HIGHLIGHTS
• Mountain forests can assist in reducing societal vulnerability of forest dependent communities.
• A combined DPSIR-ES approach proved to be useful for identifying human responses.
• The heterogeneity of perceptions reflecting on forest related decision-making has been untangled.
• Expert evaluation of the FSES can assist in designing policy and practice measures to enhance sustainability.

GRAPHICAL ABSTRACT

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To better understand how constantly changing human-environment interactions could be better organized to respond to current challenges, we examined the Ukrainian Carpathians as an example case of complex forest social-ecological systems (FSES). We did it by interviewing diverse and relevant local stakeholder (N = 450). In particular, we strived to: i) outline how people and nature are linked and interact in coupled FSES; ii) examine the preferences of stakeholders on the forests and associated ecosystem services (ES); iii) map key drivers threatening well-being of FSES and iv) identify potential responses to address the challenges at a local scale. To answer these questions we followed a mixed method route by integrating qualitative (participatory) and quantitative data collection and analyses, with further application of a Driving Force-Pressure-State-Impact-Response (DPSIR) framework in combination with the ES approach in order to assess benefits, threats to these benefits, and responses regarding the studied FSES. We found that the key benefit from FSES is timber and non-wood forest products (like berries and mushrooms), but also various regulating services were ranked highly by respondents. To explore social-ecological innovation, with potential responses of forest-dependent communities to challenges they face, we employed a commonly used assumption that governance must fit to the particular characteristics of FSES in order to enable sustainability. For the particular case of the Ukrainian Carpathians, we identified and discussed the following five nonconformities or “misfits” threatening sustainability: 1) Spatial misfit...
1. Introduction

Recent debates involving scientists, policymakers and development agencies have been focused on social-ecological systems (SES) with special attention being paid to human well-being (United Nations, 2015) and environmental sustainability (Millennium Ecosystem Assessment, 2005) and key driving forces, as well as critical uncertainties associated with them (Sarkki et al., 2016). SES are composed of ecological systems, providing basis for ecosystem services (ES), social systems diverging across stakeholder groups, and policy, and governance systems, and instruments at various levels (Ostrom, 2009). Berkes et al. (2016) consider SES as integrated complex systems that include social (human) and ecological (biophysical) subsystems in a two-way feedback relationship. The system outputs are returned to the system as an input, either to oppose the initial input (negative feedback) or to enhance it (positive feedback).

Human well-being depends on ecosystem services (ES) (Costanza et al., 2014; Knight and Rosa, 2011). Social systems are affected by changes in the functioning ecosystems and by the resultant flow of their services (Nijnik and Miller, 2013); while the ES are affected by human behaviours, including, at times, by unsustainable use of natural resources to meet human’s objectives. Due to the complexity of SES and the observed causality between the ES provision and human well-being, it is necessary to improve knowledge of the inter-linkages. This, in turn, will assist in developing socially-ecologically innovative responses to address the challenges that natural resource-dependent communities are currently facing.

This paper examines the interrelations of these systems in an in-depth manner, combining the use of ES, SES and Driving Force-Pressure-State-Impact-Response (DPSIR) concepts under a single analytical framework. Natural resources have a considerable influence on human well-being at all scales by generating multiple benefits (Nassl and Löfler, 2015). The well-being of people is threatened by increasing damages to or/and losses of natural assets (Nassl and Löfler, 2015), and these assets, as well as their users, are embedded into complex SES.

Numerous studies emphasise that people are an integral part of SES and that a dynamic interaction exists between them and other parts of the system. The following observations have been made based on analysing SES and examining the link between their human and environmental sub-systems: 1) SES are complex and difficult to quantify (Villamagna and Giesecke, 2014); 2) the realisation of non-material values of ecosystems (e.g., cultural and amenities) can promote more sustainable human behaviours (Ericson et al., 2014); 3) dependence of human society on cultural ES will likely increase in time (Daniel et al., 2012) and be more important in the future (Plieninger et al., 2013).

