

Social Amplification of Wildfire Risk: The Role of Social Interactions and Information Sources

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Wildfire is a persistent and growing threat across much of the western United States. Understanding how people living in fire-prone areas perceive this threat is essential to the design of effective risk management policies. Drawing on the social amplification of risk framework, we develop a conceptual model of wildfire risk perceptions that incorporates the social processes that likely shape how individuals in fire-prone areas come to understand this risk, highlighting the role of information sources and social interactions. We classify information sources as expert or nonexpert, and group social interactions according to two dimensions: formal versus informal, and generic versus fire-specific. Using survey data from two Colorado counties, we empirically examine how information sources and social interactions relate to the perceived probability and perceived consequences of a wildfire. Our results suggest that social amplification processes play a role in shaping how individuals in this area perceive wildfire risk. A key finding is that both “vertical” (i.e., expert information sources and formal social interactions) and “horizontal” (i.e., nonexpert information and informal interactions) interactions are associated with perceived risk of experiencing a wildfire. We also find evidence of perceived “risk interdependency”—that is, homeowners’ perceptions of risk are higher when vegetation on neighboring properties is perceived to be dense. Incorporating social amplification processes into community-based wildfire education programs and evaluating these programs’ effectiveness constitutes an area for future inquiry.

KEY WORDS: Risk perception; social amplification of risk (SAR); social interactions; wildfire risk information

1. INTRODUCTION

In the face of wildfire and other natural hazards, individuals’ perceptions of risk are shaped in part

by their social environments. According to the social amplification of risk (SAR) framework initially developed by Kaspersen *et al.*, the way a society understands risk is influenced by “expert” assessments (“science”) as well as “the cultural, social, and individual response structures that shape the public experience of risk”⁽¹⁾ (p. 178). Scientists and policymakers often focus on the former, providing expert information in an attempt to increase awareness of and response to existing, increasing, or imminent danger. However, in the case of wildfire, the social environment also provides multiple sources of information and interactions that influence the way individuals think about fire and its potential impacts on

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their lives. Inadequate attention to these social processes leads to an incomplete understanding of the public's risk perceptions and, potentially, to ineffective risk reduction policies.

Indeed, research on risk perceptions provides evidence that vertical transmission of expert information is not the sole influence on perceived risk; rather, interpersonal communication and social interactions (sometimes referred to as horizontal communication channels) also play an important role.⁽²⁻⁴⁾ These horizontal channels have received less attention, however. In the context of wildfire, it is unlikely that all residents in a fire-prone area receive or have access to expert information or engage in formal interactions (e.g., attending a wildfire-related event). Nonexpert information sources and less formal interactions can reach a broader audience and play an important role in shaping wildfire risk perceptions. Mechanisms to exploit alternative channels for wildfire risk information are currently being employed. For example, federal programs in the United States encourage the development of Community Wildfire Protection Plans (CWPPs) that identify areas of concern and strategies to reduce wildfire risk. These plans are intended to initiate from communities and require participation and certification by officials from the local government, the fire department, and a State Forester. Efforts such as CWPPs are based on the premise that in addition to vertical information transmission, horizontal interactions can play an important role in homeowners' risk perceptions and related mitigation behaviors. In this article, we draw on the SAR framework to examine the role that expert and nonexpert information sources, and formal and informal social interactions, play in shaping wildfire risk perceptions. The understanding that comes from modeling such relationships can be used to further develop and refine community wildfire programs.

In the next section, we develop a conceptual model of homeowners' risk perceptions informed by the SAR framework. Section 3 describes the methods and data used to examine information sources, social interactions, and wildfire risk perceptions among homeowners along Colorado's Front Range living in a wildland-urban interface (WUI), where the fuels for fire transition from wildland sources to human-made sources.⁽⁵⁾ In the fourth section, we describe the results and conclude by discussing the implications for wildfire programs that seek to educate homeowners about wildfire risk.

2. CONCEPTUAL FRAMEWORK

Perceptions of wildfire risk have long been a focus of inquiry. Initially, research was motivated by a desire to understand public perspectives in order to refine and improve the efficacy of agency messages related to public land management.⁽⁶⁾ More recent work has addressed property owners' risk perceptions and the attitudes and beliefs influencing implementation of risk reduction action on one's own parcel.⁽⁷⁻¹⁰⁾ Although a handful of recent wildfire publications mention the SAR framework in reference to social processes related to risk perception,⁽¹¹⁻¹³⁾ the framework has yet to be applied in the wildfire context to assess the relative influence of vertical and horizontal information sources on the amplification of wildfire risk perceptions.

This study is part of a growing literature that seeks to move beyond viewing risk perceptions as products of purely individual-level cognitive processes, and towards an understanding of how social processes shape individuals' views of and response to hazards.⁽¹⁻⁴⁾ The SAR framework provides a useful starting point. Kasperson *et al.* define the social amplification of risk as "the phenomenon by which *information processes, institutional structures, social-group behavior, and individual responses* shape the *social experience of risk*, thereby contributing to risk consequences" (p. 181, emphasis added). According to the SAR framework, amplification of risk messages occurs at multiple stages, including the transfer of risk information and related amplification or attenuation of risk perception, as well as subsequent societal response mechanisms. Importantly, SAR accounts for the processing of risk information by individuals as well as at multiple "stations" of society including scientists who communicate risk information, media, social groups, and interpersonal networks. That is, this framework recognizes that individuals' perceptions of risk are processed through filters at various levels, from individual heuristics to social and political processes that frame risk issues.^(14,15)

Within the broad SAR paradigm, this study focuses on the role of information sources and social interactions in shaping wildfire risk perceptions. The conceptual framework is presented in Fig. 1. The arrows in the figure are labeled with table numbers, which correspond to results of our empirical analysis whose methods and results are presented in Sections 3 and 4, respectively.

