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Policy strategies to foster the resilience of mountain social-ecological systems under uncertain global change

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ABSTRACT

Globalization and climate change threaten the sustained provision of essential ecosystem services (ES) for people living in and downstream of mountain regions. The increasing evidence of the many vulnerabilities of mountain social-ecological systems has highlighted the urgent need for policy-relevant research into ways of coping with these trends. In this context, resilience has been emerging as a concept for both understanding and managing the complex social-ecological systems in which ES are provided and consumed. Yet, literature on resilience of social-ecological systems is mainly theoretical with limited application in real-world mountain case studies. In this paper, we present a comprehensive quantitative assessment of the social-ecological resilience of a case study in the Swiss Alps under global change. We model and evaluate an indicator for resilience that shows the capacity of the mountain social-ecological system to provide a set of demanded ES. In a first step, we model the development of this indicator in different scenarios of global change. In a second step, we test the effect of a rich set of policy strategies under all these scenarios to identify types and timing of interventions that are robust under multiple global change settings. Results indicate that the resilience of the mountain social-ecological system is endangered in all scenarios, especially if strong globalization is assumed. Robust strategies that buffer the system against these pressures require early spatial planning action in combination with more targeted direct payments to support the current regional structure and traditional mountain farming practices. Such information is crucial to guide decision-making processes in the era of highly uncertain future global change.

1. Introduction

Mountains cover 24% of the Earth's land surface and as repositories of biological and cultural diversity they provide essential ecosystem services (ES) to mountain dwellers and people living in their vicinity (Bernués et al., 2014). In addition, they are of global significance due to their key role in regulating processes such as carbon sequestration or water storage and purification (Grêt-Regamey et al., 2012). The provision of these services depends largely on land use which itself is shaped by long-established interactions of humans with nature in social-ecological systems (Rounsevell et al., 2012; Verburg et al., 2013). Mountain social-ecological systems are ecologically and economically sensitive to rapid global change and an increasing number of studies has investigated the large consequences of global drivers for local mountain environments and human well-being (e.g. Mottet et al., 2006; Huber et al., 2013; Munteanu et al., 2014). But, while our understanding of these trends advances, there are rising concerns among scholars and policy-makers about the declining capacity of mountain social-ecological systems to cope with these trends and unexpected shocks accompanying them in future (Gurung et al., 2012). Accordingly, mountains have recently been taken up in many contemporary debates on rural development and policy-making from the national to the global level (Balsiger and Debarbieux, 2015).

Resilience is emerging as a frame for understanding the stability and trajectory of complex social-ecological systems in which ES are provided and consumed (Morehouse et al., 2008; Ifejika Speranza et al., 2014). Resilience was originally introduced by Holling (1973) as an ecological concept to help understand the capacity of ecosystems to persist in the original state when subject to perturbations. With the increasing extension of the concept to social, economic and coupled social-ecological systems since the

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late 1980s many alternative definitions have been proposed (Janssen and Ostrom, 2006). Social-ecological resilience is referred to as "the capacity of a system to absorb disturbances so as to still retain essentially the same function, structure, feedbacks and identity" (Walker et al., 2004). In the context of this study, we will equate resilience with the capacity of mountain social-ecological systems to maintain flows of target ES given by ES demand during a specific period of time (Janssen et al., 2007; Biggs et al., 2012; Bürgi et al., 2012). The more resilient a system, the better it can cope with external disturbances and continue to provide demanded ES.

Managing for resilience is becoming a central objective for policy-making, since it is expected to foster desirable development pathways in an environment of ongoing and partly unpredictable global change (Morehouse et al., 2008; Schwarz et al., 2011; Plieninger and Bieling, 2012; Farley and Voinov, 2016). Evaluating policy and management strategies for sustaining resilience requires a specification of "resilience of what to what" (Carpenter et al., 2001). In a first step, decisions about which ES to sustain have to be negotiated among different societal actors, since every social-ecological system produces a multitude of ES of which not all can be increased simultaneously (Nelson et al., 2007). In a second step, policy-makers and resource managers need to find effective ways of building resilience of social-ecological systems to deliver these key ES towards different types of stressors. Stressors take the form of both long-term sustained presses, e.g. global warming or demographic changes, and rapid sudden pulses, e.g. droughts or market shocks (Collins et al., 2011). A policy-relevant resilience assessment thus requires considering a range of plausible hypotheses about future changes and on a range of possible policy strategies against this set of potential futures, in order to derive actions that are robust to uncertainties and under different potential disturbances (Polasky et al., 2011a).

