



Research article

Assessing influences on social vulnerability to wildfire using surveys, spatial data and wildfire simulations

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ABSTRACT

A growing body of research focuses on identifying patterns among human populations most at risk from hazards such as wildfire and the factors that help explain performance of mitigations that can help reduce that risk. Emerging policy surrounding wildfire management emphasizes the need to better understand such social vulnerability—or human populations' potential exposure to and sensitivity from wildfire-related impacts, including their ability to reduce negative impacts from the hazard. Studies of social vulnerability to wildfire often pair secondary demographic data with a variety of vegetation and wildfire simulation models to map potential risk. However, many of the assumptions made by those researchers about the demographic, spatial or perceptual factors that influence social vulnerability to wildfire have not been fully evaluated or tested against objective measures of potential wildfire risk. The research presented here utilizes self-reported surveys, GIS data, and wildfire simulations to test the relationships between select perceptual, demographic, and property characteristics of property owners against empirically simulated metrics for potential wildfire related damages or exposure. We also evaluate how those characteristics relate to property owners' performance of mitigations or support for fire management. Our results suggest that parcel characteristics provide the most significant explanation of variability in wildfire exposure, sensitivity and overall wildfire risk, while the positive relationship between income or property values and components of social vulnerability stands in contrast to typical assumptions from existing literature. Respondents' views about agency or government management helped explain a significant amount of variance in wildfire sensitivity, while the importance of wildfire risk in selecting a residence was an important influence on mitigation action. We use these and other results from our effort to discuss updated considerations for determining social vulnerability to wildfire and articulate alternative means to collect such information.

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1. Introduction

A growing segment of wildfire research seeks to identify human populations most likely to experience future wildfire impacts and suggest actions they could take to best help reduce potential losses (Gaither et al., 2015; Haas et al., 2014; Wigtil et al., 2016). The logic behind those efforts recognizes that wildfire impacts to residential populations are likely to increase in the future, including injury to citizens, destruction of private structures, disruption of local economies, consumption of private timber, loss of public recreation opportunities, and difficulties associated with safe evacuation.

Likewise, concerns about public safety and protection of private property are commonly noted as important drivers for increasing fire suppression costs and political pressures that have made wildfire management such a difficult challenge (Schoennagel et al., 2017; Smith et al., 2016; WFEC, 2014).

Understanding the factors that influence which human populations are most at risk from wildfire impacts—what some call “vulnerability”—is one way to better prioritize mitigation efforts or firefighting resources in ways that reduce potential losses and suppression costs. It may also help a variety of stakeholders better understand how the legacy of past residential development, or the careful planning of ongoing land-use dynamics, may help society better live with fire (Collins, 2012; Mockrin et al., 2016; Paveglio et al., 2016). However, existing research indicates that there are few readily available and consistent indicators of human populations' wildfire vulnerability that can be used to compare across

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populations. Many existing efforts to understand hazard vulnerability adopt lessons and indicator assumptions from past hazard research to characterize aggregate populations at large scales (e.g., the county or census designations such as census blocks) (Cutter, 2015; Poudyal et al., 2012; Tedim, 2012). That approach may not be as useful for wildfire risk management, which can operate at a variety of scales and can be unique to each residential property owner. The research presented here responds to these challenges by evaluating a range of wildfire vulnerability indicators among residential populations surrounding a small city in Idaho.

Characterizing who is at risk from hazards is challenging because vulnerability emerges from the interaction of various social and biophysical processes. This includes the variable geographic scale at which hazards can cause potential impact to human populations (e.g., floodplain vs. individual property) and the ways that “social fragmentation”—or a high degree of variance in values, perspectives or mitigation actions among property owners—might influence the underlying factors creating continued risk (e.g., development patterns, resource use or management) (Collins, 2008; McNeely et al., 2017; Paveglio et al., 2017). At least three broad segments of existing wildfire research explore important aspects of vulnerability, including: (1) analysis of sociodemographic patterns that are likely to correspond with potential wildfire losses or impact (Arganaraz et al., 2017; Mann et al., 2014; Oliveira et al., 2017); (2) modeling or simulation of potential wildfire behavior based on variables such as vegetation type, climate and topography (Ager et al., 2017; Thompson et al., 2015); and (3) social science efforts that seek to understand or increase performance of mitigation actions that reduce wildfire risk to private properties (Dickinson et al., 2015; Olsen et al., 2017). Cutting across these literatures is a recognition that human actions, perspectives and values about wildfire are an important component of landscapes where fire plays a natural role, including continued efforts to manage wildfire in sustainable ways (Fischer et al., 2013; McCaffrey, 2015; Paveglio et al., 2015). Few research efforts combine elements of the above research literatures to evaluate the underlying assumptions that are often used to map vulnerability at large geographic scales. It also is important because existing efforts to characterize and compare the vulnerability of human populations need to be appropriately contextualized in order to make effective decisions about allocation of resources to reduce wildfire risk, dictate future land-use planning, or organize fire suppression.