To summarize the conceptual framework in Fig. 1, homeowners' wildfire risk perceptions, which

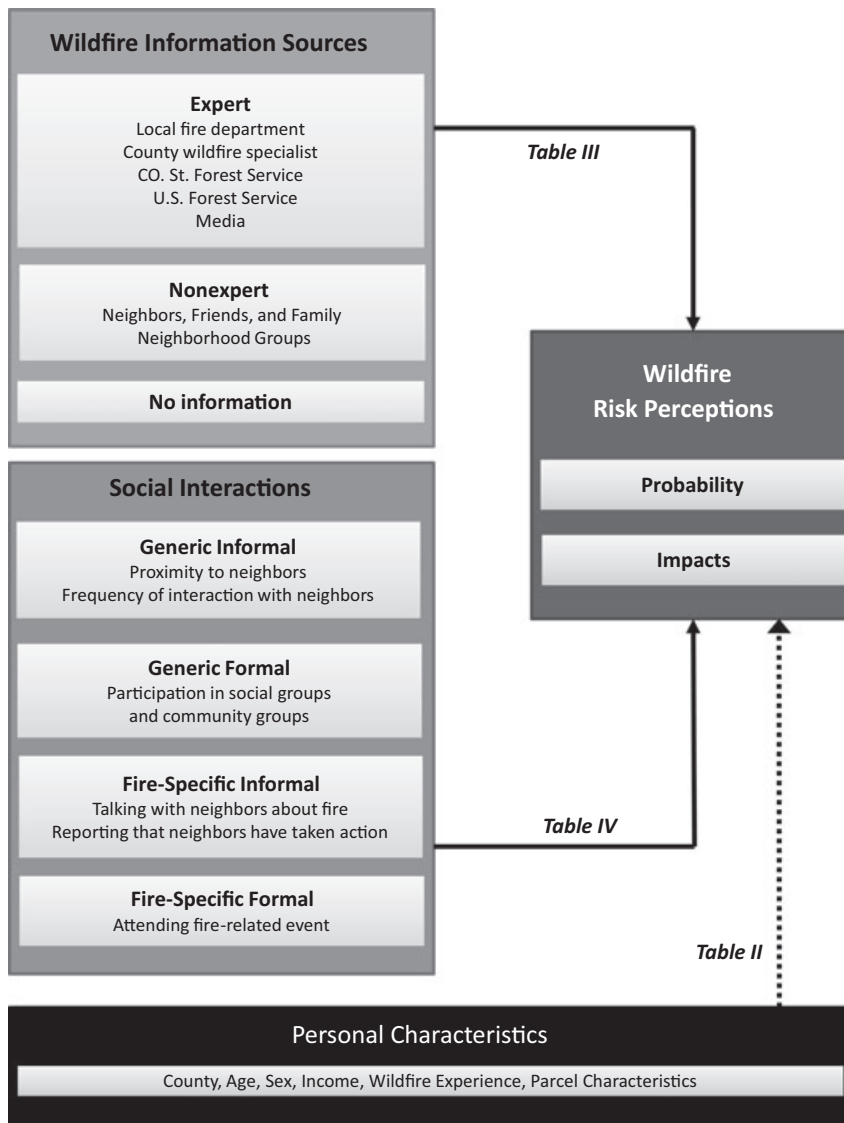


Fig. 1. Conceptual framework.

include the perceived probability of a fire occurring and perceived consequences of fire, are related to the information homeowners receive from expert and nonexpert wildfire information sources, as well as different types of social interactions. In this context, the central question emerging from the SAR framework is whether or not the various stations playing a role in wildfire information distribution are serving to amplify or attenuate risk perception among those facing wildfire. If amplification and/or attenuation is occurring, what is the relative contribution of different stations—that is, different information sources and types of interactions?

To develop this model in more detail and inform our empirical analysis, we begin with a technical

“fire science” discussion describing the wildfire problem and factors influencing fire probability and consequences. We then explain how social amplification processes are likely to play out in this context, outlining several pathways through which both information sources and social interactions may shape wildfire risk perceptions.

2.1. Wildfire Risk: A Fire Science Perspective

Risk is often defined as the product of the probability of an event occurring times the magnitude of potential consequences or impacts of that event.^(1,16,17) We thus organize this fire science discussion around the factors influencing probability of

fire occurrence (i.e., ignition) and the potential consequences of wildfire for WUI homeowners.

2.1.1. Probability of Occurrence

Wildfire ignitions are common occurrences across the Colorado WUI. In 2010, for example, 1,076 wildland fires burned 40,788 acres in Colorado.⁽¹⁸⁾ Sources of ignition may include both natural starts such as lightning and accidental ignitions from human activity such as fireworks, camp fires, and guns. In the Rocky Mountain region of Colorado in 2010, there were 941 lightning-caused fires (burning 32,929 acres) and 1,962 human-caused fires (burning 118,702 acres).⁽¹⁹⁾ Along Colorado's Front Range in the first half of 2012 alone, fires in the WUI have resulted in six deaths, 630 homes, and over 116,000 acres burned.⁽²⁰⁾

Although wildfires are increasingly common in this broad geographical region, the probability of a wildfire starting on any individual WUI property fire is relatively low. For any individual property owner, it is more probable that an ignition occurring elsewhere will eventually spread to one's home via neighboring lands. Once an ignition has occurred, the wildfire's behavior depends on many exogenous factors, including wind, humidity, temperature, topography, forest type, and some aspects of forest conditions (e.g., fuel type, aridity).

2.1.2. Consequences of a Fire Event

From the perspective of an individual homeowner, once a fire has started the consequences of a fire event are largely determined by the values at stake (i.e., what is there to lose or be damaged?). Possible losses include damage or loss of private assets such as homes and other structures and burned vegetation on private parcels as well as loss of life. Individuals may also care about damages to homes and vegetation on neighboring parcels, as well as damage to public assets such as forests, roads/infrastructure, historic values, and water resources. Fire may also have psychological impacts such as stress or dread, or the loss of aesthetic values.

Once a fire event is underway its behavior is determined by previously mentioned exogenous factors along with critical factors within human control. For example, the availability of adequate fire-fighting resources, roads for access/egress, and the time that lapses before suppression efforts are underway influence the consequences of a fire event.

More proactively, homeowners and land managers can influence fuel conditions on private and adjacent parcels that are thought to be keys determinant of damages and losses for WUI homeowners.⁽²¹⁾ Further, as fire does not respect property boundaries, one property owner's risk is the result not only of her/his own parcel conditions but also of conditions on neighboring parcels. That is, wildfire risk exhibits what Kunreuther and Heal called "risk interdependency": the protective actions of one actor affect others' risk.⁽²²⁾

2.2. Wildfire Risk Perceptions in a Social Context

The preceding discussion focuses attention on the technical aspects of fire risk—that is, the kind of information that may be relayed from expert sources. While perceptions of such processes are likely to factor into individuals' risk perceptions,⁽²³⁾ our central claim is that fire-related risk perceptions are also shaped by a number of social processes. In particular, the SAR framework is useful because it expands previously narrow considerations of risk perception to situate risk perceptions and risk-related responses within a broader social context. Like other social science hazards research, SAR moves risk perception considerations into the social, economic, and environmental contexts in which decisions are made. The framework, presented in Fig. 1, includes a variety of information sources and social interactions that may shape wildfire risk perceptions.