In the last decade, many conceptual frameworks of resilience have been developed (e.g. Carpenter et al., 2001; Walker et al., 2004; Folke, 2006; Nelson et al., 2007), but only few authors have analyzed empirical problems in social-ecological systems through a resilience lens (Plieninger and Bieling, 2012). Studies in mountain regions tend to focus either on the ecological (e.g. Rescia et al., 2010; Oteros-Rozas et al., 2012; Tomczyk et al., 2016) or the social part (e.g. Luthe et al., 2012; Bardsley and Bardsley, 2014; Schermer et al., 2016) of the system. Integrative operationalization and modeling efforts, however, are lacking, complicated by the inherent complexity of social-ecological systems, such as non-linearity, feedback loops or multiple spatial and temporal scales (Cumming et al., 2005; Filatova et al., 2015). Existing modeling studies mostly build upon generic models to understand resilience of social-ecological systems at a very aggregate level with limited potential to address real world problems in which context-specific interactions determine system behavior (Schlüter et al., 2013). But, only if the analysis comes down to empirical case studies, it can be used by policy-makers to identify their actions as being (non) resilient as system disturbances occur (Schouten et al., 2009; Ifejika Speranza et al., 2014). Consequently, calls for decision-oriented research that facilitates choices between a range of

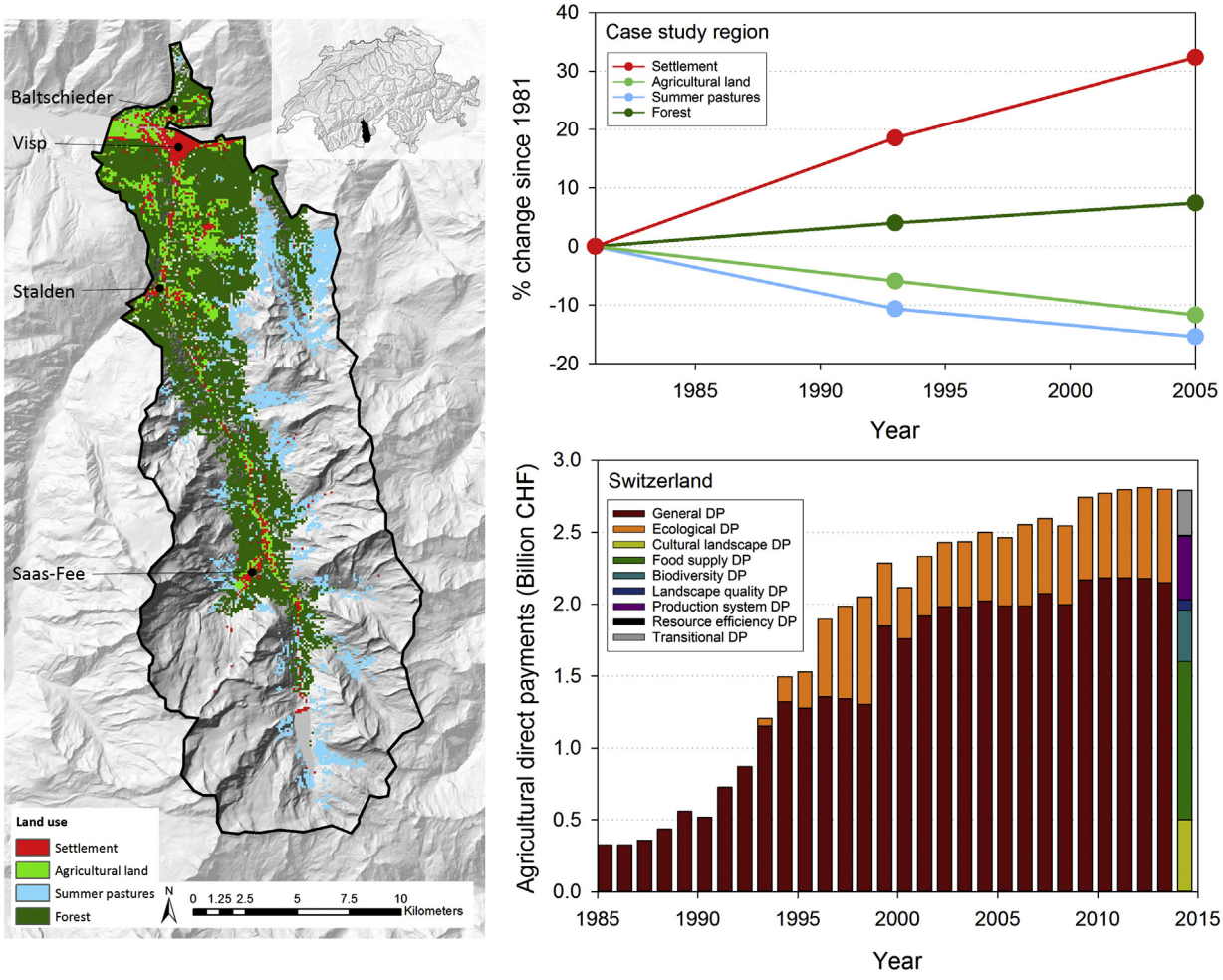

Fig. 1. Historical land-use changes in the case study region in the Swiss Alps (based on SFSO, 2009) and development of the federal agricultural direct payments (DP) (based on SFSO, 2015).