

Social Vulnerability and Wildfire in the Wildland- Urban Interface

Literature synthesis

MICHAEL R. COUGHLAN, AUTUMN ELLISON, AND ALEXANDER CAVANAUGH

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About the authors

Michael R. Coughlan is a Faculty Research Associate at the Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon.

Autumn Ellison is a Senior Faculty Research Assistant at the Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon.

Alexander Cavanaugh was a graduate student research assistant at the Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon during his work on this synthesis. He is currently a doctoral candidate in the University of Oregon English Department.

About the Northwest Fire Science Consortium:

The Northwest Fire Science Consortium works to accelerate the awareness, understanding, and adoption of wildland fire science in Washington and Oregon (excluding the SE corner). It connects managers, practitioners, scientists, and local communities and collaboratives working on fire issues on forest and range lands. The Northwest Fire Science Consortium is one of the 15 regional exchanges established by the Joint Fire Science Program's Fire Science Exchange Network to bring fire science users together to address regional fire management needs and challenges. Each regional exchange provides current and regionally-relevant wildland fire science information to users in the region. For more information: <http://www.nwfirescience.org/>.

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For more information about the Northwest Fire Science Consortium:

Janean Creighton
Oregon State University
321 Richardson Hall
Corvallis, OR 97331
541-737-1049; nw.fireconsortium@oregonstate.edu
www.nwfirescience.org/

For additional information about this report:

Ecosystem Workforce Program
Institute for a Sustainable Environment
5247 University of Oregon
Eugene OR 97503-5247
ewp@uoregon.edu
<http://ewp.uoregon.edu>



UNIVERSITY OF OREGON



Introduction

People living in the Pacific Northwest confront risks associated with environmental hazards such as wildfire. Vulnerability to wildfire hazard is commonly recognized as being spatially distributed according to geographic conditions that collectively determine the probability of exposure. For example, exposure to wildfire hazard is higher for people living in rural, forested settings than in a strictly urban neighborhood because rural housing is built in close proximity to the threat source, e.g., flammable landscapes such as forests and chaparral. Yet, even if levels of exposure are held constant, not all people are equally susceptible to wildfire events. In other words, some people are more vulnerable to harm than others. This aspect of vulnerability (i.e., social vulnerability) refers to social, economic, and cultural attributes that confer or limit access to material and informational resources, compounding simple exposure to hazards. The concept of social vulnerability refers to the socially constructed potential or susceptibility of people (as individuals, households, or communities) to be negatively affected by hazard events, such as wildfires (Cutter et al. 2000; Cutter,

Boruff, and Shirley 2003). Thus, social vulnerability is a measure of the socioeconomic factors that combine to make a wildfire more of a disaster for some than others.

Social vulnerability research contends that the potential effects of hazards such as wildfire, weather events, or climate change, are magnified by social conditions that place certain populations at a disadvantage relative to others in their ability to manage risks, respond to hazards, and minimize losses (Cutter 1996; Morrow 1999). This research shows how environmental hazards disproportionately affect socially vulnerable households and communities. For example, under conditions of social vulnerability, limited access to resources increases susceptibility to catastrophic loss by decreasing opportunities to prepare for, mitigate, adapt to, and recover from disaster events. Vulnerability is a compounding process because vulnerable people have limited access to the resources necessary for recovery following a hazard event, in turn, elevating their vulnerability to the next event (Oliver-Smith et al. 2016).

As more people move into the wildland urban interface (WUI) and as fires increase in frequency and severity, researchers agree on the importance of understanding the dynamics of social vulnerability. However, specifically recognizing and addressing vulnerability in the WUI is an emerging discussion among researchers and practitioners. The challenges for understanding social vulnerability lie in the significant complexity and diversity of factors that contribute to vulnerability in the WUI. For example, factors such as income, cultural and psychological relationships to fire and land management, social capital, and level of trust in government can all contribute to wildfire vulnerability.

To complicate the matter, different disciplines present multiple different ways to conceptualize and study these diverse social factors. Consequently, there is a general lack of consensus about how to approach or standardize social vulnerability research. Social vulnerability has been investigated as (1) a material reality related to the differential distribution of social and economic resources across different demographics, and (2) a characteristic or property of a “community” or a socioecological system tied to public perceptions

and attitudes about wildfire, land management, and why people live where they do. Across these approaches, there is little consensus about how to comprehensively measure vulnerability or apply vulnerability frameworks across different scales and geographies. This working paper provides an overview of the conceptual terms, methodologies, and findings of research on social vulnerability and wildfire hazard.

The overall objective of this paper is to clarify areas of debate, clearly define and contrast disparate approaches, and synthesize findings that may help address vulnerability to wildfires and other natural hazards. While land managers and fire personnel might find it pertinent to approach biophysical and social issues separately, addressing both aspects of wildfire hazard can be productive for minimizing risk and empowering communities, neighborhoods, and households to prepare and recover from wildfire events. We aim to provide a practical grasp of social vulnerability research as it relates to wildfire hazards in order to advance its application by people involved in wildland fire management in their efforts to address the social diversity and complexity they face in their wildfire prevention, mitigation, and suppression activities.





