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A participatory Bayesian Belief Network approach to explore ambiguity among stakeholders about socio-ecological systems

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ABSTRACT

Participatory modelling must often deal with the challenge of ambiguity when diverse stakeholders do not share a common understanding of the problem and measures for its solution. In this paper, we propose a framework and a methodology to elicit ambiguities among different stakeholders by using a participatory Bayesian Belief Network (BBN) modelling approach. Our approach consists of four steps undertaken with stakeholders: (1) co-construction of a consensual conceptual model of their socio-ecological system, (2) translation of the model into a consensual Bayesian Net structure, (3) individual parametrization of conditional probabilities, and (4) elicitation of ambiguity through the use of scenarios. We tested this methodology on the ambiguity surrounding the effect of an ecological process on a potential innovation in biological control, and it proved useful in eliciting ambiguity. Further research could explore more conflictual or controversial ambiguities to test this methodology in other settings.

Data availability

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Software required Netica (v 5.18)

1. Introduction

Modelling with stakeholders is widely recognized for its ability to enhance stakeholder knowledge and understanding of a system as well as clarify the impacts of potential solutions to a problem (Voinov and Bousquet, 2010). Stakeholder participation enhances the success of the process in which such stakeholders are involved because it favors improved decision-making processes and fewer conflicts (Voinov and Bousquet, 2010) as well as faster impact (Couvet and Teyssèdre, 2013). However, involving stakeholders comes with specific challenges. Indeed, involving multiple parties from diverse backgrounds means that a spectrum of opinions, frames and ways of making sense must be accommodated (Brugnach et al., 2008). Such endeavor is particularly challenging as different stakeholders have equally valid ways of framing a problem (Dewulf et al., 2005). Stakeholders having radically different representations of a system is recognized as being associated with action situations exposed to “wicked problems” (Rittel and Webber, 1973). A wicked problem is a complex issue to which there is no straightforward and definitive solution. Several authors suggest that, in such situations, stakeholders should construct a common understanding (Brugnach et al., 2008; Etienne, 2010). However, creating a common understanding is challenged by many different types of uncertainties that complicate this endeavor (Brugnach et al., 2008).

Uncertainty is a widely recognized concept that has been approached differently in many different scientific domains (e.g. Knight, 1921; Shannon, 1948; Crozier and Friedberg, 1977). In socio-ecological settings, three different types of uncertainties have been identified: epistemic uncertainty, ontological uncertainty (Walker et al., 2003), and ambiguity (Brugnach et al., 2008). Epistemic uncertainty is the most traditional way to consider uncertainties, as it represents the imperfection of knowledge. As Walker et al. (2003) puts it, epistemic uncertainty may be reduced by more research and empirical efforts. Ontological uncertainty refers to the inherent variability or unpredictability of a phenomenon (Walker et al., 2003), and ambiguity relates to the plurality of different persons’

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representations of a system. By representation, we mean a mental model of external reality that allows people to interact with the world (Jones et al., 2011). Ambiguity occurs in particular when stakeholders build different representations about their environment (Brugnach et al., 2008).

As regards to modelling uncertainties, the Bayesian Belief Network (BBN) approach is recognized as particularly appropriate (Aguilera et al., 2011; Ropero et al., 2016), including in the case of modelling with stakeholder participation (Voinov and Bousquet, 2010). In the field of environment management, participatory BBN modelling is recognized for its capacity to (1) represent and integrate knowledge from diverse disciplines and spheres, (2) explicitly support the inclusion of stakeholders' representations, and (3) take into account epistemic and ontological uncertainties (Düspohl et al., 2012). However, without a few exceptions (Henriksen et al., 2012; Kelly et al., 2013), BBN construction with stakeholders do not prescribe or guide on how to consider ambiguity as part of participatory modelling with stakeholders. Most of the time, different stakeholder's representations in participatory BBN are integrated either by averaging all representations in a single model (e.g. Shaw et al., 2016) or by choosing the "best available source of information" (Voinov and Bousquet, 2010:1268, Holzkämper et al., 2012). Such simplification makes sense when the objective of a participatory BBN model is decision support (Cain et al., 2003) or prediction, because integrating all available information (scientific and non-scientific) in a single final model may improve the model's explanatory power. Such integration is not satisfactory when the modelling objective is not prediction but rather exploration of different framing issues and exchanges of representations among stakeholders to "illuminate core uncertainties" (Epstein, 2008) like ambiguity. The objective of this paper is to present the testing of a participatory modelling method using BBN that enables the analysis, and comparison of the different representations brought forward by multiple stakeholders. This method allows for dealing with ontological uncertainty, which is common for BBN, in order to deal with ambiguity, which is less researched. A couple of papers mention this issue (Henriksen et al., 2012; Kelly et al., 2013), but do not provide an operational approach to deal with ambiguity, which is the purpose of the present paper and as such is an original proposition.

