 articles appear in ScienceDirect combining the keywords 'ecosystem services' and 'modelling' for the period 2010–2014,[1] which demonstrates the interest in using models in integrated assessments. Modelling tools are found useful for quantifying the provision of river ES (e.g., Liu et al., 2008), helping to better understand changes over time and space (Burkhard et al.,

* Corresponding author. Despatx Z-137, Edifici Z, Campus de la UAB, 08193, Bellaterra (Cerdanyola del Vallès), Barcelona, Spain.
E-mail address: dd.joca@gmail.com (D. Jorda-Capdevila).

[1] As of the date of February 15, 2015.

http://dx.doi.org/10.1016/j.envsoft.2016.01.007
1364-8152/

2013; Koch et al., 2009; Nelson et al., 2009), hence making water resource decisions more effective, efficient and defensible (Bennett et al., 2009; Volk, 2013). However, very few studies on modelling socioeconomic benefits provided by instream flows at a watershed level have been published (e.g., Fanaian et al., 2015; Johnson and Adams, 1988; King et al., 2003; Korsgaard et al., 2008). While their contributions are clearly insightful, they usually lack comprehensiveness in terms of the scope of ES included in the analysis, and stakeholders' engagement is usually missing (Jorda-Capdevila and Rodríguez-Labajos, n.d.). Additionally, none of these studies specifically aims at explaining conflicts or discussing their results in the light of distributional issues. The understanding of the dynamics of appropriation of water flow-related ES and their relation to social conflicts thus remains an area to be addressed.

In this respect, our specific objectives are 1) to offer an innovative methodology, based on modelling exercises with stakeholders' engagement, for assessing ES provided by water flows, and 2) to explore the potential of this methodology for understanding inter-stakeholder conflicts, in the particular case of the Ter River (Catalonia, Spain). An important aspect of the methodology is that stakeholders' engagement was promoted throughout the process.

As a case study, we selected the Ter River, since it is a paradigmatic stream. The Ter River is just 200-km long but its landscape is impressively diverse – from the high Pyrenees to marshy plains. However, it is also riddled with human impacts, the most prominent being dozens of weirs diverting water for hydroelectricity production, and three reservoirs storing and transferring the bulk of water to Barcelona.

Thus, in a relatively small area (3010 km^2), the Ter River basin offers the possibility of studying practically all the typical intra- and inter-basin socio-economic processes linked to environmental flows in a Mediterranean context, such as water transfers, run-of-the-river hydropower production and expansion of irrigated areas. Latent conflicts have remained since the three reservoirs were constructed in the 1960s, erupting during cyclical droughts. Moreover, current management is contested by different types of stakeholders, each one based on its own interests and claims.

In this paper, we use the Lower Ter subbasin to illustrate the operationalisation of the modelling approach here proposed. Details about the study area are provided in Section 2. A water management model using WEAP software recreates water flows in all watercourses either the river channel or diversion canals and demand sites. Three different management scenarios are simulated (business as usual and two environmental alternatives that consider a different implementation of environmental flows) based on available management plans as discussed with the corresponding authorities and on stakeholders' positions. These steps are described in Section 3.1.

Based on the results of the water allocation model, service suitability curves – designed by taken into account the local stakeholders' perceptions – allow a modelling of the provision of each ES under each scenario. The results are aggregated to analyse spatial/temporal patterns (e.g., seasonal variation, water-year types) and ES performance, as shown in Section 3.2. For both models (water allocation and ES provision), we introduce some specific questions in our case study in order to explore the potential usefulness of the models for solving problems related to water planning, taking into account multiple stakeholders' preferences. Finally, Section 4 discusses such usefulness and the potential of modelling ES from water flows for understanding environmental conflicts.

2. Case study

The Ter is a typical Mediterranean river. Springing at 2400 mamsl, in the Eastern Pyrenees, the Ter River flows south to the inland Vic Plain. Then, it turns west, passes through a hilly area and drains into the sea, forming a flat and marshy area at the mouth (Fig. 1).

In undisturbed conditions, the average of natural flows would be around 25 m^3/s at the mouth. However, in practice the real flow ending up in the sea has been 9.65 m^3/s for the last 10 years (http://aca-web.gencat.cat/aca). Water withdrawals and consumptive uses accent for this drift, although climate change and forest recovery in abandoned agricultural land are some other reasons explaining this decline. In the mid section of the watershed, a chain of three reservoirs (Sau-Susqueda-Pasteral) are used to regulate floods and to store water to be delivered to the Metropolitan Region of Barcelona (MRB). The MRB, which appropriates 39–81% of the total reservoirs inflow, is actually located in other river basins. Within the catchment, the water supply from the Ter includes irrigation, and domestic, industrial and hydroelectric uses (the latter diverting water but not consuming it). Up to nine hydrological alterations caused by dams and weirs deteriorate the ecological status of the Lower Ter (Benejam et al., 2010; Boix et al., 2010), also impairing ES provision (Jorda-Capdevila and Rodríguez-Labajos, 2015).

Aside from the above mentioned benefits related to water diversion, the Ter provides multiple ES from their instream flows: production of brown trout (*Salmo trutta fario*) and elver (*Anguilla anguilla*), recreational space for boating and other sports, the appreciation of the wilderness, the beauty of the waterscape, education and research materials, etc (Jorda-Capdevila and Rodríguez-Labajos, 2015). Focussing on the Ter River below the dams – typically called "the Lower Ter" – multiple inter-stakeholder tensions coexist. The most noticeable conflict is the water transfer to Barcelona, in which residents decry an inter-basin water transfer that prioritises the capital city. Other controversial management practices are the overexploitation of the water flows by some small hydropower plants (SHPP); historical canals – secular water infrastructures that became naturalised and now house protected habitats and endemic species –, whose management has been recently abandoned; the pollution of the groundwater caused by liquid manure; and water surface irrigation.

Given the multiple tensions and conflicts, the situation in the Lower Ter is then the ideal setting for the purpose of this paper. Besides the mentioned pros of selecting the Ter River case, we also had access to precise hydrological data in the basin, and local

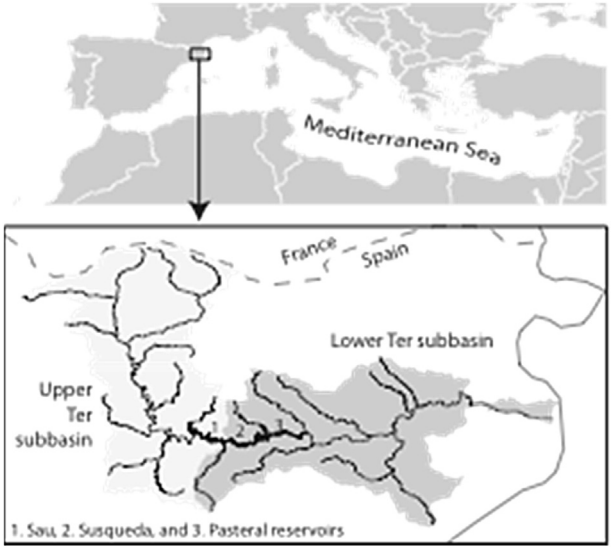

Fig. 1. Location of the Ter River basin.