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Research article

Landowner response to wildfire risk: Adaptation, mitigation or doing nothing

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ABSTRACT

Wildfire has brought about ecological, economic, and social consequences that engender human responses in many parts of the world. How to respond to wildfire risk is a common challenge across the globe particularly in areas where lands are controlled by many small private owners because effective wildfire prevention and protection require coordinated efforts of neighboring stakeholders. We explore (i) wildfire response strategies adopted by family forestland owners in the southern United States, one of the most important and productive forest regions in the world, through a landowner survey; and (ii) linkages between the responses of these landowners and their characteristics via multinomial logistic regression. We find that landowners used diverse strategies to respond to wildfire risk, with the most popular responses being "doing nothing" and combined adaptation and mitigation, followed by adaptation or mitigation alone. Landowners who had lost properties to wildfire, lived on their forestlands, had a forest management plan, and were better educated were more likely to proactively respond to wildfire risk. Our results indicate the possibility to enhance the effectiveness of collective action of wildfire risk response by private forestland owners and to coordinate wildfire response with forest conservation and certification efforts. These findings shed new light on engaging private landowners in wildfire management in the study region and beyond.

1. Introduction

Wildfire, though an integrative part of terrestrial ecosystems, has become a contentious issue in recent decades in the United States (US) and many other parts of the world, as it posts threat to properties and human life as well as ecosystems (Food and Agriculture Organization of the United Nations, 2007; Bracmort, 2012). Driven by human and natural forces such as climate change, human population growth, and vegetation change, this threat is anticipated to intensify in the future (Pechony and Shindell, 2010). Alleviating the threat calls for new or modified human interventions, which generally include mitigation (to reduce wildfire risk) and adaptation (to reduce wildfire-caused loss and impact when it occurs). Such interventions, however, are challenging, particularly in areas where coordination of actions by many diverse individuals with different interests is inevitable, because effective wildfire prevention and protection require collective actions of spatially adjacent stakeholders (Kittredge, 2005). Additionally, because wildfire prevention and protection are more like a public good, potential free riding on the benefits generated from wildfire interventions implemented by others adds to the complexity of coordinating collective responses to wildfire risk (Ostrom, 1990; Reddy, 2000).

To enhance the effectiveness of collective wildfire responses, it is imperative to understand how and why individuals respond to wildfire risk. Drawing on the behavior of non-industrial private or family forestland owners in their response to wildfire, this study is intended to shed light on this quest. Specifically, we aim to identify (i) wildfire response options adopted by family forestland owners in the southern United States and (ii) factors influencing their adoption of wildfire response options. The southern United Station is one of the most important and productive forest regions in the world (Food and Agriculture Organization of the United Nations, 2014). The region's forestlands are primarily owned by family landowners of diverse attributes (Butler et al., 2004; Smith et al., 2009). Hence, it is an ideal region to study wildfire risk response

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by private forestland owners.

A common wildfire response in recent decades, particularly in developed countries has been fire suppression carried out primarily by national and state or provincial government agencies (Food and Agriculture Organization of the United Nations, 2007). Wildfire suppression is costly, and it alone may not be effective in wildfire management. In the US, for instance, wildfire suppression costs incurred by US federal agencies alone have skyrocketed over the past few years, averaging almost US$1.5 billion annually since 2000 (National Interagency Fire Center, 2014). Fire suppression can meet, to some degree, the immediate or short-term need to protect properties, lives, and natural resources. Yet, excessive wildfire suppression could cause a greater accumulation of vegetation fuels on the ground, thus increasing fire intensity and damage when it occurs (US Department of Agriculture (USDA) and US Department of Interior, 2000; Schoennagel et al., 2004). Hence, other wildfire response options besides suppression should also be part of the solution (Food and Agriculture Organization of the United Nations, 2007). These other responses range from wildfire mitigation measures such as fuel treatments (mechanical or prescribed burning) to adaptation activities such as wildfire insurance and to combined adaptation and mitigation efforts. These efforts are typically carried out by landowners, private and public alike.

A considerable amount of research has been done on wildfire responses on public lands in the US and elsewhere. Among these responses are vegetation fuel treatments, which use mechanical means or prescribed burning to reduce fuel loads on the land, thus decreasing wildfire hazards and intensity when it occurs (Graham et al., 2004; Agee and Skinner, 2005; Reinhardt et al., 2008; Fernandes et al., 2014). However, studies aimed at understanding how and why private individuals/households respond to wildfire risk and enhancing the effectiveness of their collective responses are rare, although wildfire prevention and protection are more complex and challenging on private lands than on public lands. For instance, the concept of fuel treatments appears applicable to private landowners, yet the high cost of mechanical treatments (Rummer, 2008) may discourage private landowners from adopting them. Fuel treatments can be much more easily implemented and coordinated on public land than on private land held by many diverse small owners (Busby and Albers, 2010; Fischer and Charnley, 2012).

