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Modelling feedback processes underpinning management of ecosystem services: The role of participatory systems mapping

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ABSTRACT

Ecosystem services are dynamically interdependent. When conducting studies on ecosystem services valuation and assessment, the interdependencies and feedback structures underpinning ecosystem functioning should be identified and explicitly considered in management processes, especially when the goal is to pursue a plural and integrative approach that accounts for multiple values. This paper explores the role of a participatory system dynamics modelling approach – participatory systems mapping – as a tool to articulate different value dimensions of ecosystem services. The application of the tool is illustrated with a case study conducted in a protected area in Portugal, wherein inter-organisational stakeholder groups collaborated in the conceptualization of feedback processes characterizing ecosystem services during a group modelling workshop. The outcomes of the participatory workshop were submitted to a post-production process and returned to participants though an individual online survey aiming to validate the changes. Food production, recreation and ecotourism, biodiversity conservation and climate regulation were the ecosystem services explored. Results show that by accommodating the co-creation of causal system maps with stakeholders, the proposed approach fosters sharing of insights on the underlying cause–effect mechanisms and leverage points, supporting the identification of interrelationships between different ecosystem services and the selection of key indicators for management processes.

1. Introduction

The concept of Ecosystem Services (ES) brings forward the benefits people obtain from nature (MEA, 2005). The dissemination of ES approaches is notorious in both research (Costanza and Ida Kubiszewski, 2012) and policy arenas (e.g., MEA, 2005; TEEB, 2010; IPBES, 2012). This has led to an intensification of the debate around the conceptual and practical implications of approaches to capture the importance of ES (Costanza et al., 1997; Martínez-Alier, 2002; Spash, 2008). Moreover, the recognition of different types of value associated with ES (De Groot et al., 2002; Farber et al., 2002; TEEB, 2010), calls for new platforms capable of integrating multiple value dimensions (Chan et al., 2016; Lopes and Videira, 2013, 2016; Martín-López et al., 2014). For example, Van den Belt and Blake (2014) reviewed fifty-eight articles in the agro-ecosystem literature and concluded that there is a need to bring forward social and cultural aspects, link the supply and demand for ES and develop an integrated understanding of the institutions using ES approaches to inform better decisions.

Within this context, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has recently highlighted the role that modelling methods and tools may provide to support decision makers in the conservation of ES (IPBES, 2016). This assertion has also been defended by several authors that have recently deployed modelling approaches in the context of ES valuation and assessment processes (Burkhard et al., 2013; Bagstad et al., 2013; Boumans et al., 2015). That is the case of Guimarães et al. (2013) who tested conceptual modelling tools to integrate science and policy for natural resource management. Pascual et al. (2016) also showed that gathering information into mind-maps allows the creation of a unified knowledge base, while Costanza et al. (2014) focused on the role of simulation games for research and learning about ES (Costanza et al., 2014). As argued by Boumans et al. (2002) and De Groot et al. (2002), the feedbacks characterizing ecological functions and associated ES can be translated into dynamic models, which could then highlight important interdependences. This is also defended by Videira et al. (2011) while recognizing the benefits of integrating system dynamics modelling approaches where stakeholders are involved in the construction of models fostering knowledge co-creation. Following this rationale, different integrated models have been developed using participatory system

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dynamics approaches to support management of natural resources, with varying degrees of stakeholder engagement in the model building processes (Antunes et al., 2015; Videira et al., 2011). Other authors have been using systems thinking methods regarding policy making on natural resources (Stave, 2002, 2003; van den Belt et al., 2010) and also discussing the distinct goals of participation and how participatory methods can achieved them (Hare et al., 2003). System Dynamics is an important method since it allows to understand the structure of a specific "problem" through the identification of the feedback loops, stocks and flows and the interaction of decision-making processes with the structure (Sterman, 2000).

The calls for integrating modelling approaches and participation in ES studies (e.g., TEEB, 2010; Lopes and Videira, 2013; IPBES, 2016) pave the way for testing new platforms capable of addressing the complexity of ES. In this article we argue that collaborative causal mapping activities, also known as Participatory Systems Mapping (PSM), can provide a sound modelling option within this scope. PSM is a participatory system dynamics modelling approach that includes the preparation and development of group model building activities, engaging inter-organizational stakeholder groups in the construction of qualitative models – Causal Loop Diagrams (CLDs) – to foster knowledge exchange and sharing of insights on dynamic issues (Sedlacko et al., 2014). CLDs were studied by different authors highlighting their importance in describing a problem situation and its possible causes and solutions and their integration with simulation modelling (Randers, 1980; Richardson, 1999; Sterman, 2000; Homer and Oliva, 2001; Haraldsson and Sverdrup, 2005). PSM has already been applied to different topics by some authors aiming to promote involvement of different group of participants in debates on environmental and sustainability issues (Videira et al., 2012, 2014; Sedlacko et al., 2014). In early PSM applications, CLDs were used as a conceptualization tool to support and organize the discussions and to allow the elicitation of different individual mental models of participants (Videira et al., 2009). PSM represents an approach capable of conducting a shared understanding of systems, qualified for accommodating different perspectives from distinct stakeholders and also to provide a structured platform for sharing worldviews (Sedlacko et al., 2014). All these features are potentially well suited for addressing the complexity of ES.

