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Analysis

A framework for mapping and comparing behavioural theories in models of social-ecological systems

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A B S T R A C T

Formal models are commonly used in natural resource management (NRM) to study human-environment interactions and inform policy making. In the majority of applications, human behaviour is represented by the rational actor model despite growing empirical evidence of its shortcomings in NRM contexts. While the importance of accounting for the complexity of human behaviour is increasingly recognized, its integration into formal models remains a major challenge. The challenges are multiple: i) there exist many theories scattered across the social sciences, ii) most theories cover only a certain aspect of decision-making, iii) they vary in their degree of formalization, iv) causal mechanisms are often not specified. We provide a framework- MoHuB (Modelling Human Behavior) - to facilitate a broader inclusion of theories on human decision-making in formal NRM models. It serves as a tool and common language to describe, compare and communicate alternative theories. In doing so, we not only enhance understanding of commonalities and differences between theories, but take a first step towards tackling the challenges mentioned above. This approach may enable modellers to find and formalize relevant theories, and be more explicit and inclusive about theories of human decision making in the analysis of social-ecological systems.

1. Introduction

Formal models have been used extensively to study the interactions between humans and their environment, to advance theory as well as to inform policy making (e.g., Meadows et al., 1972; Clark, 1976; Nordhaus, 1994). In natural resource management (NRM), modelling has advanced our understanding of the dynamics of natural resources, their response to management interventions and environmental change, as well as their vulnerabilities and regenerative capacities. This has informed policy decisions on harvest quotas, agri-environmental schemes, the management of biological invasions, the location of biodiversity hotspots and corridors for inclusion in protection programs, and possible unintended side-effects of management interventions and policy options (Simberloff and Cox, 1987; Karagiannakos, 1996; Myers et al., 2000; Müller et al., 2011; Carrasco et al., 2012). However, because of the strong focus on understanding natural resource dynamics and their optimal management, human behaviours have been either neglected or oversimplified and remain a key uncertainty for sustainable management (Fulton et al., 2011).

Given that natural resource use systems are social-ecological systems (SES) in which humans shape and depend on their biophysical environment (Berkes and Folke, 1998), their adaptive responses to policy and environmental change cannot be neglected (e.g., Palmer and Smith, 2014). Modelling approaches need to explicitly combine ecological dynamics and human behaviour to address the interactions between the different domains. While a great deal has been achieved in conceptualizing the drivers, (co)evolution and implications of diverse

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human behaviour in natural resource management (Faber et al., 2002; Becker, 2006; Waring, 2010), integrating such conceptualization into formal models of natural resource use and management is still a major challenge (Janssen and Jager, 2000; Baumgärtner et al., 2008; Fulton et al., 2011; Milner-Gulland, 2012; Schlüter et al., 2012).

Common approaches for integrating human behaviour into formal models of social-ecological systems couple economic theory with resource dynamics (e.g., Clark, 1976; Nordhaus, 1994), capture human aggregated responses in feedback loops (e.g., Meadows et al., 1972), or use ad hoc assumptions (Smajgl and Barreteau, 2014). While the first of these is prescriptive in that it aims to determine the optimal resource management strategy or the optimal policy option given a set of constraints, the latter two aim to describe actual system dynamics by explicitly incorporating human behaviour. The first approach is often based on very simple assumptions about human decision-making, namely the concept of the selfish rational actor, also referred to as homo economicus. The frequent use of the rational actor in modelling human behaviour and decision-making in NRM is not surprising since it is the standard model in economic theory and is straightforward enough to include in mathematical formulations. This is perpetuated because theory building in economics often builds off a few well-established theories of human behaviour in order to allow for accumulation of knowledge. However, the key assumptions of the rational actor—that she has perfect knowledge and stable preferences, is selfish and makes calculations to identify an optimal decision that maximizes utility—are in contrast with empirical observations of how people actually make decisions concerning natural resource use (Siebenhuner, 2000; Van den Bergh et al., 2000; Hukkinen, 2014; Levine et al., 2015). Also, the assumption that these “deviations from optimal behaviour” can be considered as “noise”, and hence would cancel out in large populations, does not hold because much of these deviations are systematic. For example, in real life people have cultural habits, learn from other people, and often obtain utility from interacting with and helping other people (e.g., see Fehr and Schmidt, 1999; Gintis, 2000; Fehr and Gintis, 2007). Such behavioural drivers and processes are expected to have consequences for the dynamics and performance of social-ecological systems at large.

