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Future uncertainty in scenarios of ecosystem services provision: Linking differences among narratives and outcomes

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ABSTRACT

Future provision of ecosystem services (ES) has been increasingly analysed through the scenario approach to address uncertainties and to communicate them to stakeholders and decision-makers. Multiple uncertainty-related aspects of the scenario approach have been discussed in the literature, e.g. how uncertainty is accounted for in ES modelling processes. However, this contribution aims to address another uncertainty-related aspect of scenario analysis, exploring the relationship between the diversity of qualitative scenario narratives on the one hand and the diversity of their respective quantitative outcomes on the other. We build on a local-scale case study and present a semi-quantitative approach to compare scenario narratives and outcomes, based on participatory scenario planning and ES modelling. Our results show that different scenario narratives may lead to similar levels of modelled ES provision, and vice versa, that similar narratives may result in contrasting scenario outcomes. We use these findings to derive uncertainty-related insights, and discuss how these can help formulate landscape management decisions, resulting in desirable ES outcomes across a range of plausible futures. Finally, we discuss the need to apply both spatial and aspatial approaches to compare the convergence of scenario outcomes, and the implications for potential interpretation of the results by stakeholders and decision-makers.

1. Introduction

Ecosystem services (ES), as a vital precondition of human well-being, have gradually become a major concern for decision makers worldwide and at all scales of governance (Daily et al., 2009; Díaz et al., 2015; EC, 2011). Modelling the provision of ES and its potential future development has gained momentum across professional communities and contexts (Bagstad et al., 2013; Lorencová et al., 2013; Maes et al., 2013; Peh et al., 2013). In particular, a special attention has been given to the provision of ES bundles (Martín-López et al., 2012; Queiroz et al., 2015; Raudsepp-Hearne et al., 2010) and to assessing multiple aspects of trade-offs and synergies among ES (Daw et al., 2015; Maes et al., 2012; Nelson et al., 2009; Ruijs et al., 2013).

Future provision of ES has been increasingly explored through the scenario approach (IPBES, 2016; Kok et al., 2017; Oteros-Rozas et al., 2015). The scenario approach has been designed to capture the complex dynamics of social-ecological systems (SES), as well as to understand key natural and societal driving forces and their potential future effects, including the impact on ES provision (Bennett et al., 2003; Carpenter et al., 2006; MA, 2005a; Peterson et al., 2003). The scenario approach in ES assessments generally aims to build diverse, plausible descriptions of potential future development (qualitative “narratives”), and to quantify the levels of ES provision resulting from each narrative (“outcomes”) (Harrison et al., 2013; Reed et al., 2013; Rounsevell and Metzger, 2010). Scenario analysis has been recognised as a tool to address future uncertainties, which stem from the dynamic and changing nature of SES, by outlining multiple plausible ways of future development (MA, 2005b). Furthermore, scenario analysis helps communicate different aspects of uncertainty to decision makers and take proactive steps to enhance society’s ability to navigate future change (IPBES, 2016). Multiple uncertainty-related aspects of the scenario approach have been discussed in the recent literature, e.g. how uncertainty is accounted for in ES modelling (Hamel and Bryant, 2017; Hou et al., 2013; Schulp et al., 2014) or how different types of uncertainty emerge throughout the interplay between policy-making processes and related science-based decision support (Walker et al., 2003).

Formally, in terms of the nature of uncertainty, most of these studies generally deal with epistemic (also known as ‘scientific’) uncertainty, i.e. the uncertainty due to imperfect knowledge or data on the system being described (IPBES, 2016; Refsgaard et al., 2007). A certain level of epistemic uncertainty is unavoidable but can be reduced by additional research or empirical efforts, e.g. by improving data analysis or by

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deepening our understanding of the modelled system (IPBES, 2016; Refsgaard et al., 2007).

However, the scenario approach has the potential to addresses yet another type of uncertainty, the variability uncertainty, stemming from the random behaviour, inherent variability or unpredictability of complex natural, social and economic systems (also known as 'ontological' or – in a narrower sense – 'stochastic' uncertainty). Although variability uncertainty is inherently irreducible, it can be accommodated through the construction of a set of plausible future scenarios rather than a single one, and through analysing the differences among them (IPBES, 2016; Walker et al., 2003). Accordingly, the purpose of scenarios is not to reduce variability uncertainty, but rather to convey this source of uncertainty and its implications to policy and decision making (Enserink et al., 2013).

This contribution addresses the variability-uncertainty related aspects of the scenario approach by exploring the relationship between the range of qualitative scenario narratives on the one hand and the diversity of their respective quantitative outcomes on the other. Specifically, we focus on what insights regarding an uncertain future state of a system we can derive from the cases in which diverse scenario narratives lead to similar modelled ES provision outcomes, and vice versa. For this purpose, we present a feasible semi-quantitative approach to compare among scenario narratives and outcomes, based on participatory scenario planning and ES modelling, and illustrate it on a local-scale case study. Consequently, we discuss the relevance of the uncertainty related considerations derived from our findings for landscape management and decision-making processes.

