



Research paper

Vulnerability of socio—ecological systems: A conceptual Framework

Lina María Berrouet^{a,b}, Jenny Machado^b, Clara Villegas-Palacio^{b,*}^a Engineering Faculty, Universidad de Antioquia, Colombia^b Geosciences and Environment Department, National University of Colombia - Medellín Campus, Cra 80 No 65-223, Block M2-301, National University of Colombia - Medellín Campus Robledo, Medellín, Colombia

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ABSTRACT

The analysis of vulnerability of socio-ecological systems to threats of different types such as extreme climate events or change in land use draws attention to the factors and processes that determine whether the ecological, social and integrated socio-ecological systems are likely to experience harm due to exposure to the threat. During the last years there has been an increasing attention to the analysis of the vulnerability of socio-ecological systems when facing the loss or degradation of ecosystem services. However, despite the existence of conceptual frameworks and empirical applications to evaluate vulnerability of socio-ecological systems some open questions and challenges still remain. How to conceptually differentiate key concepts such as sensitivity, exposition, vulnerability and threat? How to consider the differences in socio-economic characteristics of the beneficiaries and in their capacity to adapt to new conditions of the ecological system? How to link ecological vulnerability with the social system analysis to obtain an integrated risk assessment of the socio-ecological system? This paper presents a conceptual framework for vulnerability assessment of socio-ecological systems that addresses the mentioned open questions based on a review of both theoretical and empirical literature related to vulnerability and socio-ecological systems. The paper identifies the attributes and indicators of the dimensions of vulnerability for understanding both the social vulnerability and ecological vulnerability separately and then jointly, in interaction with each other. The framework offers a way to communicate with practitioners and policy makers on identifying and improving the factors that reduce vulnerability. It can thus serve as a tool for targeting the implementation of policies and practices aimed at reducing vulnerability.

1. Introduction

Since several decades ago it has been widely recognized the importance that ecosystems health has on human welfare. The socio-ecological systems approach studies the relationship between ecosystems and society through three channels (Collins et al., 2011; Bodin and Tengö, 2012). First, it analyses the incidence of ecosystems in the satisfaction of human needs through the services provided by the former. Second, it studies how the social dynamics of demand and catchment of ecosystem services modify and determine the ecological integrity of the ecosystems (Burkhard et al., 2012). In these two channels, the consolidation of ecosystem services conceptual framework supports the development of different research areas like identification, evaluation, mapping and economic valuation of ecosystem services (Costanza et al., 1997; Millennium Ecosystem Assessment 2005). These research areas have provided useful tools for the design of policy instruments for

conservation, preservation and management of ecosystems at a regional level.¹

The third channel addresses the way in which both social and ecological systems respond to endogenous and exogenous drivers of change (Beier et al., 2008; Burkhard et al., 2012; Collins et al., 2011; van Oudenhoven et al., 2012).² In this topic, during the last decade there have been advances in understanding the vulnerability and response of socio-ecological systems in the face of climate change and natural phenomena. The conceptual basis for the analysis of the vulnerability of these systems is the vulnerability-risk conceptual framework. The first risk assessments and vulnerability analysis of socio-ecological systems in relation to climate change use linear approaches and evaluate the effect of climate change on the ecological integrity and the impact of this transformation on social systems (Adger, 2006, 1999; Eakin and Luers, 2006; Janssen and Ostrom, 2006; Luers, 2005; Metzger et al., 2006, 2005; Turner et al., 2003a, 2003b). However, the

* Corresponding author.

E-mail addresses: imberrou@unal.edu.co (L.M. Berrouet), jmachad@unal.edu.co (J. Machado), civilleg@unal.edu.co (C. Villegas-Palacio).¹ In the conservation approach the environment and its resources should be used by humans and managed in a responsible manner while in the preservation approach lands and their natural resources should not be consumed by humans and should instead be maintained in their pristine form.² Throughout the paper we will refer indistinctly to ecological system and to ecosystems.