Approach

To investigate the social vulnerability literature, we searched for peer-reviewed journal articles and published reports using keyword searches on Google Scholar. We reviewed references cited within this first set of papers in order to identify other relevant resources that were not captured in the initial Google Scholar searches. We limited the focus of the search to research published in the last decade (ca. 2009-2019), but also included earlier contributions that provided clear and significant foundations for current social vulnerability research (e.g., Morrow 1999; Cutter 1996; Cutter, Boruff, and Shirley 2003; Cutter et al. 2008; Collins, 2005 and 2008). This report aims to bring social vulnerability and community resilience research into productive conversation with the issue of wildfire risk management. We specifically searched for work within these bodies of literature that directly discusses wildfire or that provides relevant findings that can be applied to WUI communities or scenarios that include wildfire.

Most of the research approaches wildfire vulnerability through various combinations of the following methods or frameworks: (1) spatial distribution of vulnerability and risk, (2) social constructions of risk and responsibility, and (3) social capital and economy. These varied approaches emphasize different aspects of vulnerability, such as natural re-

source-based economy dynamics (Flint and Luloff 2005), WUI resident demographics (Collins 2005; Palaiologou et al. 2019), and historical influences (Simon and Dooling 2013). These frameworks and foci demonstrate that exposure to wildfire hazard is a biophysical condition of living in the WUI, whereas social vulnerability is a result of social, historical, and political factors that magnify the stakes of biophysical risk.

The research that we consult in this working paper investigates vulnerability and resilience at a variety of spatial and administrative scales, from regions (Cutter and Finch 2008) to counties (Cutter, Boruff, and Shirley 2003) to parcels (Paveglio et al. 2016). The data collected at these various scales lead to findings about household- to neighborhood-level vulnerability and community- to regional-level resilience in the face of wildfire. Scale, unit of analysis, and theoretical construct go hand in hand, and it is important to consider study findings within the confines of each methodological approach. Thus, in the following sections, we cover the conceptual background and development of the different approaches, followed by the key concepts present in each. We then describe the different methodological approaches and the literature included in each approach, along with the key assumptions and limitations of each approach. Finally, we present the generalizable findings from across different approaches to social vulnerability to wildfire.

Literature background

Conceptual development and history

Social vulnerability research is an expanding field in environmental studies, with researchers considering vulnerability in the context of differently-scaled environmental hazards such as climate change, weather events, floods, fires, tsunamis, and drought. This paper presents a selection of this research from three areas: (1) major contributions to social vulnerability research, (2) research that concerns community resilience to wildfires, and (3) emerging research focused on parcel-level and landowner resilience and vulnerability to wildfire. This focus brings together rich insights into social vulnerability to biophysical hazards with emerging work on the human dimensions of wildfire, specifically related to community and landowner resilience to wildfire. Many of these latter contributions raise concerns related to diverse social values, risk perception, and trust levels among WUI residents.

The concept of social vulnerability originated in the 1970s within scholarship focused on risk, hazards, and disasters. By the 1990s, the “hazards-of-place” and “community vulnerability” approaches to social vulnerability had emerged (Cutter 1996; Morrow 1999). These two similar approaches are distinguished mainly by the scale: (1) the hazards-of-place approach predominantly considers household socioeconomic diversity aggregated at the county to census block-levels which are then compared to each other within a given region or at the national level (e.g. Cutter, Boruff, and Shirley 2003; Palaiologou et al. 2019), and (2) the community vulnerability approach examines household socioeconomic diversity within a community of place (such as a city or a census block), sometimes comparing and mapping it by neighborhoods (Morrow 1999; Collins 2005).

In the context of wildfire hazards, both of these approaches focus on the WUI, a geographic zone

where residential development overlaps with wildland vegetation, resulting in complex juxtapositions of the built environment, biophysical conditions, residents’ values and preferences concerning land, and the management practices and policies of neighboring properties (e.g. federal, state, and local governments) (Collins 2005). Hazards-of-place and community vulnerability literature link social vulnerability to quantifiable disparities between privileged and underprivileged groups coexisting in WUI areas (and regions with WUI), resulting in the allocation of resources to the economically wealthy, often through privatized resources like insurance and hired fuel management services. These disparities can create “pockets” of underserved, socially vulnerable residents (Gaither et al. 2011). Scholars contend that identifying, understanding, and empowering those populations that are left vulnerable to wildfire and other biophysical hazards should be a high priority.

Within the context of the human dimensions of wildfire literature, the WUI concept is often used interchangeably with concepts such as “communities at risk from wildfire” or “fire-prone communities”, thus expanding the utility of the term WUI beyond suburban and exurban neighborhoods at the interface between wildlands and urban areas to non-metropolitan, fire-prone populated places more generally (Flint and Luloff 2005; Bihari and Ryan 2012; Abrams et al. 2015). These studies typically view vulnerability as a community-level property tied to its overall adaptive capacity and resilience toward wildfire hazard (Abrams et al., 2015). Because of their focus on vulnerability as it relates to the concept of “resilience,” we refer to these studies as the “community resilience” approach. The community resilience approach to vulnerability emerges from the communities-of-place tradition in natural resources sociology and has been critical of vulnerability frameworks and composite indices employed within the environmental hazards literature. Nonetheless, more recent work has been an attempt to synthesize, or at least reconcile, the hazards-of-place framework with community resilience approaches, in part by refining methodological approaches and identifying appropriate scales of inquiry.



