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Toward integrated water and agricultural land management: Participatory design of agricultural landscapes

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ABSTRACT

One of the great challenges of developing sustainable water management is to integrate water and land use issues, and to favor stakeholders' involvement in the process of designing a solution to the specific issues of water basins. This study aims to help reach these objectives: we present the outcomes of a methodology that aims to design, with stakeholders of a watershed facing quantitative water management issues, alternative agricultural landscapes that they each consider as potential solutions. Our design approach combines (1) facilitation of participatory workshops for designing changes in cropping systems and their spatial distributions at the landscape level with (2) formalization of these alternatives in a GIS. The formalized alternatives provide precise information about fields, farms and areas concerned by the designed changes. We present two sample results of this methodology implemented in a 840 km^2 irrigated landscape located in a water-deficient watershed in southwestern France. We discuss how our design approach may be useful for a wider design-and-assessment methodology involving researchers and stakeholders with conflicting interests. We show that our co-design approach provides fertile ground for the emergence of salient, credible and legitimate change options.

Introduction

In Europe, even though water resources have a relatively high natural availability and storage capacities are well-developed, shortages of and conflicts over the resource are common (EEA, 2012). These situations sometimes emerge when regulatory measures are set up to promote environmentally sustainable management of natural resources (e.g. Water Framework Directive in EC, 2000). By setting new restrictive standards for resource use, they call into question the sustainability of human activities that until then had been supported, such as irrigated agriculture.

A recent report by EEA (2012) highlights two challenges for water management: (1) accounting for land use management that influences water flows in hydrosystems and (2) encouraging better communication between policy makers and practitioners to consider a more integrated way to govern land and water resources. In their analysis, Narcy and Mermet (2003) and Gober et al. (2013) also emphasize the need to coordinate water resource and land use management, and the difficulty in getting stakeholders of these two groups to communicate.

"Landscape agronomy" (Benoît et al., 2012; Caron, 2005) provides a suitable scientific perspective to deal with these challenges. This field of agricultural sciences analyzes the structure and dynamics of agricultural landscapes (AL) to assist stakeholders who wish to deal with their specific natural resource management problem, for example to evaluate the sustainability of an AL (e.g. Debolini et al., 2013) or to design alternative ones (this study). The AL, defined as the area under the influence of agricultural activities, is characterized by its land cover/use types, both in composition (nature and number) and spatial configuration (pattern). Depending on the topic of interest, landscape agronomists may focus on one or both dimensions (composition and configuration) and different land cover/use characteristics of the AL. When dealing with water management issues, they have to analyze the spatial distribution of cropping systems (CS) (Leenhardt et al., 2010). More specifically, to address low-flow issues in irrigated areas, they may need to analyze relationships between the spatio-temporal distribution of farming practices (e.g. sowing dates and irrigation) and the availability of water resources at stake (Therond et al., 2014).

Spatially explicit assessment and modeling of interactions between agricultural land use and natural resources have increased

Abbreviations: AL, agricultural landscapes; D&A, design-and-assessment; WAE, water and aquatic environments; GIS, Geographic Information System; CS, Cropping System; UAA, Utilized Agricultural Area.

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since the 2000s (Debolini et al., 2013; Ewert et al., 2009; OECD, 2009; Van Berkel and Verburg, 2011). These modeling approaches are habitually developed in two key steps: (1) collection and integration of available generic information about large areas (e.g. Janssen et al., 2009), followed by (2) understanding and representing, via computer models, interactions between agricultural land use and natural resources. Computer assistance is used to assess, diagnose, or optimize systems (e.g. Castellazzi et al., 2010), or to simulate effects of specific changes (e.g. Martin et al., 2012; Salmon-Monviola et al., 2012). In the water-management domain, many studies aim to estimate the seasonal water requirements of crops at continental and regional scales (Wriedt et al., 2009). Some studies performed at smaller scales (local to regional) have also focused on representing biophysical processes (Darshana et al., 2012; Pérez et al., 2011; Sadeghi et al., 2009). Few approaches integrate the spatial variability of farmer practices; Hanafi et al. (2012) represent variability in irrigation practices, while Maton et al. (2005) integrate agricultural practices that determine the irrigation demand and, in turn, withdrawals.