2.2.1. Information Sources

Wildfire is a persistent and growing hazard facing WUI communities. As such, homeowners in fire-prone areas receive information about wildfire risks from multiple sources. These include *expert* as well as *nonexpert* sources of information. Expert sources in the United States include local volunteer fire departments (VFDs) and state and federal forest service representatives. Fire science information from these sources can help homeowners understand details of fire behavior, but the applicability of the information to an individual homeowner's circumstances may depend on the setting, the homeowner's ability to understand expert communications, and the extent to which one can interpret the information's relevance to the conditions one faces.

Individuals living in the WUI also receive information about wildfire from nonexpert sources such as friends and family or community groups (e.g.,

homeowner association, local board). Although non-expert sources are likely to vary widely in the technical accuracy of the information they provide, these sources have the benefit of being highly interactive and individualized.

Research on the provision of wildfire information has revealed the importance of supplying the public with specific information regarding local forest conditions,⁽²⁴⁾ fuel management techniques,^(24,25) and fire management techniques.^(26,27) The provision of specific information to WUI residents, particularly through one-on-one interaction, has been found to increase acceptance of wildfire risk mitigation practices.^(27,28) These findings are consistent with research based on other natural hazards that suggest people want definitive information they can use to assess personal relevance of the risks they face.⁽²⁹⁾ Thus, we expect that information sources that are more specifically tailored to the homeowners' local contexts would be more influential in shaping risk perceptions than broad-based messages.

Finally, although the preceding discussion notes that individuals "receive" information from a variety of sources, we note that a growing literature has examined risk information seeking and processing (RISP) as an active and iterative process.⁽³⁰⁾ A key lesson from this research is that initial risk perceptions are themselves an important determinant of risk-information-seeking behavior, such that individuals who think a risk is important will be motivated to learn more about that risk and, ultimately, to take protective action. Although the information-seeking process is not the primary focus of this work, we keep these issues in mind in our subsequent empirical analysis.

2.2.2. Social Interactions

In addition to the role information sources play in shaping risk perceptions, a variety of interactions between homeowners and their neighbors, community members, and other social contacts can also affect wildfire risk perceptions. We categorize these social interactions along two dimensions. First, social interactions can be either formal (i.e., organized and official interactions within defined groups) or informal (i.e., talking with neighbor about wildfire, reporting knowing one's neighbor). Second, interactions can relate specifically to wildfire, or they can be more "generic," that is, a social interaction based on anything other than wildfire. This typology gives rise to

four possible types of interactions: generic informal, generic formal, fire-specific informal, and fire-specific formal. Across these different categories, there are several pathways through which social interactions may influence risk perceptions.

First, as the SAR literature highlights, social groups embody frames of values that may serve as filters through which group participants may interpret and assess information about risk.⁽²⁾ The ability to create and reinforce shared norms provides one pathway through which generic interactions, while they are not specifically organized around wildfire, may come to shape fire-related risk perceptions. The effect of this pathway (i.e., social groups) on risk perceptions may be positive or negative—that is, either amplifying or attenuating risk perceptions.

Similarly, generic and fire-specific interactions provide opportunities for building social capital, that is, "social structures, networks, or resources that facilitate individual or collective action by generating networks of relationships, reciprocity, trust, and social norms."^(31,32) Many WUI communities lie beyond the service areas of incorporated municipal services so road maintenance, plowing, trash, and water services are homeowners' responsibilities. To this end, homeowners often join together to form community groups for vital community functions. Participation in these community groups provides opportunities to develop bridging capital based on shared investment in community affairs among those with varied ideas, beliefs, and outlooks on social matters.^(32,33) Like communities everywhere, WUI communities also may have social groups, including book clubs, support groups, etc. Participation in formal social groups provides opportunities to develop bonding capital among those who have already identified ideas, issues, or pastimes that bring them together in their WUI communities.^(32,34–36) Both bridging and bonding capital may ultimately affect the way residents perceive wildfire risk.

A third important way in which social interactions may affect wildfire risk perceptions stems from "risk interdependency," as discussed in the fire science section. Because wildfire ignores property lines, spreading across a landscape in response to vegetative conditions (as well as wind, topography, and other environmental factors), risk on one WUI parcel is integrally linked to neighboring properties.⁽²²⁾ These spillover effects function in both directions—well-mitigated parcels can reduce risk on neighboring parcels just as neglected parcels can increase risk

to neighbors. Thus, social interactions with neighbors and awareness of their fuel conditions and management decisions likely play a role in homeowners' understanding and perception of their own level of risk.

Finally, social contacts serve as an information source, and several characteristics of these sources, including the one-on-one nature of interactions and their potential for transmitting specific, locally-tailored information, increase the likelihood that homeowners' risk perceptions will be affected. Whether formal or informal, we expect that fire-specific social interactions transmit information more efficiently since these interactions are likely more targeted or "goal-directed" than generic interactions.⁽³⁾ Of course, wildfire may be discussed during generic interactions as well, particularly during times of heightened risk.

2.2.3. Personal Characteristics

A variety of personal characteristics, including age, income, and sex, have been found to be related to risk perception.^(37–39) Therefore, it is important to control for personal characteristics when examining the relationship between information and social interactions and perceived wildfire risk.

2.2.4. Hypotheses

Based on the preceding discussion, we propose the following broad, testable hypotheses where wildfire risk perceptions are as defined above and in Table I.

H1: Probability and Consequences

The fire science discussion highlights the fact that the probability of ignition is relatively fixed over space (though not over time), and is not tightly tied to individuals' mitigation behavior. In other words, some regions are particularly susceptible to wildfires and the conditions and mitigation actions on any particular parcel are not likely to affect the probability of an ignition. Consequences of fire, in contrast, are highly variable across space and depend in part on human actions (own and others').

To the extent that people are aware of these dynamics, we thus expect that: social amplification processes will have less influence on the perceived probability of wildfire risk than on the perceived consequences of wildfire risk.