Key concepts

Researchers interested in wildfire vulnerability have employed a number of different terms and concepts. Here, we explicitly define wildfire risk, hazard potential, social vulnerability, adaptive capacity (and related concepts), and community resilience in order to more clearly convey how disparate approaches and findings can be compared and synthesized. Because of the diversity of approaches, our definitions may not be equivalent to how others use the terms. For example, Fischer and Frazier (2018) use the term “sensitivity” to capture the main aspects of social vulnerability. However, while authors employ terms in slightly different ways, most agree that vulnerability and resilience (or conceptually equivalent terms) are interdependent concepts. For example, according to Smith et al. (2016) and others, vulnerability and resilience operate in a dynamic continuum where resilience is increased, in part, by lowering social vulnerability. Indeed, despite the specific terminology used, scholars appear to agree that vulnerability and resilience are caught up in the same social and ecological process, and efforts on both ends of that process should be attentive to the circumstances driving vulnerability and to the community assets

and values that build resilience (Maru et al. 2014). Nevertheless, it is useful to separate these terms and explore their definitions in the literature before examining how they come to bear on research methodologies and major findings.

1. Risk (exposure risk): Here, we define risk as the indiscriminate exposure to a hazard based on the probability that a hazardous event could occur in a given location (Cutter, Boruff, and Shirley 2003). Risk is not synonymous with vulnerability, yet it is a fundamental circumstance out of which vulnerability emerges. Risk is often measured as the probability of exposure to an environmental hazard, based on reoccurrence of historically observed events (Cutter, Boruff, and Shirley 2003).

2. Hazard potential: While wildfire risk is the probability of exposure to a wildfire event, the likelihood of an event’s outcome (e.g., its hazard potential) is scalable based on fuels management (Cutter, Boruff, and Shirley 2003). It is important to disentangle exposure risk from hazard potential because although fuels management actions can lower the hazard potential (e.g. the likelihood of catastrophic losses to wildfire such as loss of life and property) (Smith et al. 2016), these actions do not necessarily change ignition probability.

3. Social vulnerability: In contrast to exposure, the concept of social vulnerability is connected with the degree of sensitivity to a hazard (Fischer and Frazier 2018). It is commonly defined as the effect of social inequalities on sensitivity to hazards, making some groups more susceptible to harm than others while limiting their ability to adapt to changing risks (Cutter, Boruff, and Shirley 2003). Social vulnerability is also related to place-based inequalities resulting from community dynamics, urban development, rapid growth, and economic strength or weakness (Cutter, Boruff, and Shirley 2003). Taken together, these inequalities place disenfranchised households and communities at greater risk of catastrophic loss than other households and communities that have the resources to mitigate hazards and recover from losses. Social vulnerability in this “hazards-of-place” research approach is generally assessed through examining demographics indicative of social status and access to resources, such as ethnicity, gender, and income (Morrow 1999; Cutter, Boruff, and Shirley 2003).

Social vulnerability concerns the ability and, in some cases, willingness to mitigate hazard potential and recover from losses. For example, access to resources to properly manage fuels and mitigate hazard potential depends on factors such as household capacity to hire or perform vegetative fuel reduction on their properties (Collins and Bolin 2009). It may also be associated with aesthetic preferences concerning land cover and use, and the tradeoffs that residents are willing to tolerate between residential lifestyle choices and risk exposure. Lastly, social vulnerability is tied to the ability of the community as a whole to channel public investment and new knowledge into the region (Bihari and Ryan 2012; Poudyal et al. 2012). In this sense, social vulnerability is linked to the next set of concepts employed in the community resilience approach.

4. Social capital: This term describes the functional aspects of social networks, i.e., the social ties that bind individuals to one another. Social capital allows individuals or groups of people to leverage their social relationships and social norms in order to increase and secure their wellbeing (Bihari

and Ryan 2012). Social capital relies on trust, reciprocity, exchange, and the social norms that govern these (Adger 2003). Whereas financial capital is traded in markets, social capital is exchanged within social networks. Strong social capital requires well-positioned (high status) membership in socially cohesive networks.

5. Community cohesion: Community cohesion refers the sociocultural “glue” that reinforces an individual’s loyalty to other members of their group (Prior and Eriksen 2013; Paveglio et al. 2017). Community cohesion relies on perceptions and attitudes related to culture and identity that encourage participation in community social networks. It is related to factors such as community identity, sense of community, place attachment, volunteerism, length of residency, and membership in civic organizations (Paveglio et al. 2017).