These observations necessitate an improved understanding of human behaviour and of governance and decision-making processes affecting complex and dynamic SES (Roussev et al., 2010). The role of governance and social-ecological innovation (Dennis et al., 2016; GRAID, 2017) is important for sustaining SES. If governance does not match or fit to particular characteristics of the SES, it aims to govern, it is likely to lead to rigid systems, conflicts, incompliance of the rules, and environmental problems (Young, 2002; Folke et al., 2007; DeCaro and Stokes, 2013). Examples of misfits include governance focus on single resource in complex ecosystems, command-and-control governance undermining local participation, rules and laws not accepted by stakeholders, and lack of attention to particular features of local social systems (Holling and Meffe, 1996; Hiedanpää, 2013; Sarkki et al., 2015). Therefore, challenges to sustainability cannot be effectively coped with, if the governance responses do not take into account the particular social and ecological characteristics of SES and their interactions (i.e. if these responses are not socially-ecologically innovative).

Governance encompasses, but is not limited to policies and legislation, market based instruments, civil society initiatives and self-governance: all functioning at multiple levels, being the basis for innovative responses and adaptation (Lemos and Agrawal, 2006; Andonova and Mitchell, 2010; Wurzel et al., 2013). The adaptation measures are reflected in institutional behaviours, policies, the changing attitudes of relevant stakeholders, actions and practices aiming to enhance well-being in given situations, i.e. social innovations (SIMRA, 2016). In order to identify effective responses to challenges the SES must be studied in detail. There is also a need to identify particular/potential misfits resulting from governance failures to propose ways forward, and how the misfits as threats to sustainability, can be overcome.

Importantly, that different groups of people perceive a changing world and challenges they face, differently. Their preferences as to kinds of “final” goods and services of ecosystems may differ. People benefit from SES in different ways (Christie et al., 2007; Nijnik and Miller, 2013). Stakeholder priorities with respect to individual ES may be different either (Nijnik et al., 2017), as may be a range of stakeholders (Sarkki et al., 2017b). Therefore, human dependence upon ES at the individual, household, community and regional, and higher levels is a complex and multifaceted phenomenon (Reckley, 1998). This observation implies that interactions between social, governance and environmental sub-systems of forest SES (FSES) should be studied further in order to fill the existing knowledge gap, regarding the varying perceptions on ES benefits and values and to identify responses for enhancing equity and sustainability, particularly in marginalised rural areas, including in mountain regions.

The UN 2030 Sustainable Development (SD) Goals’ 2030 Agenda (United Nations, 2015) highlighted three mountain-forest related targets: 1) target 6.6 – by 2020, to protect and restore water-related ecosystems, including mountain and forest; 2) target 15.1 – by 2020, to ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and ES with particular emphasis on forests and mountain communities; 3) target 15.4 – by 2030, to ensure the conservation of mountain ecosystems, specifically their biodiversity, in order to enhance their capacity to provide benefits that are essential for SD.

Indeed, forest ES play an important role in economic and social development of mountain regions, e.g. being a source of wood and non-wood forest products (NWFPs), a renewable energy source, and a basis for outdoor recreation, in addition maintaining their ecological significance (e.g. for watershed protection, erosion control and biodiversity conservation). Mountain forests contribute to reducing societal vulnerability to climate change and to ensuring the well-being of local, forest-dependent communities. Attention is being increasingly paid to an improved understanding of human-environmental interactions within the FSES (Kalaba, 2014; Mohammed and Inoue, 2017). Recent studies seek to explain how forest ecosystems can contribute to the human well-being and provide sustainably a broad array of essential ES (Melnykovich and Solovyj, 2014). Forest-dependent communities, such as mountain communities in the Ukrainian Carpathians, use legislation; 2) Poor contextualization; 3) Trap of the single ES; 4) Participatory misfit; and 5) Robbing the commons. By conceptualizing those key threats, we proposed responses for sustainability. The findings contributed to an advanced understanding of complex FSES, their key challenges and potential solutions in order to secure well-being of people and nature in coupled social-ecological systems, in the conditions of a changing world. © 2017 Elsevier B.V. All rights reserved.
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