Journal of Environmental Management 197 (2017) 360–372

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

A structured participatory method to support policy option analysis in a social-ecological system

Sara Mehryar*, Richard Sliuzas, Ali Sharifi, Diana Reckien, Martin van Maarseveen

ITC-Faculty of Geo-Information Science & Earth Observation, University of Twente, P.O. Box 217, 7500AE, Enschede, The Netherlands

ARTICLE INFO

Article history:
Received 2 February 2017
Received in revised form
5 April 2017
Accepted 6 April 2017
Available online 10 April 2017

Keywords:
Fuzzy cognitive mapping
Driver-Pressure-State-Impact-Response
Social-ecological system
Rafsanjan
Water scarcity

ABSTRACT

In this study we demonstrate how to support policy option analysis for a problematic Social-Ecological System (SES) with the help of stakeholder participation. SES sustainability problems 1) are highly complex, 2) may lack reliable data, 3) encompass conflicting interests and 4) may require contradictory management interventions. Our approach uses a structured participatory method combining the Driver-Pressure-State-Impact-Response (DPSIR) model together with Fuzzy Cognitive Mapping (FCM) to capture the complexity of the system and simplify its representation for simulation and policy option analysis. Using this novel mixed-method was useful in dealing with above-mentioned characteristics of the complex SES problems. The method was applied in a case study of water scarcity in Rafsanjan, Iran. FCMs were produced for 60 individual farmers and 40 individual researchers and policy makers. Our mixed-method analysis reveals similarities and differences of stakeholder knowledge and problem perception, and simulates the impacts of alternative policy options according to each group's perception. The final result of our case study indicates that farmers in Rafsanjan strongly believe in the impact of economic diversification on reducing water shortage, but they have a low level of trust in the ability of the government to regulate and control water usage, whereas the policy makers and researchers still believe in the role of government control and monitoring policies to deal with water scarcity in Rafsanjan.

1. Introduction

There is a general insight that decision making in complex environmental problems requires an integrated consideration of both social and ecological systems and their interactions: the Social-Ecological Systems (SESs) (Berkes et al., 2000; Folke, 2006; Ostrom, 2007, 2009; Binder et al., 2013). SESs are dynamic systems for which states are constantly changing through the interactions among social and ecological factors (Berkes et al., 2000; Holling and Gunderson, 2002). Due to the dynamic and complex nature of such systems, the environmental management of SES has to deal with four main characteristics: 1) complexity, multi-variability and multi-disciplinarily, 2) ill-formulation of problems because of lack of or conflicting knowledge, 3) the large number of stakeholders with conflicting values and different views about problems and solutions, and 4) large number of management options and unanticipated consequences of each intervention for the whole system (Xiang, 2013; Olazabal and Reckien, 2015; Vasslides and Jensen, 2016). These four characteristics of SES problems make it difficult for policy makers to use standard dynamic modelling methods to represent and analyse such problems.

The aim of this study is to introduce a structured participatory method to support policy option analysis for a complex SES problem with the help of stakeholder perception. For this objective we use a combination of a Problem Structuring Method, i.e. Driver-Pressure-State-Impact-Response (DPSIR), with a participatory modelling method, Fuzzy Cognitive Mapping (FCM). The advantages of mixing this two methods is two-fold: methodological and structural. In methodology, DPSIR provides a structuring framework for a complex, multi-variable problem and FCM aids to 1) collect data via experts in data-scarce or poor data environments, 2) involve different interests of stakeholders and 3) simulate the impact of different interventions to the entire system (Reckien et al., 2013; Reckien, 2014; Singh and Chudasama, 2017). Therefore, the mix-method of DPSIR and FCM provides a modelling

* Corresponding author.
E-mail addresses: s.mehryar@utwente.nl (S. Mehryar), r.sliuzas@utwente.nl (R. Sliuzas), alisharifi@itc.nl (A. Sharifi), d.reckien@utwente.nl (D. Reckien), m.f.a.m.vanmaarseveen@utwente.nl (M. van Maarseveen).

http://dx.doi.org/10.1016/j.jenvman.2017.04.017
0301-4797/

platform covering all the characteristics of SES problems mentioned earlier: complexity, multi-stakeholder and conflicting interests, data scarcity and unintended consequences of interventions. The structural advantage of DPSIR-FCM method is the use of DPSIR framework for condensation and simplification of multi FCMs outcomes which will be explained further in section 2.3.2. The final point of our objective is using the stakeholders' perception for modelling the complex SES problems. In our vision successful policy making should consider multiple stakeholder views and their perceptions and reactions to policies. Therefore, policy makers need to be able to assess the local knowledge and perceptions of different stakeholders which might be missed or be in conflict with official data in a SES problem.