The research presented here evaluates the relationships between commonly cited vulnerability indicators such as sociodemographic characteristics of residents, risk perceptions, support for wildfire management strategies, or performance of mitigation activities and empirically simulated values of wildfire likelihood or potential impact. We also explore the relationships between the above factors and a monetary, parcel-specific calculation of potential wildfire risk to residential properties. The intent of our effort is to determine whether common assumptions about vulnerability indicators match the “objective” reality that many scientists and managers are now using to plan for future wildfire management. We conduct this analysis using a case study of site-specific data surrounding a city in Idaho, including a self-reported survey of 1349 property owners, Geographic Information Systems (GIS) data about their properties, and simulations of wildfire risk parameterized to the study area. Our effort also serves as a partial replication of Paveglio et al.’s (2016) study of social vulnerability in Flathead County, Montana.

Improved understanding of the factors that expose human populations to wildfire risk and determining the relationship of those factors to any mitigation action can help inform a number of critical questions that influence ongoing wildfire management. For one, it can help policymakers and emergency managers better

understand how we should characterize patterns of wildfire vulnerability at aggregate scales for comparative use. The results also can help a variety of professionals better tailor their mitigation strategies or planning efforts to populations who are most likely to help develop, benefit from, or carry out any actions being implemented. Finally, results of this research can contribute to ongoing dialogues about potential social inequality of human populations exposed to hazards and what some argue is state or federal subsidization of private property development in high risk areas through fire suppression spending.

1.1. Background: characterizing social vulnerability to wildfire

The concept of vulnerability helps better understand potential impacts of disturbance or hazard on linked social and ecological systems. More specifically, researchers often operationalize vulnerability to identify populations who are most likely to experience hazards, determine the factors that contribute to hazardous conditions, or to develop potential adaptation strategies that reduce the possibility of future impacts (Ford et al., 2010; McNeely et al., 2017; Sword-Daniels et al., 2016). Most literature identifies three primary components of vulnerability that interact to produce patterns of potential impact: (1) exposure, defined as the probabilistic likelihood that a given hazard/disturbance impacts populations or resources they rely upon; (2) sensitivity, defined as the magnitude of potential impact that could occur to a range of values, ecological processes or assets valued by a target population; and (3) adaptive capacity, or the ability of populations to adapt in ways that reduce their exposure or sensitivity and thus alleviate future impacts (Fischer et al., 2013; Norris et al., 2008; Smit and Wandel, 2006).

Climate change and hazard researchers frequently use the concept of *social vulnerability* to better understand how the characteristics of human populations influence hazard exposure, sensitivity or adaptive capacity (Cutter et al., 2003; Murphy et al., 2015; Paveglio et al., 2016). Thus, social vulnerability is one recognition of the ways that humans modify their environment to influence hazard dynamics (e.g., build-up of fuels leading to more intense wildfires) or create conditions that expose them to additional hazard (e.g., building chemical plants that could spill waste into a watershed) (Buxton et al., 2011; Whittaker et al., 2012). A focus on social vulnerability often means characterizing the intersection of sociodemographic settlement patterns (e.g., income, parcel location or density, recovery resources, risk perceptions) and sociological processes (planning, development, participation in mitigation programs) to help better explain potential impacts of hazards and determine the ways that human populations can adapt their functioning in ways that avoid severe impairment to collective functioning (Preston et al., 2009; Prior and Eriksen, 2013; Wigtil et al., 2016).

Social vulnerability is a useful concept because it treats risk as both a probabilistic occurrence resulting from landscape dynamics and something that is created by human populations through their collective actions, values, and perspectives about what they stand to lose (Eriksen and Simon, 2017; Smith et al., 2016; Sword-Daniels et al., 2016). Its assessment frequently includes the comparison of various populations’ potential for loss from range of hazards or stressors using a common scoring system. Comparisons often occur across population units spanning large regions (e.g., U.S. South, United States, Western Canada) or at a national scale to provide insight about the effective allocation of mitigation, education or recovery resources that help reduce future disturbance (Martín et al., 2017; Murphy et al., 2015; Poudyal et al., 2012). As such, many social vulnerability studies use an indicator approach that aggregates secondary sociodemographic data (e.g., Statistics

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