



TECHNICAL NOTE

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# Private landowner interest in prescribed fire in California: findings from workshops in the Sierra Nevada

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## Abstract

**Background** Globally, prescribed fire political interest and practice has been rekindled following recent devastating wildfire seasons. This phenomenon was especially acute in areas with dual wildfire and forest health crises, like California. Previous research has investigated prescribed fire on public lands or on private lands in other regions, but little is known about prescribed fire practice or interest on private lands in California. Therefore, we sought to understand private land managers' perceptions of prescribed fire compared to other land management techniques, treatment pathways, motivations, and barriers to complete these treatments in California.

**Results** Before workshops on prescribed fire for private lands, we surveyed participants in six prescribed fires on private lands workshops in the Central Sierra Nevada from 2018 to 2019 ( $N=172$ ). We found that participants "want to use" pile burns and broadcast prescribed fires more than other land management treatments. There was also a strong interest in mechanical treatments in contrast to low interest in grazing. Some participants had "heard about" and "want to use" some pathways to apply prescribed fire on their lands, including government programs, contractors, friends and family, and Prescribed Burn Associations (PBAs). People had multiple objectives for their prescribed fire goals, and the majority wanted to promote ecosystem health, e.g., reduce fire hazards, foster natural land health, and reduce invasive plants. Perceived barriers were greatest for safety, cost, and resources while fewer participants perceived permits as a barrier.

**Conclusion** Participants were in the early stages of considering using broadcast prescribed fire and would like to burn small areas, potentially to build confidence and skills. At the time of our research, there was strong interest in using prescribed fire on private lands, and some perceived best pathways and barriers to be unique from prescribed fire practice on public lands. At the same time, private lands managers who responded said they want to promote ecosystem health and reduce wildfire risk and impacts, which is a shared a common motivation with public lands managers. Studies and reports on prescribed burning need to clearly distinguish between broadcast prescribed burning and pile burning to ensure consistency in results and conclusions about prescribed fire use.

**Keywords** Prescribed fire, Sierra Nevada Mountains, California, Private lands, Workshops, Wildfire risk reduction, Cooperative extension, Capacity building

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## Resumen

**Antecedentes** Globalmente, el interés sobre las políticas y las prácticas de quemas prescritas han sido reavivadas luego de las recientemente devastadoras estaciones de fuego. Este fenómeno fue especialmente agudo en áreas con crisis duales de salud de los bosques e incendios, como en California. Investigaciones previas fueron desarrolladas sobre quemas prescritas en áreas públicas o predios privados en otras regiones, aunque poco es conocido sobre las prácticas de quemas prescritas o el interés en desarrollarlas en tierras privadas en California. Por ese motivo, decidimos entender las percepciones de los manejadores de tierras privadas sobre las quemas prescritas comparadas con otras técnicas de manejo, vías de tratamientos, motivaciones, y barreras para llevar a cabo esos tratamientos en California.