Among the few existing studies on the responses of private landowners to wildfire risk, the focus has been on a specific response type (e.g., fuel reduction) instead of a wide spectrum of response options including doing nothing, mechanic fuel reduction treatments, prescribed burning, fire line construction, and insurance. In terms of wildfire mitigation activities, Fischer (2011) examined factors influencing the decisions of non-industrial private forestland owners to implement fuel reduction treatments in the western US. Kaval et al. (2007) and Walker et al. (2007) estimated willingness-to-pay of landowners for vegetation fuel treatments. Comparisons of the willingness-to-pay with fuel treatment costs could reveal whether these landowners would adopt fuel treatments on their lands and/or support fuel treatments on neighboring public or private lands in a financial perspective. A study in Australia found that the owners of private conservation lands did take some action to reduce vegetation fuel hazards, but directed much greater efforts to other conservation management than to wildfire management (Halliday et al., 2012).

Insurance has long been considered a wildfire adaptation option for private landowners (Yatagai, 1933; Shepard, 1935, 1937). Participation of private landowners in wildfire insurance markets could be influenced by gender, education, ownership type, and previous property damage caused by fire and other disturbances (Gan et al., 2014). Also, lower income households are less able to afford fire insurance and protection services than their richer neighbors, leading to poor households bearing a disproportionate amount of wildfire losses (Collins, 2008).

In this paper, we intend to examine a wide spectrum of wildfire response options ranging from “doing nothing” to adaption or mitigation alone and to combined adaption and mitigation. This will enable us to investigate how and why private landowners may adopt a specific wildfire response from a complete set of responses available to them. It not only better reflects the reality of wildfire responses by private landowners, but also provides a more comprehensive figure of landowners' preferences over different wildfire response options. Our findings provide insights into the behavior of these landowners in response to wildfire risk and the driving forces of their behavior, contributing to the literature and informing policy to engage private landowners in addressing the pressing and complex wildfire issue.

2. Methods

2.1. Landowner survey and wildfire response classification

A landowner survey was conducted to identify the responses of family forestland owners to wildfire risk in the southern US. This region consists of 13 states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. It is considered one of the most productive and important forest regions nationally and globally. Forests in this region supply approximately 60% of roundwood in the US market and over 14% of industrial roundwood in the world (Smith et al., 2009; Food and Agriculture Organization of the United Nations, 2014), in addition to non-timber benefits ranging from carbon storage to water regulation (USDA Forest Service, 2012).

Family forestland owners possess approximately 60% of timberlands in the region (Smith et al., 2009). These landowners have diverse ownership objectives, forest tract sizes, and socioeconomic characteristics (Butler et al., 2004). Although the region differs from other US regions in terms of biophysical conditions, forest type, and forest ownership structure, it faces a similar wildfire threat. Wildfire has recently become an increasing concern for forestland owners and local residents in the region, despite the fact that it has played an important role in ecosystem dynamics and human history (Stanturf et al., 2002; Fowler and Konopik, 2007).

Our survey targeted the population of family forestland owners who owned 10 acres or more of forestland in Alabama, Florida, Georgia, Mississippi, and South Carolina. We drew the survey sample of 2500 landowners from the population via cluster sampling (500 from each state). We employed a mail survey, which was designed and administrated following the standard approach proposed by Dillman et al. (2009). We received 585 surveys, yielding a response rate of 24.7% after excluding 127 undeliverable mails. The response rate is typical for this kind of surveys in the region (Molnar et al., 2007), and the key characteristics of the survey respondents resemble those of the study population (Jarrett et al., 2009). Of the 585 surveys received, 37 survey participants provided inconsistent or missing answers to the questions about how they responded to wildfire risk. One example of inconsistent answers was when a landowner simultaneously selected “doing nothing” and a mitigation or adaptation option. These inconsistent answers were removed; the remaining 548 observations were used in this analysis.