6. Adaptive capacity: In hazards literature, this term refers to the ability of a household or community to cohesively respond to hazards by mediating risks, learning from past experiences, and recovering from losses. Adaptive capacity involves the motivation and organizational ability to direct material and social resources toward reducing the long term, potential impacts of wildfire (Paveglio et al. 2012). High levels of adaptive capacity require high levels of social capital and cohesion. While increasing a community’s adaptive capacity does not necessarily decrease risk of exposure to environmental hazards (Fischer et al. 2013), it indicates a community’s ability to cope with and recover from these events by reducing the catastrophic impacts of some events.

When used in the social vulnerability literature, lack of adaptive capacity is tied to unequal access to material and informational resources needed to prepare, mitigate, and recover from environmental hazards (Collins 2008). In this sense, the concept is linked reciprocally to social vulnerability, with increases in adaptive capacity causing decreases in vulnerability and vice-versa (Maru et al. 2014). Literature taking the community resilience approach in wildfire-prone areas additionally associate adaptive capacity with sociocultural attitudes toward fuels management and firesafe practices

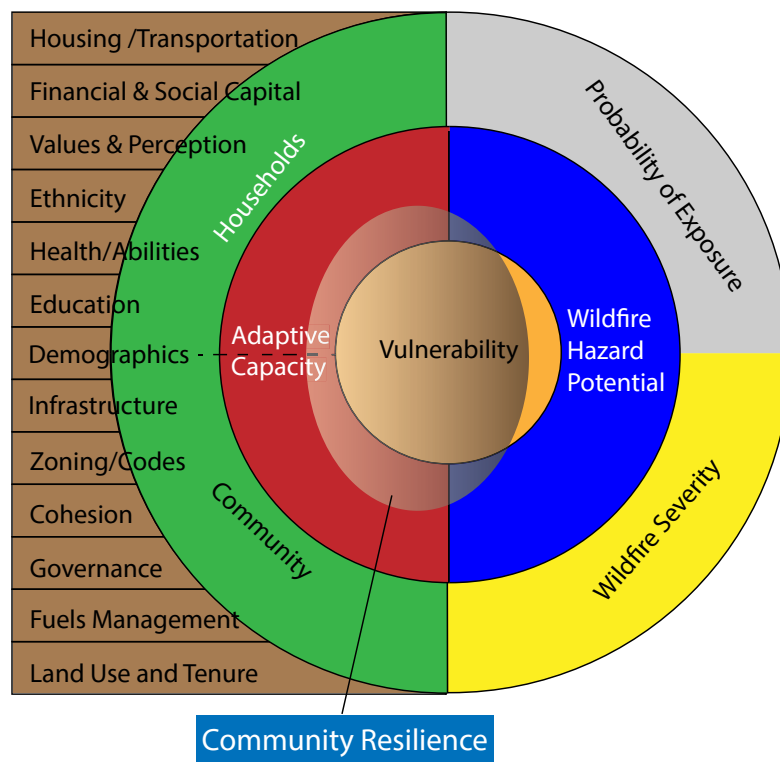
(Collins 2005), as well as residents’ reasons for living where they do (Carroll and Paveglio 2016). This body of research identifies potentials for communities and organizations to increase resilience to wildfires by examining attitudes toward wildfire and landscapes (Prior and Eriksen 2013; Abrams et al. 2015). Here the focus is less on addressing inequity and more on addressing difficulties associated with governance, communication, and institutional collaboration.

7. Resilience: Community resilience relates conceptually to adaptive capacity in that it reflects residents or property owners’ collective ability to recover from hazard events. In other words, adaptive capacity contributes to a community’s overall resilience, but considerations of resilience also seek to understand how conditions of social vulnerability affect adaptive capacity and how and if communities leverage their adaptive capacity to offset social vulnerability. Early research sees “social” resilience as the opposite of vulnerability (Cutter, Boruff, and Shirley 2003), yet recognizes

resilience as a dynamic process combining pre-existing conditions, the severity of hazards, and factors that limit access to resources (Cutter et al. 2008).

To synthesize and visually represent the community resilience concept with the social vulnerability approach, we adapted the conceptual framework put forward by Davies et al. (2018) (see Figure 1, below). In our diagram, community resilience occupies a space overlapping adaptive capacity, vulnerability, and wildfire hazard potential. Rather than a measurable condition, we present the idea of resilience as an outcome that emerges from the adaptive pathways collectively taken by community members following a wildfire event. Whereas building adaptive capacity and reducing vulnerability are potentially measurable objectives, achieving resiliency is a goal. Thus, in order to achieve wildfire resilient-communities, it is necessary to build sufficient adaptive capacity and mitigate and reduce the social causes of wildfire vulnerability.

Figure 1 Conceptual diagram showing relationship of key concepts in social vulnerability research
Adapted from Davies et al. (2018)





Methods in social vulnerability research

The main research methods for examining and responding to vulnerability and resilience include measuring or assessing social vulnerability, mapping patterns of vulnerability, and exploring different approaches and responses to environmental hazards through community case studies.