2. Method

2.1. Case study background

We tested our BBN participatory modelling approach in southwest France in an agricultural region specializing in fruit tree production (mainly apples) located on alluvial terraces along the Aveyron and Tarn rivers. Conventional apple orchards require intensive chemical treatments to control pests. Integrated pest management (IPM) in the 1980–90s promoted the use of natural enemies in the area to encourage fruit growers to implement biological control of some insect pests. Natural enemies are species which activity of predating or parasiting other species considered as pests may reduce their negative impacts on crops. Recent public policies in France are trying to reduce farmers' pesticide use by 50% by 2025. They foresee the possibility of doing so by enhancing natural enemy activity by engineering pest-suppressing landscapes (Potier, 2014). Some landscape ecologists' findings back up such potential innovation by demonstrating that a high presence of natural habitats such as meadows and woods enhances biological pest control by providing food and shelter for these natural enemies (Bianchi et al., 2006; Rusch et al., 2016). Some authors modelled pest-suppressing landscapes and indicated that agent-farmers would always benefit from such landscape-scale management (Cong et al., 2014). Another theoretical model indicated a high outcome when farmers cooperate in the management of natural enemy habitats (Bell et al., 2016). However, scant attention has been paid to the question of whether it is in the interest of farmers to manage habitats at the landscape scale (Cong et al., 2014). In this regard, we previously identified that, in this area, local stakeholders (whether farmers or their advisors) had representations of their landscape in which landscape stimulated occasional pest damage, and no effect whatsoever of the landscape on natural enemies was mentioned (Salliou and Barnaud, 2017). This difference in representations between scientists and local stakeholders came as a surprise, as the effect of local or regional landscapes on the natural enemy populations of orchards is reported by many authors (see Simon et al.'s, 2010 synthesis). A top-down science-based approach to innovation might consider scientific findings as more relevant than farmers' local knowledge. In our co-innovation approach however, we wanted to give careful consideration to both scientific and local representations, which are a priori equally legitimate in regard to this potential innovation (Jalonen, 2012). The modelling approach presented here aims to explore ambiguity between landscape ecology findings and local stakeholders' knowledge about the effect of the landscape on natural enemies and pest control. In our study area, the modelling process involved five willing stakeholders: a conventional fruit tree grower, an organic fruit tree grower, a pedagogic fruit farm manager, a technical advisor, and a landscape ecology researcher. These participants are representative of the diversity of local stakeholders involved in the fruit tree production sector studied.

2.2. Modelling approach

We designed a four-step protocol in order to compare stakeholders' representations about the same socio-ecological system (Fig. 1). We describe here the global modelling approach and main steps, which are detailed in later sections. As a first step, stakeholders (the scientist and local stakeholders) co-constructed a consensual conceptual model of the socio-ecological system using the ARDI methodology, specifically designed for it (Etienne et al., 2011). In a second step, this conceptual model was collectively turned into a Bayesian net structure. This Bayesian net structure is a collectively agreed understanding among involved stakeholders about how main variables and states of the system are defined and connected. In the following step, each stakeholder individually parametrized the Bayesian net structure by eliciting probabilities attached to each variable in the system. Doing so, we finally constructed five individual BBNs of the same socio-ecological system conceptualization, one for each stakeholder. As a final step, we applied the same scenario of a pest-suppressing landscape to each individual BBN. The impact of the scenario on each individual BBN model was then discussed together with each participant. Ambiguities were analyzed by comparing the effect of the same scenario on each stakeholder's BBN.

2.2.1. Co-constructing a consensual conceptual model of a socio-ecological system using the ARDI methodology (step 1)

The ARDI (Actor–Resource–Dynamic–Interaction) method is specifically designed to build together with stakeholders a consensual conceptual model of a socio-ecological system (Etienne et al., 2011). It consists of a series of workshops where stakeholders are aided by a facilitator to build collectively a conceptual model of a socio-ecological system representing its key actors (humans and non-humans), its key resources, their dynamics, and the interactions among them. Workshops first focus on listing Actors (A) and Resources (R) and eventually Dynamics (D). Finally, the last step is about synthesizing and connecting previously identified