Hence, this paper aims to shed new light on the role of PSM in the context of promoting a deeper understanding of ES to support management processes. Through a collaborative process of mapping stakeholders' perceptions of specific ES it is possible to define interrelations and feedback models that explain the dynamics of ES and highlight the relations between people and nature, enabling also to emphasise relational values (Chan et al., 2016). We further reflect on the translation of PSM causal diagrams into a comprehensive set of socially constructed indicators. The proposed methodology is illustrated with a case study, where stakeholder groups were invited to co-create causal diagrams for key ES provided in the Arrábida Natural Park (ANP), a Portuguese natural area with protected coastal and marine ecosystems.

The expected contribution of this work is threefold: (i) develop an approach to articulate different values on the same modelling platform, providing room to discuss intrinsic, instrumental and relational values through the understanding of feedback processes underlying management of ES; (ii) bring an holistic perspective on the interrelationships among different ES identified in a study area; (iii) test a structured methodology to define key indicators for the supply and demand of ES supporting decision-making processes.

The paper proceeds as follows. The next section describes the methodology to conduct a collaborative mapping of ES using PSM. Section 3 presents the results from the application of the methodology to the ANP case study, including the CLDs developed in the workshop, the integration of the causal maps for each ES into a holistic model, and the analysis of CLDs through a cross impact matrix to identify key variables and indicators. Section 4 discusses the role of PSM in mapping feedback processes, identifying leverage points and defining ES indicators. Section 5 concludes with main lessons and future developments.

2. Methods and PSM process

The proposed methods emerged from a broader participatory framework for valuing and assessing ES (Lopes and Videira, 2013). The framework facilitates the study of ES through a participatory process that integrates a mixed set of tools, leading to the articulation of multiple value dimensions (Fig. 1). It comprises three major interconnected stages, the first one is called *set the scene*, where a collaborative scoping workshop is promoted following an institutional context and stakeholder analysis. This initial stage envisages the identification of ES, their threats and linkages with human wellbeing, their relative social, economic and ecological importance and the development of stakeholder networks depicting ES dependencies (Lopes and Videira, 2016). The second stage, which is addressed in this paper is called *deepen understanding*. As highlighted in Fig. 1, such co-learning process may be achieved through a PSM exercise for modelling with stakeholders the feedbacks and interrelationships identified in the first stage. The third and last stage aims to *articulate values* in the context of a specific decision, which should be informed by the results achieved at the previous stages.

The methods for the proposed 'deepen understanding' stage are centred on a PSM process, which provides a modelling platform where different stakeholders can collaboratively draw a CLD including the variables and causal links describing a given ecosystem service.

CLDs, also called 'system maps', are a particular type of model representation used in the system dynamics approach (Forrester, 1971; Lane, 2008; Sterman, 2000). These diagrams are built through the identification of system variables that are linked to each other through arrows depicting cause–effect relationships. If variable 'A' is connected to variable 'B' through a positive link a '+' sign is drawn to indicate that the variables change in the same direction, i.e., if 'A' increases, all else equal, 'B' increases. On the other hand, two variables connected through a negative '–' sign, means that they change in opposite directions. Feedback loops are drawn when two or more variables are connected in a closed cycle. Feedback loops are classified as Reinforcing (R) if they propagate an initial change in one of the loop variables, or Balancing (B), if the loop counteracts the initial change. Based on a CLD, modellers may develop a dynamic hypothesis about the causal chain of effects that may happen if a certain change occurs within a system. Assumptions of the method consider that any cause–effect relationship depicted between two variables must be read *ceteris paribus* (Lane, 2008).

Using the CLD language in a PSM workshop means that stakeholders are invited to collaboratively construct themselves a causal structure of the problem under study, with the support of group facilitators. This creates an open learning platform, structuring the deliberative process and fostering the co-production of knowledge (Sedlacko et al., 2014; Videira et al., 2012).

To conduct a PSM process for exploring the causal relationships underpinning ES, a sequence of tasks was designed to lead a participant group in the development of CLDs during a half a day event. In the case study described in this paper, the methodology depicted in Fig. 1 was applied as follows. First, a script was developed (Lopes and Videira, 2015), involving group modelling tasks and workshop preparation. Here, the information produced in the first stage – s*et the scene* – was retrieved. This included the selection of ES to map, based on the obtained information regarding