Measuring and mapping vulnerability to environmental hazards

General approach

At its most basic inception, studies of social vulnerability seek to understand how hazards differentially affect populations. Early studies in risk, hazards, and disasters were tied to theory in human geography and global development studies and focused more specifically on place-based populations that exhibited social and economic inequalities (Cutter 1996; Morrow 1999; Eakin and Luers 2006). In this research, “place” or “lo-

cality” furnishes the unit of analysis because the focus is on a spatially explicit area of disaster outcome (Cutter 1996). However, different studies have operationalized “locality” at different scales, comparing vulnerability (1) within communities/places – e.g. households or neighborhoods (Morrow 1999) and (2) across communities/places (e.g. comparing across census blocks or tracts) (Cutter, Boruff, and Shirley 2003).

The hazards-of-place framework identifies and measures vulnerability through composite indices (i.e. social vulnerability indices or SVI) of household-level data tied to spatially explicit (i.e. geographically mapped) sample areas or “places” (Cutter 1996; Cutter, Boruff, and Shirley 2003). An important basic assumption underpinning the hazards-of-place framework concerns the idea that “most people experience and respond to [hazards] as members of households,” (Morrow 1999: 2). Thus, the research methods involve aggregating household-level data into a SVI that assign specific vulnerability values for each “place.” These

social vulnerability indices range in complexity, with one of the main models tracking wealth, age, density of the built environment, single-sector economic dependence, housing stock and tenancy, race, ethnicity, occupation, and infrastructure dependence. For studies in the US, research generally relies on aggregated household-level data from the US Census and American Communities Survey.

Mapping the location of socially vulnerable populations identified through a SVI is a central feature of the hazards-of-place approach (Eakin and Luers 2006). Its importance derives from the idea that maps allow management agencies to target potentially vulnerable populations for resource allocation (Morrow 1999). For example, the disaster resilience of place (DROP) model is a place-based approach to socio-ecological vulnerability that assesses equity and human rights issues related to vulnerability in tandem with environmental hazard zones (Cutter et al. 2008).

Until the last couple of decades, wildfire vulnerability research was largely limited to a biophysical exposure focus that ignored advances in the social science of environmental hazards (McCaffrey 2004). The initial social science approaches to wildfire vulnerability introduced factors such as residential risk perceptions, previous experiences with wildfire, access to information about wildfire hazards and mitigation options, and feasibility of implementing mitigation techniques (including fit with existing land use and cultural landscape preferences) (McCaffrey 2002). Collins' (2005) case study of wildfire hazard in a WUI setting was one of the first to synthesize these approaches with hazards-of-place concepts. His study supplemented census data with a household survey technique to compare home ignitability with household level risk perceptions, institutional incentives to mitigate wildfire hazards, and political-economic constraints indicative of social vulnerability. Other studies of wildfire vulnerability have combined the hazards-of-place framework with models of wildfire potential (Gaither et al. 2011; Wigtil et al. 2016) as well as simulations of wildfire transmission and structure exposure (Palaiologou et al. 2019).

Limitations

It is important to note that researchers using the hazards-of-place approach produce representative models of vulnerability based on aggregated (mean) characteristics of a community or region. One drawback of these methods has been that their scope and scale, based on the data required, are limited to census tract- to block-level representations of vulnerability. Thus, depending on the scale of the input dataset, within place, "local" variability is effectively invisible (e.g. house-to-house, neighborhood-to-neighborhood, town-to-town differences) (Flint and Luloff 2005). The approach has other limitations as well, including problems related to scalar mismatch between data sets, problems that arise from spatial aggregation, and problems interpreting results due to complexity and uncertainty within these analyses (Tate 2013). Particularly pernicious for this latter problem is the ecological inference fallacy, whereby individual attributes are deduced from inferences about the group to which they belong. For a detailed explanation of this problem, see the bibliographic annotation for Wigtil et al. (2016).

Summary

Hazards-of-place methodologies are useful for the broad-scale "identification of areas that are poorly equipped to respond to wildfires" (Davies et al. 2018). This information can be extremely important for national- to state-level policy and allocation of resources. However, most social vulnerability metrics are not universally applicable to local wildfire mitigation and recovery planning at smaller scales, such as in WUI communities and neighborhoods (Paveglio et al. 2016). Indeed, the methodological limitations outlined above are common to most hazards-of-place approaches to wildfire. Appropriate hazard mitigation management interventions based solely on such metrics may suffer without additional consideration of the local, community-level distribution of social vulnerability and biophysical exposure to wildfire. In short, managers and policy makers need to carefully examine methodological choices, before applying research to local-level wildfire mitigation strategies.

Vulnerability and resilience through community case studies

General approach

Key informant interview- and survey based-community case studies represent an increasingly common research approach to understanding wildfire vulnerability and resilience. Community case study approaches to wildfire vulnerability emerged from two more or less distinct theoretical foci: natural resources/rural sociology and political ecology.