H2: Information Sources

We expect that: use of expert and nonexpert wildfire information sources by homeowners will be positively associated with wildfire risk perceptions.

Information sources that provide information closely tailored to the local context will be more strongly associated with higher risk perceptions than information sources that provide more general information.

H3A & H3B: Social Interactions

A: Fire-specific social interactions will increase perceived wildfire risk more than generic social interactions.

B: Due to risk interdependency, perceptions of fuel density on neighbors' property will be positively associated with wildfire risk perceptions.

3. METHODS

To test the hypotheses laid out in the previous section, we use data from a survey of WUI homeowners in Boulder and Larimer Counties in Colorado, USA. Boulder and Larimer Counties sit along the Front Range of the Rocky Mountains. That is, as one travels from east to west the elevation increases (peaking at the Continental Divide) and the landscape shifts from plains and agricultural areas through three distinct forest types, all of which respond to wildfire differently and require different management approaches. Most of the landowners are in the lower foothills in predominantly ponderosa pine and Douglas fir forests (lower montane: 5,900–8,000 feet in elevation). These ecosystems are dependent on frequent (every 10–30 years) low-to-moderately intense fire to maintain open park-like forests resulting in mature, well-spaced clumps of ponderosa pine trees, with Douglas fir in moist drainages or on northerly slopes.^(41,42,43) Land ownership is a mosaic of private and public holdings of varying sizes, with terrain that is often steep and rugged. Most communities are rated as having high, very high, or extreme wildfire risk based on vegetative and structural fuels, topography, and accessibility (among other factors). Most communities do not receive municipal services and most fire and emergency services are provided by local VFDs. The area has an active wildfire history with fire events possible throughout the year, though more common during the hot, dry, and windy summer and early fall months. Based on an assessment of the number of square miles of developed land within the WUI, the

Table I. Variable Descriptions

Variable Name	Variable Definition	N	Descriptive Stats	
			Range	Mean
Risk Perceptions				
Probability	probindex	696	0-100	73.80
	conindex	700	Likert: 1 = Strongly agree – 5 = Strongly disagree	3.78
Consequences	conindex	701	0-100	4.10
	conindex	685	0-100	66.40
<p><i>Input variables:</i> Index generated using principal components analysis A wildfire is unlikely to happen within the time period you expect to live here Your property is not at risk of wildfire</p> <p><i>Input variables:</i> Index generated using principal components analysis If there is a wildfire on your property, how likely do you think it is that the following would occur? • There would be some smoke damage to your home • There would be some physical damage to your home • Your home would be destroyed • Your trees and landscape would burn</p>				
<p>Likert: 1 = Not likely – 5 = Very likely</p>				
<p>698 3.93</p>				
<p>696 3.66</p>				
<p>696 2.90</p>				
<p>696 4.10</p>				
<p><i>Respondent reports receiving information about reducing the risk of wildfire from...</i></p>				
Information Sources				
Expert	localfiredept	728	0 = Did not Receive information; 1 = Received information	0.60
	countyspec	728		0.27
	costate	728		0.28
	usfs	728		0.21
	media	728		0.48
Nonexpert	neighbfriend	728		0.38
	neighbgroup	728		0.34
No sources	noinfo	728		0.08
	noinfo	728		0.08

(Continued)

Table I. (Continued)

	Variable Name	Variable Definition	N	Descriptive Stats	
				Range	Mean
Social Interactions					
Generic Informal	closeighb	Closest neighbor is less than 100 ft away	720	0=no; 1=yes	0.28
	knowneighb	Interact with neighbors at least monthly	701		0.75
Generic Formal	socgroup	Participate in social groups at least monthly	702		0.33
	comgroup	Participate in community groups at least monthly	700		0.17
Fire-specific Informal	talkfire	Ever talked to neighbor about fire	668		0.76
	neighbdens	Vegetation on neighboring properties is "dense" or "very dense"	699		0.32
Fire-specific Formal	fireevent	Participated in wildfire-related event	701		0.44
Personal Characteristics					
	county	Respondent lives in Larimer County (1) vs Boulder (0)	728	0-1	0.44
	age	Respondent's age	677	18-87	55.9
	sex	Respondent is female (1) vs male (0)	693	0-1	0.46
	income	Income in 10,000s (with missing values imputed)	671	2.5-20	9.57
	lotsize	Lot size in 10s of acres	693	.025-75	1.06
	evacuated	Ever evacuated or prepared to evacuate	718	0-1	0.38
	fire10	Wildfire within 10 miles of property	718	0-1	0.74
	highextreme	High or extreme wildfire hazard rating based on vegetation density	659	0-1	0.73

study counties rank as the top two counties at risk of wildfire in Colorado.⁽³⁷⁾ Here, we briefly describe the survey design, as well as the specific measures we use in our analyses.

3.1. Survey Design and Sampling Methods

The survey was constructed to collect comprehensive data on the environmental and social contexts of WUI residents. The survey included seven sections that asked about where respondents live, their experiences with wildfire, actions taken to reduce wildfire risk, attitudes about wildfire risk, social interactions (two sections), and demographic characteristics.^(38–40)⁵ The survey design was informed by an earlier qualitative study, recent fire and hazards literature,^(6–13,24–28) and four focus groups with WUI residents in the two target counties.^(45,46) We used geographic information systems (GIS) and geo-coded data from the County Assessor's offices to populate county wildfire risk maps with parcel information for privately owned residential properties. These maps allowed us to draw random samples of 1,750 fire-prone properties for each county for a total of 3,500 potential survey participants.

During the summer of 2007, potential participants were mailed a letter of invitation to participate in the survey. Participants could choose to complete a web-based or paper survey. Online participants entered a unique identifier to login to a secure website. Paper survey participants returned a postage-paid postcard included with the letter of invitation and were sent a survey, a letter with instructions and thanks, and a postage-paid return envelope. Second and third mailings were sent to nonrespondents at one-week intervals. Overall, 2,053 letters were successfully delivered and we received 747 responses for a 36% response rate. Although nonresponse bias is always a concern if a response rate is less than 100%, we did not conduct a formal assessment of nonresponse bias. Although we are not able to compare the demographic characteristics of the survey respondents to U.S. Census data due to the mismatch between census data blocks or tracts and WUI areas, examining county census data for the counties reveals that survey respondents were more educated and wealthier than residents in

the counties as whole. Specifically, 83% of the Boulder respondents was at least a college graduate compared to 52.4% for the county as a whole and 70% of the Larimer respondents was at least a college graduate compared to 30.5% in the county as a whole. Mean income also appears to be higher within the study sample than the rest of the counties. It is not surprising that the WUI respondents would have somewhat different demographic characteristics than the counties as a whole as both WUIs are within commuting distance of major universities (Colorado State University in Larimer County and University of Colorado in Boulder County) and are very desirable locations due to proximity to environmental amenities. There were also differences among marital status, income, and education between the survey respondents from the two counties.