The survey instrument consisted of 30 questions pertinent to landowners' experience with wildfire, perception of wildfire risk, wildfire response strategies, awareness of wildfire assistance programs, forest tract features, ownership objectives, and

demographic and socioeconomic characteristics. Except for two questions asking about the age of the landowner and the percentage of his or her household income from rural land, answers to all other questions were multiple choices. Table 1 summarizes the main survey questions that were contained in the survey instrument and are relevant to this paper. More details about the survey design, implementation, and responses are provided in Jarrett et al. (2009). While Jarrett et al. (2009) addressed landowners' awareness of wildfire assistance programs and their overall response to wildfire threat (i.e., whether or not a landowner took any action to respond to wildfire threat), this paper goes one step further to examine the different response options taken by these landowners and the factors attributable to their actions.

There were multiple choices for answers to the survey question regarding wildfire response adopted by a survey participant. These choices included doing nothing, removing unwanted trees or shrubs, constructing fire line, buying wildfire insurance, and other (to be specified by the survey respondent). Survey participants were asked to select or specify all wildfire response options they had adopted. This open-ended answer allowed the landowner to provide all wildfire response measures he or she had taken in addition to those listed in the multiple choices. Among the returned surveys, prescribed burning dominated the "other" wildfire response option. Based on his or her answer in the survey, a landowner's wildfire response strategy was classified as one of the four categories: doing nothing, adaptation, mitigation, and both adaption and mitigation. Because these four categories were complete and mutually exclusive, a landowner's wildfire response option(s) could be classified into one and only one of the categories.

Mitigation options including mechanical treatments of vegetation fuel and prescribed burning can directly reduce wildfire risk. Adaptation choices, though not intended to directly reduce wildfire risk, can alleviate the adverse impacts of a wildfire on the landowner when it occurs. Purchasing wildfire insurance and constructing fire line were two major adaptation options adopted by these landowners. We classified fire line construction as adaptation rather than mitigation because the main reason for building a fire line is to prevent external fires from spreading into the landowner's property. Thus, to the landowner, the fire line built did not affect the occurrence of fires outside (adjacent to) the property but could reduce the damage of these external fires to the owner's property.

This classification of wildfire responses is not only mutually excludable but also inclusive or complete (i.e., all wildfire response alternatives can be represented by one of these four categories). The inclusiveness is helpful in lessening possible complications resulting from the potential violation of the Independence of Irrelevant Alternatives (IIA) assumption in multinomial logistic regression. The IIA assumption implies that the odds ratio of choosing one option over another does not change when a new "irrelevant" option is added (Greene, 2008).

2.2. Multinomial logistic regression

We applied the random utility model (RUM) to analyzing landowners' adoption of wildfire response options. The RUM is a widely used tool for examining consumer choices of products and services (Manski, 1977; Baltas and Doyle, 2001). A landowner may have several available wildfire response options. The utility for

Table 1
Descriptions of variables included in the multinomial logistic regression.

Variable	Value	Frequency or mean[a]
Dependent variable		
Response to wildfire risk	doing nothing = 0	0.307
	adaptation = 1	0.197
	mitigation = 2	0.195
	adaption & mitigation = 3	0.301
Independent variables		
Presence of wildfire on the land in the last 10 years	yes = 1, no = 0	1: 0.276
Property loss caused by wildfire in the last 10 years	yes = 1, no = 0	1: 0.232
Belief in the potential of the land to be burned by wildfire	yes = 1, no = 0	1: 0.961
Gender	female = 1, male = 0	1: 0.265
Age	40 or younger = 0,	0: 0.024
	40–49 = 1, 50–59 = 2, 60	1: 0.132
	or older = 3	2: 0.318
		3: 0.526
Race	white = 1, non-white = 0	1: 0.915
Personally managing the land	yes = 1, no = 0	1: 0.876
Living on the land	yes = 1, no = 0	1: 0.522
Timber production	yes = 1, no = 0	1: 0.705
Possession of a forest management plan	yes = 1, no = 0	1: 0.529
Pine beetle infestation on the property	yes = 1, no = 0	1: 0.345
Hurricane hit on the property	yes = 1, no = 0	1: 0.230
Education	less than high school = 0,	0: 0.023
	high school graduate = 1,	1: 0.281
	college or technical	2: 0.397
	school graduate = 2,	3: 0.299
	greater than 4-year	
	degree = 3	
Annual household income	lower than $30 k = 0,	0: 0.143
	$30 k~49 k = 1,	1: 0.134
	$50 k~69 k = 2,	2: 0.162
	$70 k~89 k = 3, $90 k-	3: 0.126
	119 k = 4, $120 k or	4: 0.165
	higher = 5	5: 0.270
Percent of household income from rural land	0–100	11.63 (22.40)[b]
Internet access	yes = 1, no = 0	1: 0.733

[a] All are frequencies except for the one denoted by the superscript b.
[b] Mean with standard deviation in parentheses.

landowner i to adopt response option j can be written as $U_{ij} = \beta' \mathbf{X}_{ij} + \varepsilon_{ij}$, where $\mathbf{X}_{ij}$ is the vector of characteristics of choice j and landowner i, β is the vector of coefficients associated with $\mathbf{X}_{ij}$, and ε_{ij} is the random disturbance.