1.1. The Driver-Pressure-State-Impact-Response (DPSIR)

DPSIR, adopted by the European Environment Agency (EEA, 1999), is widely used as a problem structuring method to capture and structure the complex causal interactions of human-environmental systems (Bell, 2012; Gregory et al., 2013). This framework categorizes the complex indicators of an environmental problem into social-ecological *driver* indicators that exert *pressures* on the system and consequently affect the *state* of the environmental problem indicators, leading to *impacts* on the system and triggering societal *responses* that may in turn feed back to the drivers, pressures, state, or impact variables. Although DPSIR can help to structure and analyse complex SESs problems, it cannot capture trends of change in a dynamic system, as it builds a snapshot of the current situation of a system in the form of causal chains but not its causal networks (Svarstad et al., 2008; Maxim et al., 2009; Atkins et al., 2011; Gregory et al., 2013; Gari et al., 2015). Thus, DPSIR itself does not have the capacity of modelling a complex SES, while its combination with other tools such as FCM can create more valuable outcomes to overcome DPSIR's limitations (Bell, 2012; Lewison et al., 2016).

1.2. Fuzzy cognitive mapping

FCM is a participatory modelling method recently used in very different disciplines including SES modelling (Fairweather, 2010; Wildenberg et al., 2014; Gray et al., 2015). Structurally, it is a directed graph with feedback, consisting of nodes and weighted interconnections. It is a useful method in eliciting data from experts and stakeholders in data-scarce or poor data cases (Reckien, 2014, 2016); it helps to capture stakeholders' perceptions and communicate their knowledge in decision making processes (Papageorgiou and Kontogianni, 2012), and, moreover, by representing the semi-quantitative cause-effect relationships of a system, it can simulate the unanticipated impact of an intervention on different components of a complex SES. But combining a large number of cognitive maps can result in very complicated maps with too many nodes and connections, making the understanding and analysing of the maps very difficult. According to graph theory, an effective way to better understand the structure of complex FCMs is to condense them. However, the process of condensation is not well-documented nor standardized (Gray et al., 2014). By combining the structuring capabilities of DPSIR with the analysis and simulation capacity of FCMs we demonstrate a potentially fruitful method for FCM condensation.

1.3. Case study

We used our methodology in the case of water scarcity in Rafsanjan, Iran; a major producer and exporter of pistachios in Iran (see Fig. 1). Being in an arid and semi-arid region, pistachio farmers

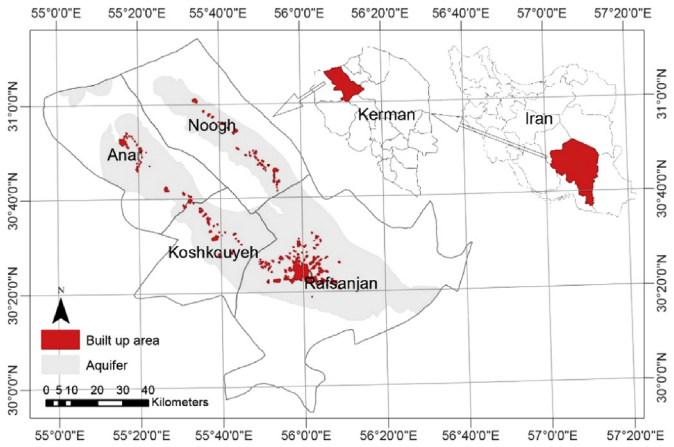

Fig. 1. Rafsanjan Township in Kerman province and in Iran.

in Rafsanjan are dependent on ground water for orchard irrigation. Rapid agro-economic development of the land and unsustainable water management have led to a high water demand of pistachio lands and overexploitation of groundwater. Frequent droughts and climate change are also contributing to the depletion of the area's aquifer.

Water scarcity in Rafsanjan is a tightly intertwined social-ecological problem. Water is almost free of charge, the energy for pumping groundwater is subsidised and the government has shown little control on the growing number of wells and their extraction limits. While pistachio farmers' associations have co-operated in the management of shared wells, they are not generally involved in policy and decision making about water management. Pistachio associations also have little contribution in water demand reduction activities since their main concern is the increase of production and export capacity of pistachio. This situation indicates a complex SES where various variables from social, economic, ecological and political disciplines are interdependently affecting the state of ground water in Rafsanjan.

Lack of data and their unreliability are challenges too. Besides conflicting data from different reports, government data are inaccessible due to the high sensitivity of the water crisis in Iran and its political and societal implications.

Currently, there is an “every man for himself “ situation in Rafsanjan: farmers maximize water extraction for their remaining lands or move the pistachio orchards to other regions once they can no longer make the desired profit in Rafsanjan. Attempts to manage groundwater reserves at a sustainable level are not adopted. There are many different actors and institutions with conflicting interests that complicate the decision making process related to groundwater and pistachio production in Rafsanjan.

There are alternative strategies for monitoring and limiting water use: applying advanced irrigation technologies, regulating water supply and demand provisions, and educating farmers, but their effectiveness in this complex SES of Rafsanjan is unclear. Most of these strategies are either new or have not yet been applied. Even when some water is saved, it is often used for the expansion of pistachio cultivation (Mehryar et al., 2015, 2016).

Considering the sustainability challenges of water scarcity in Rafsanjan, a tool to help policy makers in assessing the impact of their policy options is potentially useful. The tool should be able to deal with complexity of various changing factors, conflicting interests of stakeholders, the lack of reliable data and also the unanticipated consequences of the policy interventions in the whole system.