The survey included measures related to wildfire-related risk perceptions, information sources, and social interactions. Variables used in the analyses included in this article are described in Table I. We discuss these measures and our analyses of their relationships to one another, which shed light on risk amplification or attenuation processes.

3.2. Risk Perception Measures

Turning first to risk perceptions, the survey included two questions that directly address the perceived *probability* that a wildfire will occur on the respondent's property, as well as four variables related to the perceived *consequences* of a fire on the respondent's home and property were a fire to occur⁶ (Table I). We performed principal components analyses⁽⁴⁸⁾ to combine the respective variables into a probability index variable and a consequence index for each respondent. Descriptive statistics for the resulting indices, which were scaled to have a range from 0 to 100, as well as the Likert-scale variables used as inputs, are also presented in Table I. Because our first hypothesis posits that social amplification processes will affect perceived consequences more than perceived probability of wildfire, we keep the probability and consequence indices separate rather than aggregating these into a single "risk perception" measure.

⁵The survey is available upon request and descriptive reports can be found at <http://www.fs.fed.us/rm/pubs/rmrs/rn048.pdf> and <http://www.fs.fed.us/rm/pubs/rmrs/rn047.pdf>.

⁶While we acknowledge that individuals may care about a range of other fire consequences beyond damages to one's own property, we limit our attention to these immediate impacts for the purposes of these analyses.

3.3. Information Sources

The information source measures are from a survey question that read: “From which of the following sources have you received information about reducing the risk of wildfire?” The information sources that were included as options in the survey were based on consultation with local fire experts who advised us of potential sources of wildfire information in the study area. Expert information sources include local sources: VFDs and county wildfire specialists. VFDs are composed of community members trained to fight wildland fires who may provide parcel-level risk assessments, participate in community processes for community wildfire preparedness planning, and in some cases provide fuel reduction assistance. County wildfire specialists provide parcel-level risk assessments upon request, engage in outreach and education efforts by attending local meetings, and in some cases facilitate community efforts to win funds to offset fuel reduction efforts. Other expert information sources that may be less local include representatives from the Colorado State Forest Service and the U.S. Forest Service who may engage in work from forest thinning and prescribed burning to outreach and education efforts. Media sources were also a response option. Since news coverage can serve as an opportunity for expert informants or reporters to share fire-specific information with the concerned public, we also classify media as an “expert” source, though we acknowledge that the expertise of the media is likely to vary widely across different media outlets.

Nonexpert information sources include neighbors, friends or family members, and community groups. In addition, we also provided a “none of the above” option, and include a variable that identifies individuals in this category—that is, respondents who indicated they had not received information about wildfire risk from any source.

3.4. Social Interactions

Respondents were asked about several types of interactions with neighbors and social contacts. We categorize these multiple measures of social interaction into four groups, as discussed in the conceptual framework section. Generic, informal social interactions include two measures: a measure of whether the respondent interacts with his or her neighbors on at least a monthly basis and a measure of physical proximity (whether the closest neighbor’s house is within

100 feet of the respondent’s house). The landscape of the WUI varies from small densely situated private parcels surrounded by forests to sprawling parcels that spread the population across a vast forested landscape. Physical proximity among neighbors can influence both the frequency of social interactions as well as the extent to which the conditions on neighboring parcels (vegetative and structural) affect one’s own fire risk. Generic, formal interactions include participation in social and community groups that are not related specifically to wildfire. Fire-specific, informal interactions include whether the respondent reported ever talking to his/her neighbor about wildfire, as well as perceptions of whether the vegetation on neighboring property is dense or very dense. The latter is not an interaction *per se*, but is potentially relevant to the risk interdependency question. Finally, our fire-specific formal interaction measure records whether or not the respondent reported participating in an organized wildfire event. This could include attending a community wildfire meeting, serving on a community fire board, or participating in a fire-related community event (e.g., slash collection day).

3.5. Personal Characteristics

To examine the relationships between risk perceptions, on the one hand, and information sources and social interactions, on the other, we control for other demographic variables and individual characteristics that may affect risk perceptions. The control variables we include in the analyses are listed in the bottom section of Table I. First, though both counties are engaged in outreach and education efforts, county wildfire information and outreach programs are not identical. Therefore, we include county as a control variable. Second, three demographic variables (age, sex, and income) are included in the models because natural hazards research has found correlations between risk perception and these specific demographic characteristics.^(38–40)⁷

Third, lot size influences the amount of land that is susceptible to wildfire and the amount of fuel management required, as well as factors affecting risk interdependency such as the length of shared property lines and the potential number and types of

⁷Marital status, employment status, race, residential tenure, and presence of children in the household were included in previous analyses but were not found to be significant determinants of risk perceptions.

neighboring owners.^(21,49) Fourth, because prior hazard experience has been found to affect risk perceptions in some studies^(10,47,50–52) we include two measures of wildfire experience (whether the respondent had ever been or prepared to be evacuated, and whether he/she has experienced a wildfire within 10 miles of the property).⁸

Finally, we include an objective measure of the hazard rating on the property. This variable was constructed using satellite data for each respondent's parcel in consultation with county wildfire mitigation experts such that high/extreme (1) was assigned if the fuel coverage on the property constituted a high or extreme risk level.⁹

3.6. Data Analysis

To assess how each of the information sources and social interaction variables relates to risk perceptions, we estimate two sets of regressions. First, for the information source analyses, regressions are of the form:

$$R_i = \beta_1 \text{Info}_i + \gamma X_i + \varepsilon_i, \quad (1)$$

where R_i is one of the two risk perception indices (probability or consequences), and Info_i is one of the eight information source indicators listed in Table I. That is, we run a total of $2 \times 8 = 16$ regressions capturing each combination of risk perception and information source variables. Each regression includes the full set of control variables (X_i) listed in Table I. In each regression, the β_1 coefficient provides a measure of the association between the risk perception index and the information source.