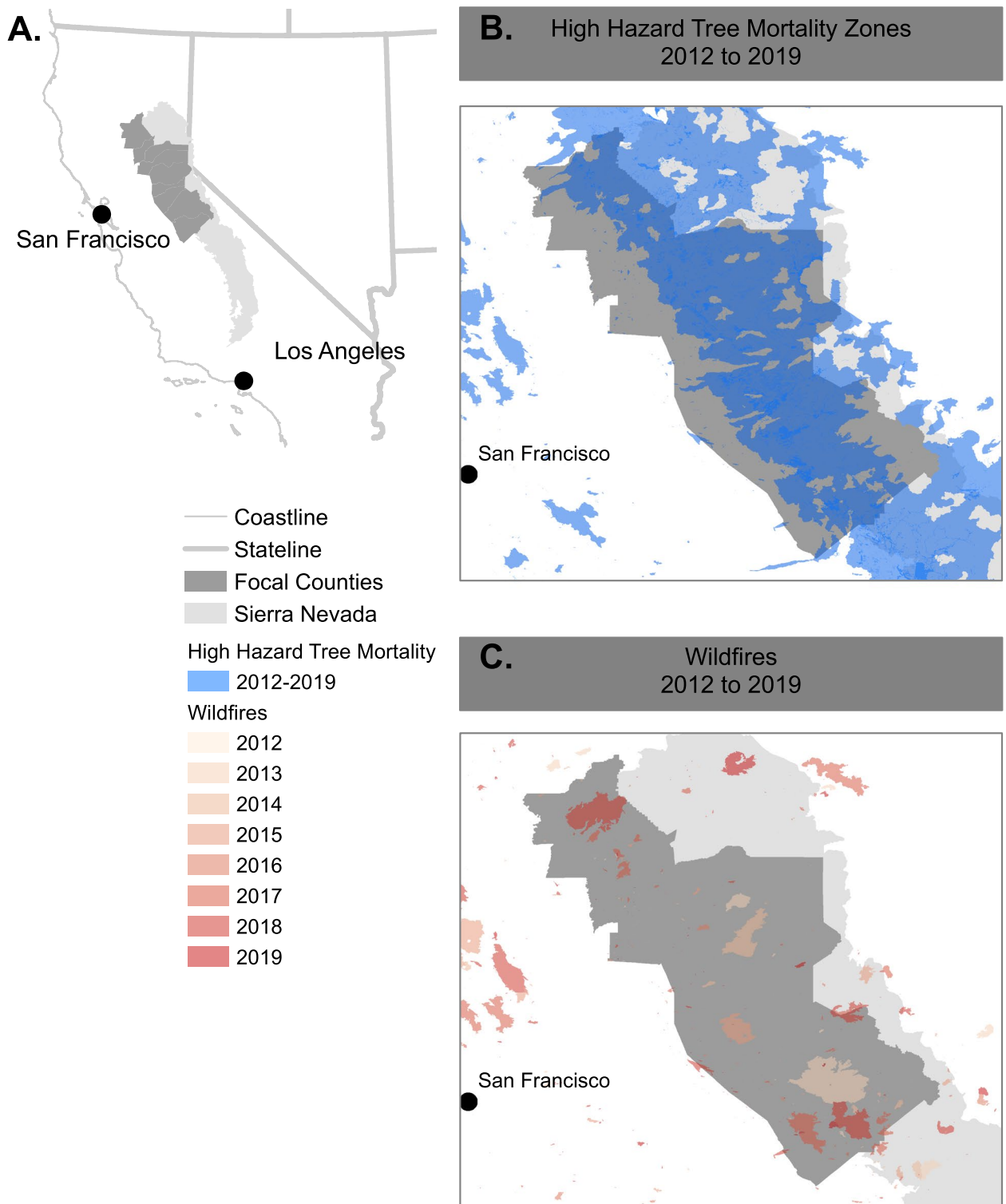
**Resultados** Antes de realizar talleres sobre quemas prescritas en áreas privadas, entrevistamos a participantes en seis quemas prescritas realizadas en talleres en campos privados en la Sierra Nevada Central entre 2018 y 2019 ( $N=172$ ). Encontramos que los participantes “querían usar” quemas en pilas y quemas prescritas expandidas sobre el terreno mucho más que otros tipos de tratamientos de la vegetación. Hubo también un fuerte interés en tratamientos mecánicos en contraste con un bajo interés por el pastoreo. Algunos participantes “habían oído” y “querían usar” algunas vías para poder aplicar quemas prescritas en sus predios, incluyendo programas gubernamentales, contratistas, amigos y familiares, y asociaciones de quemas prescritas (PBAs). Esa gente tenía múltiples objetivos para sus quemas prescritas, y la mayoría quería promover la salud del ecosistema (i.e. reducir el riesgo de incendios, propender a la salud natural del ecosistema, y reducir plantas invasoras). Las barreras que se percibieron fueron mayormente la seguridad, los costos, y los recursos, mientras que muy pocos percibieron a los permisos como barrera para la ejecución de las quemas.

**Conclusiones** Los participantes estaban en sus estados iniciales de considerar las quemas prescritas en grandes áreas, y preferían quemas en áreas pequeñas, preferentemente para ganar confianza y construir destrezas en la quema. En el momento de nuestra investigación, había un interés muy fuerte en usar las quemas prescritas en campos privados, y algunos percibían mejores vías y barreras para ser únicas en relación a las quemas prescritas en tierras públicas. Al mismo tiempo, los manejadores de tierras privadas que respondieron a la encuesta dijeron que ellos querían promover la salud de los ecosistemas y reducir al mismo tiempo el riesgo e impactos de los incendios, que es compartido como motivación común con los manejadores de tierras públicas. Los estudios y reportes sobre quemas prescritas deben distinguir claramente entre quemas en pilas y quemas en el terreno para asegurar la consistencia en los resultados y conclusiones sobre el uso de las quemas prescritas.