The landowner will take option j from a total of n choices available to him or her if $U_{ij} > U_{ik}$ for all $k \neq j$. Thus, the probability for landowner i to choose option j is $Pr(U_{ij} > U_{ik})$ for all $k \neq j$. This can be written as

$$P_{ij} = Pr(Y_i = j) = F(\beta' \mathbf{X}_{ij}). \quad (1)$$

Two widely used link functions to convert (1) to a linear function are the logistic distribution function and the normal distribution function. For computational convenience, the logit is often used when responses are multinomial (Greene, 2008).

We employed the multinomial logit model in this study. With the normalization of $\beta_r = 0$ (r being the reference response), our model takes the form:

$$ln\left(\frac{P_{ij}}{P_{ir}}\right) = \beta_j' \mathbf{X}_{ij}. \quad (2)$$

We adopted an interactive stepwise approach to empirically specify the multinomial logit model. This approach involved three steps. First, we selected a set of independent variables that were likely to influence landowners' decisions on responding to wildfire risk. These variables range from the characteristics of forestlands and their owners to landowners' perception of and experience with wildfire and other natural disturbances. Table 1 shows the descriptions of these variables along with their measurements and descriptive statistics.

Second, the stepwise backward approach was then used to eliminate statistically insignificant independent variables one by one and to estimate a pre-final regression model. Independent variables were eliminated from the model based on a chi-square (Wald) statistic and its associated P-value. All independent variables with a P-value greater than 0.10 were removed. P-value used for variable selection in regression modeling ranges from 0.05 to 0.20; $p = 0.10$ reflects the average of this range. Also, the interactive stepwise approach can minimize the possibility of leaving some significant variable out of the model even though a lower p-value is used.

Third, the stepwise forward approach was employed to re-enter the previously eliminated independent variables, one by one, into the model. The independent variable with a P-value greater than 0.10 was removed; others remained. Steps 2 and 3 were repeated interactively until the model converged, which derived the final regression model. The final model was further validated using several statistical tests in addition to the chi-square test for significance of individual variables, including the log likelihood, likelihood ratio, and Wald tests. No evidence of multicollinearity among the independent variables in the final model was found according to the variance inflation factor (VIF) and simple correlation coefficients. SAS version 9.3 (SAS, 2011) was used in the modeling.

3. Results and discussion

3.1. Landowner response to wildfire risk

Of the 548 observations (survey responses) valid for this analysis, 168 landowners (30.7%) did nothing to lessen wildfire risk; 108 landowners (19.7%) took only adaptation actions; 107 landowners (19.5%) adopted only mitigation measures; and 165 landowners (30.1%) employed both adaptation and mitigation (Table 1). This indicates that landowners used diverse options in response to wildfire risk. Although almost one-third of landowners were not proactive, the majority of them did something to protect their forestlands from wildfire. Interestingly, almost the same proportion of landowners either did nothing or adopted both adaptation and mitigation measures, suggesting that a similar number of landowners either were very serious about wildfire threat or did not take any action against the risk.

3.2. Factors influencing landowner response to wildfire risk

The final multinomial logistic regression model (Table 2) passed several statistical tests. The −2 log likelihood, likelihood ratio, and Wald tests all indicate that the independent variables are jointly significant ($P < 0.001$) in predicting the log odds ratio of landowner response to wildfire risk relative to "doing nothing".

Previous property loss caused by wildfire was a significant predictor of a landowner's adoption of adaptation and combined adaptation and mitigation. Landowners who had previously experienced a wildfire-caused property loss were much more likely to employ adaptation or combined adaptation and mitigation relative to "doing nothing" than those who had not suffered from a property loss resulting from a wildfire. The odds ratio for the former to adopt adaptation and both adaptation and mitigation versus "doing nothing" was approximately 1.2 and 3.9 times higher than that for the latter, respectively. However, previous experience with a wildfire-caused property loss did not affect the probability that the landowner took a mitigation action relative to "doing nothing". This implies that a previous wildfire loss would prompt the landowner to take wildfire response measures associated with adaptation, especially more comprehensive measures (i.e., both mitigation and adaption). However, because it would take some time for trees to re-establish or recover after a fire, a preceding fire would reduce the urgency of wildfire mitigation (e.g., fuel reduction treatment), thus lessening the propensity of the landowner to adopt a mitigation-alone measure.