⁸Respondents were also queried about whether or not they had suffered damages/losses due to wildfire, whether or not they had experienced wildfire at a previous residence, and whether they knew someone who had experienced damages/losses due to wildfire.

⁹Land cover data were obtained from the National Land Cover Data Set (2006) using satellite data to classify fuel type for Larimer County, and from the County GIS/Mapping Office using USDA Forest Service Arapaho and Roosevelt National Forests Office land cover data for Boulder County. GIS was used to overlay the fuel type and county parcel maps. In consultation with local fire experts we created a variable such that high/extreme wildfire risk was assigned for parcels with closed canopy conifer with sparse ground litter, closed canopy with concentrated downed material, dense conifer with heavy amounts of downed material, woody wetlands, deciduous forest, or evergreen forest. Due to the nature of the data it is possible, particularly with the larger parcels, that more than one fuel type could be present on a parcel.

Similarly, for our social interaction measures, we estimate regressions of the form:

$$R_i = \beta_2 \text{Social}_i + \gamma X_i + \varepsilon_i. \quad (2)$$

In this case, Social_i denotes one of the seven social interaction variables described in Table I, such that we run an additional 14 regressions to estimate β_2 coefficients: the pairwise relationships between risk perceptions and social interactions, controlling for personal characteristics. Analyses were performed using Stata 11 (StataCorp 2009).

4. RESULTS

4.1. Personal Characteristics of Survey Population

Descriptive statistics for the survey respondents are presented in the bottom panel of Table I. The average respondent was 56 years old. Slightly more men responded (54%) than women. The average lot size was just over 10 acres. Most survey respondents had some prior experience with wildfire: almost 74% of the respondents reported that a wildfire had come within 10 miles of their home at some point, and about 40% of respondents reported that they had evacuated or prepared to evacuate for a fire. Objectively assessed wildfire hazards are also quite high in this area, with 73% of parcels deemed to have a “high or extreme” hazard rating based on satellite-based vegetation density data (Table I).¹⁰

4.2. Relationships Between Personal Characteristics and Risk Perceptions

Before we present results from our focal analyses showing associations between information source and social interaction measures, on the one hand, and risk perceptions, on the other, we present results from regressions that include only the personal characteristics control variables listed in Table I. That is,

¹⁰The WUI is defined based on land use and fire risk and does not overlap neatly with census blocks or tracts. As such, we are not able to use readily available data (e.g., census data) to make a direct comparison between our survey respondents and the WUI population. Looking at Boulder and Larimer Counties as a whole using 2000 U.S. Census data, we observe that the survey respondents were more educated and that mean household income also appears to be higher within the study sample than the rest of the counties. However, we would not necessarily expect our study population of WUI residents to have demographic characteristics similar to the entire county—for one thing, the WUI is less urban than the rest of the county. As our interest is in a relational model, we do not generalize beyond the pool of respondents.

Table II. Associations Between Personal Characteristics and Risk Perceptions

	Dependent Variables: Risk Perceptions	
	Probability Index	Consequence Index
Personal Characteristics		
County (Larimer)	-4.06** (1.70)	-3.24 (2.02)
Age	-0.12 (0.08)	-0.20** (0.09)
Sex (female)	3.84** (1.71)	6.87*** (1.99)
Income	-0.13 (0.18)	-0.30 (0.20)
Lot size	0.44*** (0.14)	-0.28** (0.12)
Evacuated	5.91*** (1.84)	2.46 (2.08)
Fire10	4.79** (2.04)	0.83 (2.50)
highextreme	2.41 (1.84)	8.37*** (2.19)
Observations	568	561
R-squared	0.07	0.08

Coefficient estimates (robust standard errors) from two ordinary least squares (OLS) regressions. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.1$.

Table II presents results from two regression models of the form:

$$R_i = \gamma X_i + \varepsilon_i. \tag{3}$$

Several personal characteristics are indeed associated with the risk perception indices. Variables associated with higher perceived probability of experiencing a wildfire include residence in Boulder County (compared to Larimer), female, larger lot size, and previous fire experience (both prior evacuation and experiencing a fire within 10 miles of the home). Meanwhile, perceived consequences were higher among younger respondents, females, respondents with smaller lot sizes, and respondents with high/extreme fire ratings. Because these characteristics may also influence which information sources are chosen and how people interact socially, they are included as control variables in subsequent analyses.

4.3. Information Sources

Turning now to our social amplification results of interest, we begin by examining how receiving information from various sources is associated

Table III. Associations Between Information Source Variables and Risk Perceptions

Information Sources	Dependent Variables: Risk Perceptions	
	Probability Index	Consequence Index
Expert		
localfiredept	7.45* (1.82)	2.25 (2.18)
countyspec	8.98* (1.70)	-0.53 (2.07)
costate	5.26* (1.76)	-0.03 (2.08)
usfs	3.15** (1.82)	2.82 (2.27)
media	-0.25 (1.67)	0.07 (1.91)
Nonexpert		
neighbfriend	8.90* (1.59)	4.44*** (1.93)
neighbgroup	3.66*** (1.76)	2.39 (1.98)
noinfo	-10.43* (3.33)	-6.32 (3.89)

Coefficient estimates (robust standard errors) from 16 ordinary least squares (OLS) regressions – that is, each coefficient comes from a separate regression model where the column variable is the dependent variable and the row variable is the explanatory variable of interest. Each regression model also includes the full set of personal characteristics (see Tables I and II). *** $p < 0.1$, ** $p < 0.05$, * $p < 0.01$.

with wildfire risk perceptions. Table III presents the β_1 coefficients from information source regressions (Equation (1)). That is, each cell in this table is generated from a separate OLS regression where the risk perception variable (in the columns) is regressed on a single information source variable (in the rows) and the control variables discussed above. Therefore, the associations that are represented in Table III are holding the control variables constant.