Community case studies are a long-standing research approach in the natural resources and rural sociology traditions (Hillery 1955; Kaufman 1959; Wilkinson 1991). Although the term “community of place” is employed within this body of literature, it should not be confused with the use of the term “community” within the hazards-of-place social vulnerability approach. The terms “community” and “place” within the hazards-of-place approach signify geographically bounded territories representing areas potentially effected by hazards and containing the households that comprise a sampled population. On the contrary, because of its origin in sociology, the concept of a “community of place” used in the community case study approach is much more focused on intangible and nested aspects of local social networks, interactions, and shared institutions than it is on a specific populations or territorial boundaries (Carroll 1995). Paveglio, Boyd, and Carroll (2017) describe this distinction as studies in community versus studies of community, with hazards-of-place approaches fitting the former and community resilience the latter. Although the application of “community” as a unit of inquiry has been inconsistent and weakly theorized (Machlis and Force 1988), this lack of rigid definition also gives it some degree of plasticity (Paveglio, Boyd, and Carroll 2017).

Following this theoretical interest, community case studies typically use key informant interviews and survey methods to produce fine-grained

narratives of how specific populations collectively build adaptive capacity and respond to hazards. Case studies have been particularly useful for drawing specific insights about the extra-household social interactions responsible for much of the activities that mitigate and prepare a community for wildfire. Flint and Luloff (2006) suggest that hazards are experienced collectively as part of social processes. They argue that hazard-relevant social processes occur at the community-level, thus, “community-based study is needed to expose both vulnerabilities and community capacities for inhibiting or supporting local recovery efforts” (2005: 402). Focal interests of these studies include local-level institutions or sets of institutions, both formal and informal, such as community and neighborhood associations, non-profit organizations, and government agencies. These structured spaces of social interaction form the main unit of analysis in studies of community adaptive capacity and resilience. This focus stands in contrast to the hazards-of-place and political ecology approaches, which tend to assume that the hazard-relevant unit of social organization is the household (e.g. Collins 2005; 2008).

The political ecology approach to wildfire vulnerability differs not only in that its focal interests center on how vulnerability is produced and differentially distributed across households and neighborhoods (Collins 2008), but also how it is “embodied, experience, and lived,” by individuals (Erikson and Simon 2017). For political ecologists, case studies provide a means of understanding local knowledge (Collins 2008), as well as the often complex historical and political developments that effect how vulnerability is actually experienced by people (Simon and Dooling 2013; Eriksen and Simon 2017).

Limitations

The community case study approach has several limitations. Firstly, although case studies can provide in-depth, contextual information on social vulnerability, their focus on local contexts can hinder their generalizability at larger scales. Case studies of communities are time consuming and resource intensive in comparison to the hazards-

of-place approach which leverages secondary GIS and census data for its analyses. Consequently, to provide generalizability, it becomes necessary to sample a number of “representative” communities, for example across a region. This problem has led to the community archetype approach which attempts to classify communities with similar socioeconomic characteristics (Carroll and Paveglio 2015). Secondly, because of constraints in time and funding, rapid assessment methods are often used which run the risk of collecting biased information. For example, in cases where interviews are limited to key informants, such as community leaders and land managers, the perspectives of socially vulnerable people may be missed entirely. Thirdly, from the standpoint of geographically locating and mapping areas of intersection between wildfire exposure and socially vulnerable popula-

tions, case study results are not as useful because they are not often spatialized.

Summary

Although focal interests of political ecologists differ from those of natural resource sociologists, case study methods and objectives are essentially the same. In short, case studies are used to represent the complexity of local social interactions and experiences in ways that illuminate how vulnerability indices and concepts can be re-tooled to fit the complexity of wildfire hazard (Collins 2008; Collins and Bolin 2009; Paveglio et al. 2016; Carroll and Paveglio 2019). The high resolution of this approach allows for more comprehensive representations of vulnerability and resilience as conceptually linked, place-based processes (Maru et al. 2015).



Parcel-level and landowner approaches

General approach

Some emerging approaches are synthesizing different aspects of wildfire vulnerability studies and producing new types of data relevant to social vulnerability analyses. For example, Nielsen-Pincus et al. (2015) combined parcel-level property characteristics with a survey of landowner decision-making and management. This study used a market segmentation methodology to identify different groups of landowners with shared values relating to wildfire risk reduction (e.g. foresters, farmers, multipurpose small holders). They then used GIS-based parcel characteristics to build a probabilistic map of the spatial distribution of landowner type. In their discussion, they relate components of their landowner typology to aspects of social vulnerability and discuss how spatial heterogeneity of landowner types could indicate the potential for community level vulnerability due to difficul-

ties implementing strategies across groups. Another approach combines spatial and social network analyses to map aspects of social vulnerability created through scalar mismatch in wildfire mitigation planning (Ager, Kline, and Fischer 2015). This approach models and maps relationships between wildfire probability and the probability that landowners will reduce fuels on their property, a parameter based on “social capacity” to implement mitigation strategies (Fischer et al. 2014).

Paveglio et al. (2016) and Paveglio, Edgeley, and Stasiewicz (2018) synthesized lessons learned from studies on residential- and community-level wildfire mitigation strategies, collectively termed “adaptive capacity,” with concepts from the social vulnerability literature. These analyses tested factors attributed to wildfire exposure, sensitivity, and adaptive capacity at the household and parcel levels using a self-administered survey, wildfire simulations, and GIS-based parcel characteristics of neighborhoods within the WUI.