Landowners residing on their forestlands were more likely to adopt any of the three proactive wildfire response options than those who did not live on their lands, echoing the previous finding that residential landowners were more willing to implement fuel reduction treatments (Fischer, 2011). The odds ratio to employ adaptation, mitigation, and both adaptation and mitigation versus "doing nothing" was, respectively, approximately 1.1, 2.0, and 3.6 times higher for landowners residing on their forestlands than that for non-residential landowners. Interestingly, the odds ratio increases considerably from adaptation to mitigation and to combined adaptation and mitigation. This suggests that landowners living on their forestlands were concerned more about personal safety than about their properties. Adaptation alone could not reduce wildfire risk and thus threat to human life whereas mitigation or combined adaptation and mitigation options could.

Landowners who managed their lands for timber production also tended to be reluctant to employ wildfire mitigation options, compared to those who did not produce timber from their lands. This may be partly due to the fact that some timber management practices (e.g., pre-commercial and commercial thinning, prescribed burning, etc.) can also reduce wildfire risk, generating a similar effect of wildfire mitigation options. Thus, additional wildfire mitigation efforts seemed unnecessary for these landowners.

Landowners who had a forest management plan were much more likely to adopt wildfire adaptation, mitigation, and combined adaptation and mitigation measures relative to "doing nothing". The odds ratio for this group of landowners to adopt adaptation, mitigation, and combined adaptation and mitigation options

Table 2
Maximum likelihood estimates of the multinomial regression model.

Parameter[a]	Wildfire response[b]	Estimate	Odds ratio	Wald chi-square	P-value
Intercept	1	−2.2739		20.4930	<0.0001
	2	−1.7783		13.8759	0.0002
	3	−3.1124		38.0803	<0.0001
Wildfire-caused property loss	1	0.8058	2.238	4.6996	0.0302
	3	1.5789	4.850	20.8043	<0.0001
Live on the land	1	0.7385	2.093	5.7965	0.0161
	2	1.0853	2.960	12.0456	0.0005
	3	1.5293	4.615	26.3454	<0.0001
Timber production	2	−0.6509	0.552	3.8843	0.0487
Forest management plan	1	1.7275	5.626	29.2681	<0.0001
	2	1.7723	5.884	28.9159	<0.0001
	3	2.1840	8.882	48.3859	<0.0001
Pine beetle infestation	1	−0.5617	0.570	3.1676	0.0751
	2	−0.5490	0.578	2.7566	0.0969
	3	−0.8905	0.410	8.3285	0.0039
Education	3	0.5900	1.804	10.8224	0.0010
−2 Log Likelihood (intercept and covariates)		1082.82			
Likelihood ratio		148.36			
Wald		111.59			

[a] Only the independent variables with a P-value < 0.10 are listed.
[b] See Table 1 for the wildfire response codes. Doing nothing was used as the reference category.

relative to “doing nothing” was 3.8, 4.7, and 7.9 times higher than that for landowners without a forest management plan, respectively. This is parallel to the previous finding that landowners with a written forest management plan tended to take action to prevent their forests from being infested by the southern pine beetle, another major disturbance to pine forests in the southern US (Molnar et al., 2007). A management plan is usually written by a professional forester who is aware of wildfire risk and often incorporates fire prevention and protection measures into forest management practices. Thus, following the guidelines set up in a forest management plan would automatically prompt the landowner to implement wildfire prevention and protection activities.

The owners of forests infested by pine beetles would rather do nothing than adopt adaption, mitigation, or both. Although trees damaged by beetles were more susceptible to fire, these trees also became less valuable to landowners. Hence, they were less motivated to take additional wildfire protection and prevention measures.

Landowners with a higher level of education were more likely to adopt combined adaptation and mitigation versus “doing nothing”. On average, an increase in landowners’ education by one level would increase their odds ratio to use both adaptation and mitigation measures relative to “doing nothing” by 80%. Hence, education stimulates landowners to implement more comprehensive response activities against wildfire threat. This also reflects the previous finding that education makes people become more risk averse (Hersch, 1996).