Results indicate that the perceived probability that a wildfire will occur is significantly correlated with receiving information from almost all of the sources included in the survey, including expert and nonexpert sources. The only source that is not significantly associated with the probability index is news media. Looking at the magnitude of the effects, we see that two expert sources (county specialist and the local fire department) and one nonexpert source (neighbors and friends) are the most strongly positively correlated with the probability index. We also observe that individuals who stated that they had not received information about wildfire from any source

Table IV. Associations Between Social Interaction Variables and Risk Perceptions

	Dependent Variables: Risk Perceptions	
	Probability Index	Consequence Index
Social Interactions		
Generic Informal		
closeneighb	-3.79* (2.05)	3.84* (2.32)
knowneighb	-1.43 (1.71)	-2.74 (2.14)
Generic Formal		
socgroup	1.89 (1.79)	2.01 (2.12)
comgroup	4.84** (2.25)	1.40 (2.42)
Fire-Specific		
Informal talkfire	12.04*** (2.18)	4.42* (2.50)
neighbdens	7.32*** (1.68)	6.74*** (1.96)
Fire-Specific Formal		
fireevent	7.97*** (1.71)	2.24 (2.02)

Coefficient estimates (robust standard errors) from 14 ordinary least squares (OLS) regressions – that is, each coefficient comes from a separate regression model where the column variable is the dependent variable and the row variable is the explanatory variable of interest. Each regression model also includes the full set of personal characteristics (see Tables I and II). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

had significantly lower expected probability measures. Meanwhile, the story is quite different when we examine the perceived consequence index: only nonexpert information (from neighbors and friends) is significantly correlated with this risk perception indicator.

4.4. Social Interactions

The preceding results show that information from neighbors and friends is positively and significantly associated with perceived probability and consequences of wildfire. This result previews the potential importance of horizontal peer-to-peer interactions in shaping individuals' perceived fire risk. Table IV examines these social interactions in more detail by reporting β_2 coefficients from social interaction regressions (Equation (2)). As above, these coefficients measure the association between risk perceptions and social interaction measures holding personal characteristics constant.

Results confirm that various types of interactions are associated with risk perception measures. As with the previous analyses, perceived fire probability tends to have significant associations with more variables than the perceived consequence index. Indeed, the probability index shows a strong correlation with fire-specific interactions, both formal and informal. Talking with one's neighbors about fire has the strongest positive relationship, followed by attending a fire-specific event. Respondents who report that the vegetation on neighbors' land is dense also have higher fire probability assessments. Although the magnitudes of the estimated coefficients are not as large, we also observe a couple of significant relationships between perceived probability of wildfire and generic social interactions. Respondents who participate in formal community groups tend to perceive that wildfire is more likely, and there is a marginally significant (i.e., significant at the 10% level) negative association between having neighbors in close proximity to the home and perceived fire probability. Turning to perceived consequences, the strongest association is with neighbors' vegetation density: individuals that perceive neighboring vegetation to be dense believe that fire would have larger consequences if it occurred. Two additional informal interaction measures are marginally significantly associated with the perceived consequence index. These include one generic indicator, physical proximity to neighbors, and one fire-specific measure, talking to neighbors about fire, both of which are associated with higher perceived consequences.

5. DISCUSSION

As the population at risk of wildfire grows, it is important to understand risk perceptions among homeowners in affected areas. This is of particular importance because current programs that educate property owners about wildfire assume that social effects are at play, but have little data about how specific processes amplify or attenuate risk perceptions. Although research on other hazards has examined these processes, the work presented here is the first to look at whether wildfire information sources and social interactions amplify or attenuate wildfire risk perceptions and the relative magnitude of such effects. We organize our discussion around three questions. First, we examine whether the results of our empirical analyses support the hypotheses coming out of the conceptual framework. Second, we discuss

some of the limitations of our study and possible extensions that could address these shortcomings. Finally, we offer some possible implications of this line of research for wildfire mitigation policies.

5.1. Do Our Results Support the Stated Hypotheses?

H1: Social amplification processes will have less influence on the perceived probability of wildfire risk than on the perceived consequences of wildfire risk.

The results of this study do not support this hypothesis. Across the many different analyses, the evidence suggests that the perceived *probability* of wildfire shows more evidence of social amplification than perceived *consequences*. This runs somewhat counter to the fire science discussion, since from a technical perspective local social context should have little effect on fire probability, but may affect consequences (e.g., through risk interdependency). What we are seeing suggests people are learning and shaping their beliefs about the likelihood of fire through diverse social channels, whereas beliefs about the consequences of fire seem relatively independent of information sources and social interactions. It appears that respondents' beliefs about how damaging a fire would be were not generally related to where they received information about wildfire or social interactions. This could be the case if, for example, people exhibit optimism bias⁽⁵³⁾ and tend to think that fire, even if it occurred, would not be particularly damaging to their property.

The two exceptions are receiving information from neighbors or friends, and perceiving that neighbors have dense vegetation, both of which do increase perceived consequences. The latter suggests possible awareness of risk interdependency, which we discuss in more detail below.

H2: Use of expert and nonexpert information sources will be positively associated with wildfire risk perceptions.

Our results support this hypothesis. In particular, we find that receiving information from expert and nonexpert sources increases the perceived probability of experiencing a wildfire. As expected, the strongest relationships are with sources that have the potential to offer personalized information, such as the VFD and neighbors/friends. These findings corroborate other fire studies that emphasize the importance of one-on-one interaction and the importance of local sources rather than media sources for pro-

viding personalized risk information.^(27,28) This is further corroborated by the relative importance of the role of the county wildfire specialist in perceived likelihood of fire, as we know that fire education and outreach programs in both counties included in this study include specialists who perform parcel-level risk evaluations and attend local meetings to provide more personalized fire information. However, the lack of data on the content of the information received precludes us from firmly concluding that this "personalization effect" is indeed responsible for the relationships we observe. Exploring the importance of personalized information constitutes an area for further inquiry.

Another notable result is that receiving information via the media is not associated with risk perceptions. Some prior studies and the fact that news coverage is nearly ubiquitous and often dramatic during major events would suggest that media would tend to amplify risk perceptions.^(54,55) However, our results are more in line with studies that have found a limited role of mass media sources in shaping individuals' perceptions of hazards.^(56,57) It is possible that the limited effects are related to the fact that our focus is not on media as a source of information during or in the immediate aftermath of a wildfire event. We speculate that this result could also be driven by the location of the study, an area that has active wildfire programs at all levels of government. It is possible that residents in this area are not influenced by the information provided by media, either because they do not deem it to be credible or because they already received it from other sources. In areas where outreach efforts are lacking and citizens are initially less informed, we might expect media sources to have an effect on risk perceptions.