2. Methods

Building on an illustrative case study, we first analysed the social-ecological dynamics of the selected SES and developed an array of local-scale, participatory scenario narratives. Second, the narratives were translated to spatially explicit land use and land cover (LULC) scenarios, which were subsequently used as the basis to model potential future ES provision (further denoted as scenario outcomes). Finally, a semi-quantitative approach was applied to compare the differences among scenario narratives on the one hand and among their respective ES outcomes on the other, using multiple quantification and visualization approaches (Fig. 1).

2.1. Case study area

The case study was carried out in Třeboň Basin UNESCO Biosphere Reserve (BR) in the Czech Republic (Fig. 2), as a part of a research project focusing on the development of Long-Term Socio-Ecologic Research in the study area (Harmáčková and Vačkář, 2015). The study area (700 km^2) is most distinctly characterized by coniferous forests, wetlands, wet meadows and artificial water reservoirs (fish ponds). The region has had a historical tradition of fish-farming since the 15th century and has been highly valued due to its natural and cultural assets. Třeboň Basin has been recognized as a UNESCO Biosphere Reserve, a Long-Term Ecological Research site, wetlands of international importance under the Ramsar Convention on Wetlands as well as a Protected Landscape Area (Jeník and Přibyl, 1978; Pokorný et al., 2000).

Although Třeboň Basin is a declared Protected Landscape Area, several exploitive activities are permitted within its boundaries as a legal consequence of previous protection regimes. At the same time, it draws the interest of multiple businesses due to the economic potential of local natural resources. Therefore, Třeboň Basin has faced pressures in the form of intensively fertilised fish-farming (IUCN, 1996; Pechar et al., 2002; Vinciková et al., 2015), sand and gravel mining along protected water and wetland ecosystems, and biogas energy production (which serves as an energy supply for Třeboň spas). Beside fish-farming and agriculture, Třeboň Basin is an important destination for tourism and recreation, which presents another source of pressure on this vulnerable area. In sum, local landscape management is challenged by a trade-off between sustaining current levels of landscape protection and promoting economic growth, potentially counterbalanced by decreasing provision of ES.

2.2. Step 1: Scenario planning

As the first step, we developed an array of participatory scenario narratives, capturing local social-ecological dynamics, key driving forces and their potential future impact on local landscape and ecosystems in the medium-term future (to 2050) (Rounsevell and Metzger, 2010; Spangenberg et al., 2012). We used the approach of participatory scenario planning, collaborating with a wide range of local stakeholders (Hanspach et al., 2014; Peterson et al., 2003; Reed et al., 2013).

In the initial stage of the study, we identified local stakeholders either substantially influencing the land use regime in Třeboň Basin, or having expertise in the driving forces forming the local landscape. The key stakeholders involved in the study represented industrial, agricultural and tourism sectors, nature protection, as well as scientific and educational institutes conducting research in the study area (Table S1). The representatives of local fishing industry and forestry were unwilling to participate in the scenario building process; thus, plausible trends in these sectors were elicited from researchers involved in local hydrological, ecological and landscape research.

In total, 14 key stakeholders participated in the study through a series of semi-structured interviews and individual discussions to identify driving forces most influential in the local SES and key benefits provided by the local landscape (Box S1) (Celio et al., 2015; EEA, 2012; Fagerholm et al., 2013; Reed, 2008; Termorshuizen and Opdam, 2009). Furthermore, the stakeholders were asked to describe how they assume the landscape will develop in the medium-term future (2050) and what their preferences are regarding landscape development according to their professional perspective. Although expectations of a certain type of a future development and preferences regarding future development represent two distinct perspectives, we believe both are important for envisioning different futures. Therefore, we addressed them explicitly in the interviews, and the themes and trends identified under both of these perspectives were treated equally as building blocks for the subsequently formed narratives.

In the material from the interviews, key topics and trends in social-ecological dynamics, landscape development and landscape management were identified and grouped into several coherent scenario narratives (Hunt et al., 2012; Kok et al., 2011), namely the Market narrative, the Exploitation narrative, the Business-as-Usual (BaU) narrative, the Conservation narrative and the Biofuels narrative (see the Results section).

2.3. Step 2: LULC scenarios

In the second step, we translated the participatory narratives into spatially explicit LULC scenarios and used these as the basis to model potential future ES provision. In order to capture both the locally specific landscape dynamics and larger-scale drivers of landscape change, we combined the participatory narratives compiled based on stakeholder input (Box S1) with European-scale LULC datasets (CORINE Land Cover; EEA, 2007) and dynamic LULC change scenarios (the 6th Framework Programme ALARM project scenarios; Dendoncker et al., 2006; Rounsevell et al., 2006; Settele et al., 2005; Spangenberg et al., 2012), using spatial modelling tools in ArcGIS (ESRI, 2013). The ALARM scenarios were used as at the time of the analysis, they represented the only downscaled set of LULC scenarios for Europe with a fine spatial resolution; CORINE Land Cover was selected as its resolution and LULC categorization corresponded to those of the ALARM scenarios.

The modelling framework is outlined in Fig. 1 and described in