Findings

Although there are different ways to define, approach, measure, and examine the variety of factors that contribute to and determine social vulnerability to wildfire, these disparate approaches have nevertheless contributed to a set of related findings. Below, we organize and discuss the various contributions to four specific findings surrounding social vulnerability and community resilience to wildfire:

1. Social vulnerability increases the risk of catastrophic loss from wildfire.
2. Risk, fuels management responsibilities, and public trust are contingent upon social contexts.
3. Solutions for mitigating social vulnerability and building community resilience may require multi-method, engaged, place-based approaches.
4. Social vulnerability is difficult, but important to assess.

Social vulnerability increases the risk of catastrophic loss from wildfire. Some emerging approaches are synthesizing different aspects of wildfire vulnerability studies and producing new types of data relevant to social vulnerability analyses. For example, Nielsen-Pincus et al. (2015) combined parcel-level property characteristics with a survey of landowner decision-making and management. This study used a market segmentation methodology to identify different groups of landowners with shared values relating to wildfire risk reduction (e.g. foresters, farmers, multi-purpose small holders). They then used GIS-based parcel characteristics to build a probabilistic map of the spatial distribution of landowner type. In their discussion, they relate components of their landowner typology to aspects of social vulnerability and discuss how spatial heterogeneity of landowner types could indicate the potential for community level vulnerability due to difficulties

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Risk, fuels management responsibilities, and public trust are contingent upon social contexts. Social contexts play a significant role in community adaptive capacity and resilience, particularly for collaborative investment in fuels management and preventative activities (Paveglio et al. 2012; Bihari and Ryan 2012; Prior and Eriksen 2013). For example, adaptive capacity may be compromised in fire-prone areas that see a relatively rapid influx of amenity migrants (i.e., new residents moving to forested areas for aesthetic rather than economic reasons) following the closure of local natural resource industries (Collins and Bolin 2009). Difference in attitudes toward landscapes between newer and older residents can complicate efforts to reduce community-level vulnerability, e.g., amenity migrants may value densely forested landscapes for aesthetic reasons and may discount the fact that dense forest increases fire risk for themselves and their neighborhood (Collins and Bolin 2009). Amenity migrants and wealthier residents in general may choose to rely on insurance and firefighting services instead of contributing to proactive, collective action measures to reduce fuel accumulation. This leaves lower-income residents more vulnerable because, lacking social and economic capital, they are less likely to be able to effectively organize and implement collective mitigation strategies. Further, these residents are unlikely to be able to individually afford the expense of clearing vegetative fuels, fire-proofing their homes, or rebuilding after a fire (Davies et al. 2018; Poudyal et al. 2012).

To overcome these barriers to community wildfire resilience, some researchers emphasize the importance of community building across social boundaries presented by class, length of residency, or culture to foster collective action (Bihari and Ryan 2012; Prior and Eriksen 2013). Others resist stereotyping amenity migrants as poor property managers, placing the blame on institutional and funding constraints (Poudyal et al. 2012). Regardless of approach, studies of vulnerability must take account of the values and practices that govern local participation and define peoples' reasons for living where they do (Carroll and Paveglio 2016). Management efforts should not assume that residents hold identical sets of values regarding the forest and its management. While differences in cultural perspective might result in conflict among different types of residents, institutional flexibility to adapt approaches and actions can help harness the diversity of local knowledge and experiences to contribute to a community's fire resilience (Carroll and Paveglio 2016; Abrams et al. 2015).

Solutions for mitigating social vulnerability and building community resilience may require multi-method, engaged, place-based approaches. Social vulnerability is multidimensional. It is subject to geographic variability and a myriad of causes, including resource dependence, social perceptions of risk, poverty, and sociopolitical marginalization (Cutter, Boruff, and Shirley 2003; Collins 2008). As scholars study the diversity of WUI residents and community dynamics, they increasingly point to the wealth of local knowledge and approaches to resilience that already exist (Carroll and Paveglio 2016). Building networks to share that knowledge among different WUI resident groups is key to building resilience and public trust in institutions and forest management organizations (Abrams et al. 2015).

Social vulnerability is difficult, but important to assess. Social vulnerability to wildfires is frequently unrecognized due to difficulties in identifying or quantifying vulnerability. This problem is exacerbated by underreporting of costs and losses after disasters (Cutter, Boruff, and Shirley 2003).

However, tracking characteristics and drivers of social vulnerability improves general awareness.

Identifying the location and degree of social vulnerability is therefore the first step toward mediating environmental hazard risks for communities. Researchers have used a combination of indexing and place-based modeling to map patterns of social and economic factors related to increased vulnerability (Cutter et al. 2008). This approach has been used to spatially locate vulnerable pockets, or "hot spots," of residents at greatest risk to catastrophic loss in a disaster event (Gaither et al. 2011). Mapping patterns of vulnerability at the regional level (Cutter and Finch 2008), county level (Cutter, Boruff, and Shirley 2003), and parcel level (Paveglio et al. 2016) renders social vulnerability more visible to policymakers, land management agencies, and community-level entities, respectively. Following a general assessment of exposure risk, vulnerability assessment should be the first course of action in plans addressing environmental hazards at the neighborhood, community, or regional levels.