We also find that respondents who reported that they had not received wildfire information from any source tended to think that fire was significantly less likely than individuals receiving information from at least one source. This suggests that not receiving wildfire risk information may attenuate perceptions of the probability of a wildfire. As previously noted, however, causality may also run in the opposite direction, with individuals who do not think fire is likely engaging in less information-seeking.⁽³⁰⁾ Further study of these information-seeking and processing behaviors is another priority for future work.

H3A: Fire-specific social interactions will increase perceived wildfire risk more than generic social interactions.

The results support this hypothesis. The social interaction variable most strongly associated with perceived probability of experiencing a fire is talking with one's neighbors about fire (an informal interaction), and the second strongest association is with attending a fire-related event (a formal interaction). Thus, the distinction between *formal* and *informal* interactions appears less important, in that both types of interaction show strong relationships with risk perceptions, compared to the distinction between *fire-specific* and *-generic* interactions. We note, however, that generic interactions are not totally irrelevant. In particular, participating in a community group is associated with higher perceived probability of experiencing a fire. This may reflect the fact that in the unincorporated areas of the wildland-urban interface, community groups often provide the infrastructure of WUI neighborhoods—including managing community resources such as road maintenance and other community business that may require awareness of wildfire risk management. These groups also provide venues for wildfire outreach programs to gain entrée into communities. Thus, even nonfire-specific events may play a role in the spread of wildfire information, norms, and perceptions.

H3B: Perceptions of fuel density on neighbors' property will be positively associated with wildfire risk perceptions.

Finally, our risk interdependency hypothesis also finds support in these data. Perceiving that neighbors' vegetation is dense is associated with higher perceived probability and consequences of wildfire. As noted above, these results may provide evidence that homeowners are aware of the interdependent nature of wildfire risk in the WUI.

5.2. What Are the Limitations of Our Study?

We acknowledge a few important limitations of this study. First, our cross-sectional survey data allow us to examine *associations* among different variables in our data set, but not necessarily *causal relationships*. For example, although we can say that people who talk to their neighbors about fire tend to believe that fire is more likely compared with people who do not talk to their neighbors about fire, we cannot say that talking to one's neighbors causes respondents to increase their wildfire risk perceptions. Indeed, it is quite possible that people who are more worried about fire initiate conversations with neighbors on this topic. Similarly, as we have al-

ready noted, it is likely that risk perceptions play an important role in information-seeking behaviors,⁽³⁰⁾ and that this is partially responsible for the finding that risk perceptions are lower among individuals who have not received any fire-related information. Noncausal results are still informative, however: what we have shown is that there is *some relationship* between social context (information and interactions) and risk perceptions. In all likelihood, causality runs in both directions, in a back-and-forth manner that is at the heart of the social amplification process. People with high risk perceptions seek out information, which further reinforces risk perceptions, while those who do not are left out. Our study takes an important first step in highlighting one end result of this process—the association between social processes and risk perceptions—while uncovering more specific mechanisms and causal relationships is left to future work.

A somewhat related concern that we have already mentioned is our lack of more specific data on the content of information that was received from different sources, or on the precise nature of the social interactions in which respondents engage. One area where this is particularly important is in relation to our conjecture that the information sources we found to be most strongly related to risk perceptions, such as the VFD and the county wildfire specialist, are those that have the potential to provide more personalized information to WUI residents. In a cross-sectional, quantitative survey, it would be difficult to comprehensively measure the specific messages that individuals received from a wide variety of sources, particularly because the respondents are from many communities in the two counties. Since community-level programs vary widely, pursuing such a line of inquiry might be better suited to a qualitative study with the ability to “drill down” and analyze the content of information and interactions in more detail.

Finally, we note that our findings are specific to the sample of Boulder and Larimer County respondents. For the purposes of this article, we are primarily interested in a relational model that looks closely at how risk perceptions relate to information sources and social interactions for this particular group of individuals, and we are careful to note that the relationships we observe in this setting may not translate to other groups. Attempts to generalize beyond this sample would need to grapple with the question of, first, whether our sample is representative of the Boulder/Larimer WUI as a whole, and, second, whether results from this area are likely to translate

to other WUI areas in Colorado and elsewhere. Regarding the former question, we note that the invitation to participate in the survey was sent to a random sample of WUI residents in Boulder and Larimer Counties such that, nonresponse bias aside, our sample should be fairly representative of this area. We are more cautious in generalizing to other populations. However, it is likely that there are WUI areas across the American West that exhibit similar characteristics to the study area. Indeed, we expect that the main results from our research—for example, the importance of both vertical and horizontal information sources, and of fire-specific social interactions, in shaping wildfire risk perceptions—are unlikely to be purely artifacts of our particular sample.

5.3. How Can the SAR Framework Inform Wildfire Mitigation Policies?

The conceptual contribution of the SAR framework in the context of wildfire mitigation policy making is a renewed emphasis on the importance of social context, alongside “fire science,” in shaping individuals’ perceptions of the probability and consequences of wildfire for homeowners in fire-prone areas. Since risk perceptions are likely to be one of the key factors influencing whether or not individuals take action to reduce their own and their communities’ risk^(9,26,50)—for example, by managing fuels on their property, purchasing fire insurance, or evacuating their home in the event of a fire—understanding and incorporating this social context into mitigation policy making may improve policy outcomes.

As described at the outset, Community Wildfire Protection Plans (CWPPs) have been one prominent effort to incorporate social processes into the wildfire mitigation landscape in the United States. Based on our results, there are several reasons to see CWPPs and related efforts as a promising approach to wildfire mitigation. First, our results show that both expert and nonexpert information sources have the potential to shape homeowners’ wildfire risk perceptions. CWPPs offer both, incorporating the types of experts that our results showed to be important (e.g., VFD, county specialists) while also providing opportunities for horizontal (and likely fire-specific) communication among community members.

Other results offer a point of caution, however. In particular, we note that community-based programs are not likely to reach all members of the community, and that the people that choose not to

attend these events or seek out wildfire-related information may be those who do not think fire is a problem (i.e., the people policymakers may most want to reach). As such, community-based programs may need efforts to more actively reach out to *all* community members, not just those who already think fire is an issue. These efforts may be able to build on our finding that homeowners perceive a connection between the conditions of their neighbors’ properties and their own risk. By continuing to emphasize these linkages, CWPPs and other fire programs may be able to galvanize collective efforts to address wildfire risk at scales beyond the individual parcel.

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