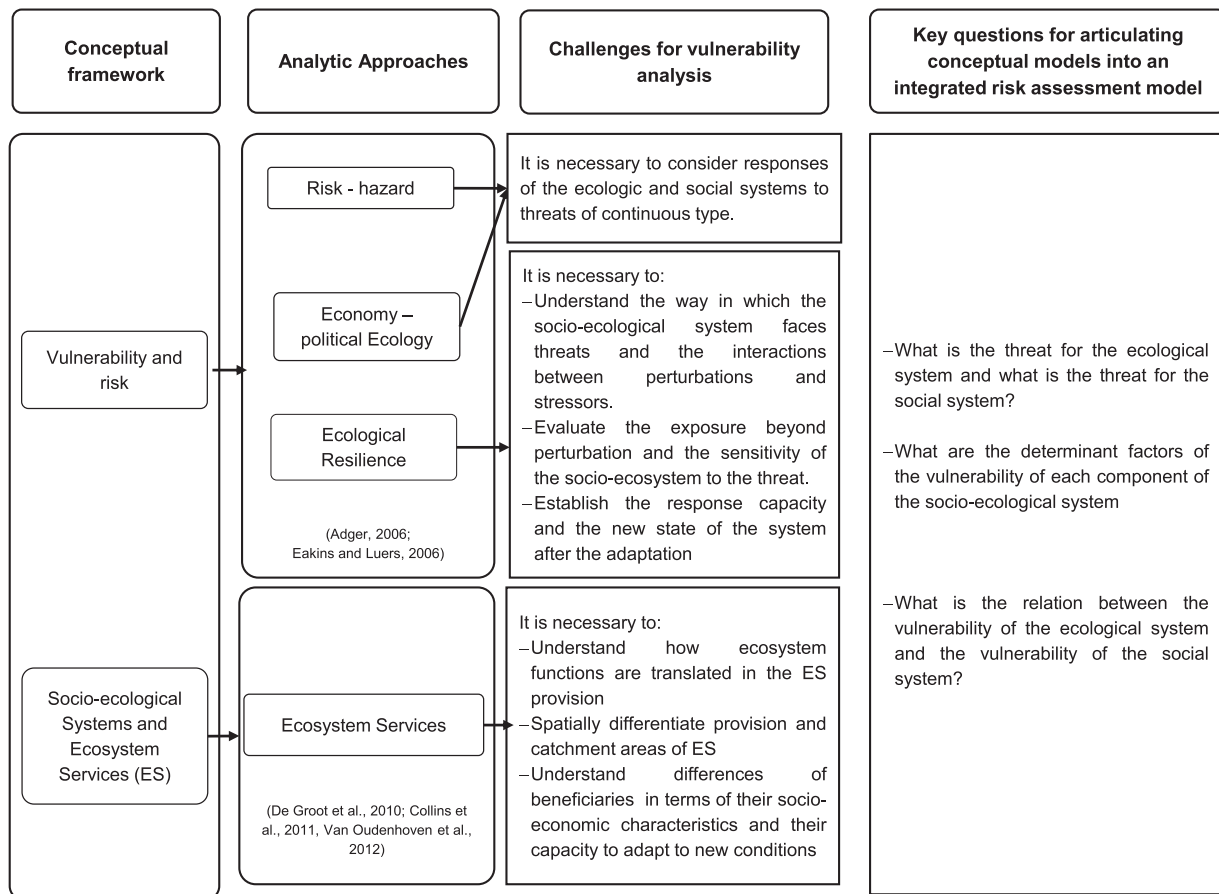


Fig. 1. Conceptual models, challenges and key questions for vulnerability analysis in the framework of an integrated risk assessment model.

analysis of how environmental changes derived from human activities at local scale, such as vegetation cover transformation, affect the ecosystem functioning and how the social system is affected by this has been poorly studied (Balvanera et al., 2012; Johnson et al., 2016; Kumar et al., 2016). According to previous literature, although the linear approach has been used in risk assessments its articulation to the ecosystem services conceptual framework is limited and brings up some challenges as explained below (Balvanera et al., 2012; de Groot et al., 2010; Serna-Chavez et al., 2014; van Oudenhoven et al., 2012).

The first challenge is related to the complexity associated with establishing a link between environmental changes that affect the ecological systems, their ability to provide ecosystem services and the effect that changes in the ecosystem services provision have on the welfare of the social system (de Groot et al., 2010; Dominati et al., 2010; Fisher et al., 2009; Robinson et al., 2013). This complexity is mainly due to differences in the spatial and temporal scales of the changes in both systems (Brown et al., 2016; Ciftcioglu, 2017; Kotzee and Reyers, 2016; Turner et al., 2003b). If the link between the environmental changes and the impacts on the social system is poorly understood there is a risk of both, misestimating the impact on the social system and poorly designing public policies for territorial planning and adaptation to such a changes. Not always a transformation in the ecological systems reduces their ability to maintain ecosystem functions and provide ecosystem services to society. There are studies suggesting that higher landscape connectivity does not always have a positive impact on ecosystem services and that sometimes appropriate landscape fragmentation can offer a method for preventing and

controlling forest pests and diseases (Zang et al., 2017). Sometimes, however, a small change in the ecological system may dramatically reduce the supply of ecosystem services (Quintas-Soriano et al., 2016; Sample et al., 2016; Zang et al., 2017).

The second challenge is that the linear approach ignores the multiplicity of types of ecosystem services beneficiaries' in terms of the differences in their socio-economic characteristics and needs (Dumenu and Obeng, 2016; Rasheed et al., 2016). When facing a change in the supply of ecosystem services not all beneficiaries are affected in the same way and considering such differences would allow for the design of better differentiated policies of adaptation to drivers of change. This would ultimately contribute to aspects of equity, environmental justice and social welfare maximization.

The third challenge is related to the conceptual definition of important aspects of vulnerability analysis and risk assessments. Some concepts are not homogeneously defined and sometimes inconsistent in previous literature. Concepts like vulnerability, sensitivity, threat, exposition and adaptation capacity are often mixed up leading to confusion, lack of consistency and the inability to make comparisons between different studies in different regions (Beroya-Eitner, 2016; Füssel, 2007; Hinkel, 2011; Paloviita et al., 2016).

In the traditional approach for the analysis of socio-ecological vulnerability, three main aspects have been studied: (i) how the ecosystems are transformed and respond to different types of threats (Lindner et al., 2010; Petrosillo et al., 2013; Shoyama and Yamagata, 2014), (ii) the impacts that such modifications have on the welfare of social groups and how some socio-economic characteristics in the social system

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