The importance of including the relevant complexity of human behaviour in the study of human-environmental interactions has been alluded to in recent publications (e.g. Levine et al., 2015; Worldbank, 2015). The World Bank's report on “Mind, Society and Behaviour” (Worldbank, 2015) explicitly acknowledges the importance of capturing the most advanced understanding of how humans think and how context shapes thinking for the design and implementation of policies. Others argue that the current focus on a small set of theories of human decision-making in policy assessment (such as climate policy) limits the relevance of those exercises (Victor, 2015). Since formal models are used to inform policy making, the lack of inclusion of social science expertise can considerably limit both the usefulness of formal models and the effectiveness of policies.

There is an abundance of theories in the social sciences that describe and test how people behave in various contexts. For example, in social and cognitive psychology, research has focused on processes of decision-making (e.g., Todd et al., 2012), social influence (e.g. Cialdini and Goldstein, 2004), information processing (e.g., Anderson, 1990), time discounting (e.g., Hardisty et al., 2012), and reinforcement learning (Skinner, 1953), just to mention a few. Theories have been developed on the gains and losses of group decision-making and situational and procedural contexts that affect outcomes (for an overview see e.g., Kerr and Tindale, 2004). In behavioural economics, the focus is directed at heuristics and biases, prospect theory and the framing of decisions (see e.g., Kahneman, 2003; Venkatachalam, 2008). However, this impressive body of knowledge has barely found its way into the field of natural resource management in general, and social-ecological systems modelling of resource management contexts in particular.

Modellers who aim to introduce alternative theories on human behaviour and decision-making in their models of natural resource management face several challenges (see Section 2 for a more detailed discussion): (i) the vast array of theories on human decision-making, some of which are even competing, makes orientation in the field very difficult. Moreover, knowledge is fragmented across disciplines and disciplinary languages. Theories can have different foci, such as emphasizing the importance of selected social or environmental aspects. (ii) As a consequence, some theories on human decision-making address very detailed aspects of decision-making, while others are very broad and comprehensive. Modellers need to recognize this diversity in scope and aim, and may even need to combine several theories in order to model the process of human decision-making in a comprehensive way. (iii) The degree of formalization varies depending each theory's methodological roots (experimental, conceptual, empirical). Correspondingly, modellers will be required to specify the elements and/or processes embedded within theories to varying extents. (iv) Modelling social-ecological systems necessitates simulating systems over time, requiring the specification and representation of causalities in the models. Many theories on human decision-making tend to focus on correlations and thus lack an understanding of causal mechanisms that can be translated into a dynamic model. Modellers, thus, have to make assumptions about causalities when using such theories. Overall, these issues make the selection of relevant theories for natural resource management problems, their formalization in social-ecological models, and comparison with each other very challenging indeed.

This manuscript is a modest step towards providing a framework to facilitate the broader inclusion of knowledge on human decision-making into formal models of social-ecological systems. The aim of the framework is to support the identification and operationalization of alternative behavioural theories into formal models by providing and defining a set of concepts commonly found across different behavioural theories. Specifically, we aim to encourage modellers to think more systematically about the implementation of human decision-making in their models and make use of the diversity of human decision-making theories from the social sciences, where possible. We also intend to support experimental and empirical researchers in the behavioural sciences engage with a broader range of theoretical perspectives. The purpose of this framework is therefore threefold:

- to provide a tool and common language for mapping, describing, organizing, comparing and communicating theories of human decision-making, and by doing so
- to enhance understanding of commonalities and differences such that modellers can make informed choices on which theory is relevant for a given context and research question, and
- to support the operationalization of behavioural theories in formal models by providing guidance on relevant factors and processes of decision-making and facilitating a more systematic implementation

To provide a framework that meets these purposes is an ambitious goal. In order to make concrete progress, we narrowed down the type of decisions we focus on. Accordingly, we focus on resource users (representing individuals, households or villages) making decisions on when, where, how and how much to appropriate from a resource — these are decisions on what crop to plant, where to fish and how many trees to cut. We do not include, for now, higher-level collective choice decisions, such as changing institutional rules, but we do include decisions on compliance to rules and social norms.

The remainder of the paper is organized as follows: In Section 2, we discuss the challenges modellers face when formally modelling human behaviour. In Section 3, we introduce the framework *MoHuB* (*Mo*delling *Hu*man *Behaviour*) and apply it to a number of well- established social-science theories in Section 4. In Section 5, we discuss the framework and conclude by considering how we may use this framework to implement