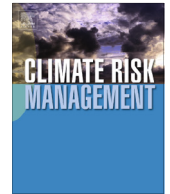




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## Expanding vulnerability assessment for public lands: The social complement to ecological approaches

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### ABSTRACT

In recent years, federal land management agencies in the United States have been tasked to consider climate change vulnerability and adaptation in their planning. Ecological vulnerability approaches have been the dominant framework, but these approaches have significant limitations for fully understanding vulnerability in complex social-ecological systems in and around multiple-use public lands. In this paper, we describe the context of United States federal public lands management with an emphasis on the Bureau of Land Management to highlight this unique decision-making context. We then assess the strengths and weaknesses of an ecological vulnerability approach for informing decision-making. Next, we review social vulnerability methods in the context of public lands to demonstrate what these approaches can contribute to our understanding of vulnerability, as well as their strengths and weaknesses. Finally, we suggest some key design principles for integrated social-ecological vulnerability assessments considering the context of public lands management, the limits of ecological vulnerability assessment, and existing approaches to social vulnerability assessment. We argue for the necessity of including social vulnerability in a more integrated social-ecological approach in order to better inform climate change adaptation.

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## 1. Introduction

Recent and continuing changes in climate have resulted in alterations to both human and natural systems across the globe, necessitating adaptive measures by decision makers acting at all levels of socio-ecological systems (i.e., systems in which humans are interconnected to and dependent on natural systems) (Bierbaum et al., 2013; IPCC, 2014). In the United States, significant impacts from climate change have already been felt, and warming is projected to continue for the foreseeable future (Walsh et al., 2014). As a result, changes to natural resources and the social systems that rely upon them will continue through decreased snowpack and more rapid snowmelt, more pronounced drought impacts and variability in precipitation regimes, increased incidence of wildfire, longer but more variable growing seasons, and a variety of other factors (Melillo et al., 2014; Walsh et al., 2014). In the United States, the federal government has introduced several Executive and Secretarial Orders directing federal agencies to prepare for and adapt to climate change (e.g., EO 13514, 2009; EO 13653, 2013; EO 13693, 2015; DOI Order 3226, 2001; DOI Order 3289, 2009), and several states have taken similar actions (e.g., Colorado's House Bill 13-1293; Washington's Senate Bill 5560) (Colorado General Assembly, 2013; Washington, 2009). However, work within individual agencies to meet these mandates has been uneven at best, with significant work remaining to be done in assessing vulnerability and developing actionable adaptation plans at scales relevant to the wide variety of administrative domains at play in the complicated U.S. governance system (Bierbaum et al., 2014, 2013). Here we define "vulnerability" as the susceptibility of an individual, household, or community to suffer from the impacts of climate change, which is a function of their exposure to climate stress, their sensitivity to being affected by it, and their adaptive capacity to respond to or prepare for climate change (IPCC, 2014).

For the U.S. Bureau of Land Management (BLM), whose management mandate includes huge tracts of publicly-owned land in the Western U.S. and Alaska – and even more widespread mineral resources – efforts to plan for and adapt to climate change present a variety of complex challenges. The BLM mediates multiple land uses, including extraction and conservation, which requires managers to take into account both the needs and environmental impacts of a broad array of human activities. In particular, communities heavily invested in livestock ranching and outdoor recreational tourism depend on public lands for economic, social, and cultural well-being. At the same time, their uses impact the biophysical environment and ecosystem services (e.g., production of food and water, maintenance of nutrient cycles and pollination to crops, and recreational or spiritual benefits) that public lands agencies manage. Similarly, agency management decisions, in turn, impact human livelihood viability, both in the immediate and long-term (Kachergis et al., 2014).

Given these feedbacks between land-based livelihoods, ecosystems, and management, and the resulting impacts to the vulnerability and adaptive capacity of each (Kachergis et al., 2014), it has been noted at a variety of levels that there is a need to better understand the climate vulnerabilities of those individuals and communities that depend upon resources managed on public lands (Archie et al., 2012; DOI, 2014; Joyce et al., 2009). However, ecological vulnerability assessment has been the primary approach for assessing vulnerability and planning adaptation actions on public lands, despite a broad and growing body of research examining the complex economic and cultural ties between public lands and the human communities that rely upon them (e.g., Bates, 1993; Bergstrom, 2012; Dombeck et al., 2004; Eichman et al., 2010; McNealey and Shulski, 2011; McNealey, 2012; Loomis, 2013; Sheridan, 2007; Yung et al., 2010; Knapp et al., 2015). There has also been relatively little consideration of the unique context of the U.S. public lands management system in climate vulnerability research. While there have been a small set of reviews of social vulnerability methods in the context of public lands (Preston et al., 2011; Hinkel, 2011; Fischer et al., 2013; Murphy et al., 2015), a comprehensive argument for the importance of an integrated social-ecological approach in contrast with purely ecological vulnerability approaches has not been made, nor have key principles for such an integrated approach been identified. We argue for the necessity of including social vulnerability in a more integrated social-ecological approach in order to better inform climate change adaptation for public lands and natural resource management.

In this paper, we describe the context of public lands management with an emphasis on the Bureau of Land Management to highlight this unique decision-making context. We then assess the strengths and weaknesses of an exclusively ecological vulnerability assessment approach for informing decision-making. Next, we review social vulnerability methods in the context of public lands to demonstrate what these approaches can contribute to our understanding of vulnerability. Finally, we identify three key principles for this more integrated social-ecological approach that includes: 1) participatory stakeholder engagement, 2) consideration of institution-actor relationships, and 3) the integration of scientific with local knowledge.

## 2. Public lands management context

Nationwide, the federal government manages over 640 million acres of publicly owned lands, just under a third of the nation's total land surface. Of this, 440 million acres are managed by two distinct but often spatially adjacent agencies: the United States Forest Service (USFS) and the Bureau of Land Management (BLM) (Vincent et al., 2014). In this paper,

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