Other demographic and socioeconomic characteristics of landowners such as age, gender, race, and annual household income did not show a significant impact on landowner response to wildfire risk. This does not seem to be a surprise. Age has been found to have a mixed effect on farmers’ risk preference (Picazo-Tadeo and Wall, 2011). Previous studies also suggest that women in general are more risk averse than men (Jianakoplos and Bernasek, 1998; Eckel and Grossman, 2008) and that female landowners were more likely to purchase wildfire insurance than males (Gan et al., 2014). However, in terms of overall response to wildfire risk including the combination of wildfire insurance purchase with other adaption options, gender did not make a statistically significant difference. Additionally, our regression result did not show a statistically significant difference in wildfire risk response among different racial backgrounds of landowners. Only 8.5% of our survey sample was minorities (Table 1), which might have prevented us from detecting racial difference in response to wildfire risk.

The insignificant effect of income on landowner response to wildfire risk may be attributable to the complex relation between income and risk preference (Arrow, 1965; Cleeton and Zellner, 1993). An increase in income would increase relative risk aversion but decrease absolute risk aversion (McKee, 1989), contributing to the ambiguity of income effect on landowner response to wildfire threat.

Surprisingly, although approximately 96% of landowners believed that their lands could be damaged by wildfire, their belief did not prompt them to take action against the threat. The mystery of the disparity between landowners’ belief and action invites additional research efforts, although the complexity of the wildfire issue and the public good nature of wildfire mitigation could be part of the reason behind.

Finally, the three intercepts are all negative and statistically significant at the 1% significance level (Table 2). Thus, landowners, who had not encountered property damage by wildfire or pine beetles, did not live on their forestlands, had no forest management plan, did not produce timber, and had an education less than high school, tended to do nothing against wildfire risk.

4. Conclusion

We employed landowner survey data and multinomial logistic regression to identify (i) wildfire risk response strategies used by family forestland owners in the southern US and (ii) factors attributable to their adoption of wildfire response strategies. We found that these landowners used diverse strategies to respond to wildfire risk, with the most common being “doing nothing” and combined adaptation and mitigation, followed by adaptation or mitigation alone. Many factors contributed to landowners’ selection of wildfire response options. Landowners who had lost properties to wildfire, lived on their forestlands, had a forest management plan, and were better educated were more likely to take some action (adaptation, mitigation, or both) in response to wildfire risk. On the other hand, those who produced timber or had experienced pine beetle infestations were more likely to do nothing against wildfire risk.

Our findings have several implications for wildfire protection and prevention on private forestlands in the region and beyond as well as for future research. First, the majority of family forestland owners in the southern US did take some measure against wildfire risk although their wildfire risk response strategies were diverse. This

points to the possibility of encouraging individual landowners to consider collective actions to promote the common interest of wildfire prevention and protection in the region. Given the diverse responses adopted by these landowners, however, some coordination of their response efforts is needed to ensure the overall effectiveness of their individual actions. How and who would coordinate such efforts are yet to be answered. Second, landowners' belief in wildfire risk (stated risk) did not necessarily lead to their action against the risk; yet those who lived on their lands or had experienced wildfire-caused property losses were more likely to proactively respond to wildfire risk. Hence, personal safety and economic consequences of wildfire, instead of stated risk of wildfire, were the major drivers for landowners to take action against wildfire threat. Incorporating these considerations into designing coordination mechanisms for wildfire response by private landowners can improve the effectiveness of their collective actions. Third, possessing a forest management plan was highly and positively correlated with the propensity of landowners to respond to wildfire risk. Thus, assisting landowners in developing forest management plans can boost their wildfire risk response efforts. Additionally, a forest management plan is a prerequisite for a landowner to be enrolled in many conservation cost-sharing programs and sustainable forest management certification programs. Also, beetle infestations reduced landowners' motivation to take proactive action against wildfire risk, revealing the interconnection between overall forest health and landowner response to wildfire risk. These suggest that wildfire prevention and protection can be coordinated with forest conservation and certification programs and efforts.

Community-based wildfire management is globally recognized as one of the most sustainable and effective wildfire prevention and protection strategies (Food and Agriculture Organization of the United Nations, 2007). Engaging private landowners is an essential part of community-based wildfire management. This study shows new light on this aspect. Although our findings may have implications for other regions in the world, cautions should be taken in extending our results beyond the study region. Given regional differences in wildfire issues, effects, and management, a call for similar studies in other parts of the world is in order.

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