Factors that generally amplify vulnerability to other environmental hazards are not necessarily the same as those that increase vulnerability to wildfire (Paveglio et al. 2016). This fact makes comparisons between different types of hazards difficult. Further, many of the factors related to wildfire vulnerability in the WUI are unavailable in secondary data sources such as the US Census or the ACS. For example, few existing datasets identify wildfire risk-transmission connectivity between landowners (Ager et al. 2015). Yet, one significant source of social vulnerability to wildfire is whether neighboring landowners have taken wildfire-mitigation actions on their properties.

The diversity of factors indicative of social vulnerability to wildfire that reach beyond census data, such as length of residency, land management values, and public trust, can make identifying and addressing wildfire vulnerability more complicated than those studied in research on other environmental hazards (Paveglio et al. 2017; Carroll

and Paveglio 2016). The research calls for closer attention to place- and community-specific aspects of social vulnerability as well as the design of strategies for informing and empowering residents in their efforts to build resilience. Despite

the structural challenges associated with social vulnerability, efforts that combine institutional, local, and scholarly bodies of knowledge can create social capital and develop adaptive capacity (Abrams et al. 2015).





Summary and conclusions

Social vulnerability and resilience to wildfire is a growing field of research, and we sought to track the conceptual debates and emerging insights from multiple disciplinary and methodological directions. We examined works on social vulnerability and community resilience, with an emphasis on research that investigates social vulnerability among WUI communities in fire-prone regions. Although our selected literature review is not exclusively dedicated to wildfire research, we found that the foundations of social vulnerability research demonstrate existing methods that can be useful for understanding wildfire risk and social vulnerability. The methods of conceptualizing, identifying, measuring, and mapping vulnerability and building community resilience that are outlined in early research can be productive for managers and researchers looking to understand how social vulnerability effects efforts to prepare WUI communities for wildfires.

Nevertheless, considerations of social vulnerability pose a number of theoretical and practical problems. Theoretical problems arise because scholars coming from different disciplines have variously defined terms and sometimes (unintentionally) conflated and repurposed them throughout the development of this field. This may cause confusion for practitioners who lack the time or background to unpack the meaning of specific jargon or the significance of a particular finding. From the practical side, issues arise in how to evaluate social vulnerability within sensitive social and political contexts. For example, labeling a community as socially vulnerable takes on a politically charged assessment that can potentially limit a community's sense of agency and adaptive capacity. It is important to think of vulnerability and resilience as conjoined sets of conditions, on a sliding scale that is built on individual and collective land values, social capital and social cohesion, access to resources, and economic dynamics.

While accurately indexing and mapping vulnerability to environmental hazards is an important first step towards targeting communities in greatest need of interventional support, these methods and principles are not always a good fit for understanding social vulnerability in wildfire-prone WUI communities specifically. The unique dynamics of these communities, which can feature a mix of long-term residents and amenity migrants and frequently experience economic instability based on natural resource industries, differ in scale and social contexts from those in investigations of social vulnerability to other types of environmental hazards. These differences require carefully constructed, strategic, contextualized approaches that consider biophysical conditions alongside social constructions of risk and responsibility.

The research we reviewed finds that social vulnerability is a reality that affects economically disadvantaged and marginalized communities, resulting in disproportionate levels of exposure to catastrophic loss. This conclusion is applicable, yet challenging, for wildfire researchers and agencies responding to wildfire risk. Researchers contend that it is vital that agencies and organizations avoid limiting their efforts to only identifying social vulnerability or adopting a paternalistic relationship with socially vulnerable communities (Murphy et al., 2015); rather agencies and organizations should seek to build adaptive capacity and community resilience by relying on local knowledge to build collective trust among different resident groups and institutions. It is also important to value and integrate diverse knowledge from communities themselves about land management and fire preparedness, methods of conceptualizing and understanding vulnerability and resilience, and methods of building resilience. These methods, at once collective and interdisciplinary, help to strengthen social cohesion and empower communities to take collective action to reduce vulnerability.

Recent research on social vulnerability, community resilience, and wildfire risk point in several fruitful directions for future work. Ongoing re-

search emphasizes concerted community-centered efforts to identify sources of vulnerability, suggesting a move away from problem-oriented inquiry toward solution-oriented inquiry. Ongoing research has also increasingly taken up case studies to understand risk perception among communities, yielding intimate views of how communities contend with risk and move forward toward greater fire preparedness.

As many of the researchers included in this literature review note, the realities of fire risk in the WUI are intensifying over time, and the urgency to equip communities to effectively mitigate fire risk and build adaptive capacity is greater than ever. Regardless of the ongoing debates over conceptualizing, politicizing, or mobilizing research into vulnerability and resiliency, agencies, organizations, and communities can only benefit from collectively brainstorming ways to increase adaptive capacity by combining knowledge and finding their own paths toward resilience.





Annotated references

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