The use of these modeling approaches in decision-making processes and in promoting communication between viewpoints raises methodological issues (Olsson and Andersson, 2007): (1) models are laden with choices and thus depend on assumptions and priorities of modelers, and (2) several factors influence the ability and willingness of stakeholders to criticize or accept results of the modeling exercise. We believe that when a model is built by researchers to answer questions they developed themselves, the thematic conclusions drawn from these models are usually not accepted, or are at least questioned, by one or more of the parties involved in a natural-resource management problem. Although they aim to produce knowledge about resource management, studies using computer-based modeling are most often developed with little or no interaction with local actors. That is, they fall within "laboratory research" and "field research" ("Modes" I and II, respectively, of Hatchuel, 2001). Because they maintain such "distant" relationships with local actors, they are poorly suited for considering their constraints and objectives in a given context (Larsen et al., 2012). Additionally, McCall and Dunn (2012) stress the lack of methods that capture, represent, and integrate local knowledge to better address local knowledge in natural resource management.

Yet, the spatial management of water resources is a complex and trans-disciplinary problem that involves many actors with divergent interests (hereby called *stakeholders*), at different levels of action (IAASTD, 2009). It requires the collaboration of policy makers, local actors as experts or as lay persons, and researchers (Newig et al., 2008). To understand such situations where "facts are uncertain, values in dispute, stakes high and decision urgent", Funtowicz and Ravetz (1993) explain that society and science must move forward together through dialog. The challenge is then to implement "research-oriented partnerships" or "intervention research" ("Mode III" in Hatchuel, 2001), in which scientists are in charge of creating intermediary objects ("a sort of arrangement that allows different groups to work together without consensus" in Leigh Star, 2010; e.g. maps, computer or conceptual models, role-playing games) and collective action processes that enable stakeholders to deal with their specific natural-resources management problem. Research activities should bring science into the action process, typically with approaches from the "Sciences of Design" (Hatchuel and Weil, 2002; Martin et al., 2012; Nassauer and Opdam, 2008; Tittonell, 2013). In design activities, researchers are in charge of managing the boundaries between knowledge and action so that practical problems will influence scientific inquiry and scientific knowledge will be useful in decision making, i.e. credible, salient and legitimate.

"Credibility involves the scientific adequacy of the technical evidence and arguments. Salience deals with the relevance of the assessment to the needs of decision makers. Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests" (Cash et al., 2003).

To address these science-society interface issues, we developed a participatory methodology to design and to assess alternative AL in a river basin experiencing quantitative water imbalance. This methodology, hereafter called design-and-assessment (D&A) methodology, aims to incorporate different sources of knowledge and support a social learning process to enable social negotiation of satisfying solutions rather than computation of optimal ones (Giampietro, 2002; Newig et al., 2008; Pahl-Wostl and Hare, 2004; Sterk et al., 2009). Organizing information flows is one of the key scientific challenges of such a D&A process (Alcamo, 2008; Leenhardt et al., 2012; Martin et al., 2012; Olsson and Andersson, 2007). Boundary objects, developed by scientists, are used to facilitate expression of knowledge, mutual understanding and development of shared representations of the system and expected or desired changes. The D&A methodology we propose is composed of three collaborative steps (Barreteau et al., 2010) (1) representation of the AL in respect of quantitative water management issues, i.e. distribution of CS in the landscape, (2) design of alternative AL, and (3) integrated assessment of alternative AL effects on water resources via a multi-agent simulation platform. The main challenge of this third step is to simulate functioning of the entire social-ecological system (Ostrom, 2009), i.e. interactions between AL, water-resource and normative aspects (water releases from dams and water-use restrictions). All three steps are participatory, i.e. they involve both researchers and stakeholders, and may constitute iterative cycles. This article focuses on the description of the collaborative design activities (step 2, hereafter called co-design). We only briefly describe step 1 to show its importance in implementing step 2, and do not describe step 3. Steps 1 and 3 will be the subject of future articles.

Hereafter, we first present the study area and second the methodology for the collaborative design of alternative AL. We then provide two examples of alternatives designed by stakeholders. Finally we discuss the integration of this design exercise within the entire iterative D&A methodology.

Materials and methods

The D&A methodology was implemented in a region where the high irrigation requirements of the dominantly maize-based CS are incompatible with the current availability of water. Water availability is in fact constrained by a legal framework that requires environmental low-flows of rivers to be respected using either dam water storage or setting withdrawal restrictions. We collaborated with stakeholders concerned by quantitative water management issues, both those involved in agriculture and those involved in water management. In total, 62 people participated in the study in either expert interviews, semi-directed interviews on farms, workshops for participatory mapping, or workshops for designing options for change.

Study area

In the Adour-Garonne basin in southwestern France, the local state services regularly intervenes to manage what are commonly called "quantitative water management crises", i.e. when river flows fall below legal thresholds that are supposed to ensure proper functioning of aquatic environments. They use two main mechanisms to protect water flow: releases from large collective reservoirs and withdrawal restrictions. Agriculture is most affected