## Background

Fire, a natural ecological process, has been dramatically altered in the United States (US). Over a century of fire exclusion and suppression policies have caused a fire deficit in the western US. Prescribed fire is often suggested as a solution to this fire deficit issue, but most prescribed fire in the US occurs in the southeast (Kobziar et al. 2015; Kolden 2019; Statistica 2021). Historically, approximately 1.8 to 4.9 million hectares burned in California, USA, annually (4–12% of the land area) due to lightning and Indigenous ignitions (Stephens et al. 2007). There is a long history of Indigenous people and a recent history of other private landowners using prescribing fire in California. Indigenous peoples' burns were regular, and to improve travel routes, deer forage, and food and fiber crops among others (Anderson 2006). However, Indigenous peoples' burning changed due to disease decimating populations, forced removal from their lands in the 1800s, and genocide (Madley 2016). Furthermore, policies did not allow Indigenous peoples to continue their cultural burns (Norgaard 2014). As recently as the early

1900s, many private grass and shrub lands had prescribed fire (Biswell 1999) while there was great opposition to burning forest lands (Stephens et al. 2021). It became illegal in California in 1924, but permits were issued beginning in 1945 (van Wagtendonk 1995). State policies became restrictive in the mid-1960s and prescribed fires by private citizens and agencies nearly stopped. More recently, area burned remained lower than historically, and from 2012 to 2019 only 2.8 million hectares burned (2.7 million hectares during wildfire and 127,000 hectares during prescribed fire), with private individuals burning less than 2% of the prescribed fire acreage (Fire and Resource Assessment Program 2021). In contrast to the uncharacteristic, severe fire effects from recent wildfire events (Williams et al. 2023), prescribed fires facilitate fire as an ecological process under ideal conditions that allow managers to avoid detrimental fire effects. California's twin crises of declining forest health and increasing wildfire risk (Cisneros et al. 2018; Axelson et al. 2020) may be partially addressed via more prescribed fire (Fig. 1).



**Fig. 1** Map of study area includes (A) where the workshops were advertised (statewide and focal region, e.g., central and northern Sierra Nevada Mountains, California, USA (light gray)), workshop locations (dark gray, including including Amador, Butte, Calaveras, El Dorado, Mariposa, Nevada, Placer, Tuolumne, and Yuba Counties), (B) high hazard tree mortality zones (blue, 2012–2019), and (C) recent wildfires (green to red, 2012–2019). The 2012–2019 period most likely to influence participants before the 2018 and 2019 workshop series

Several authors investigated the fire deficit issue by exploring enablers of and barriers to prescribed fire on US public lands (Miller et al. 2020; Schultz et al. 2019; Quinn-Davidson and Varner 2011; Laband et al. 2008; Williamson 2007; Ascher et al. 2012; Cleaves et al. 2000). Fire prescribed outside of agencies or in cooperative groups, like Prescribed Burn Associations (PBAs) or hunting clubs, also occurs in the USA, particularly in the midwest and southeast where a larger portion of lands are private (as compared to the western USA). Some authors have begun to explore trends in prescribed fire use in private-land dominated spaces (e.g., Shrestha et al. 2021; Wilbur et al. 2021; Bendel et al. 2020; York et al. 2020; Kobziar et al. 2015; Wonkka et al. 2015; Toledo et al. 2014). There is an increasing need to explore prescribed fire on or across private lands in western USA, especially in states like California where the majority of acres are privately owned and the wildland urban interface is a significant concern.

We examined private land managers' (e.g., landowners, stewards, and advisers) perceptions of using prescribed fire on the private lands they manage. We surveyed a pre-workshop convenience sample of individuals who attended "Prescribed Fire on Private Lands" workshops facilitated by University of California Agriculture and Natural Resources (UCANR) in the central Sierra Nevada of California. We explore the following questions:

- (1) What characterizes individuals who want to learn about prescribed fire?
- (2) What land management treatments are individuals willing to use?
- (3) What land management pathways are individuals willing to use?
- (4) What motivates individuals to be interested in using prescribed fire on their land?
- (5) What barriers to prescribed fire do land managers perceive?

## Methods

The research occurred in central and northern Sierra Nevada, California, USA (Fig. 1A) (including Amador, Butte, Calaveras, El Dorado, Mariposa, Nevada, Placer, Tuolumne, and Yuba Counties). We chose this area because (1) land managers' interest has increased in prescribed fire following recent tree mortality (e.g., more than 100 million trees died in California from 2012 to 2019) (Fig. 1B) and catastrophic wildfires (e.g., 2017 Tubbs Fire; 2018 Camp Fire) (Fig. 1C) and (2) prescribed fire was underused in the region. UCANR facilitated and organized six in-person prescribed fire workshops in 2018 and 2019. We advertised through email listservs, newsletters, Facebook groups, local radio stations, and

local and regional online and print news (Appendix). All visual advertisements include photographs of broadcast burns. Registration cost \$20 USD per workshop or was waived for needs-based scholarships. Participation was limited by venue size (25 to 50 people) and most workshops had waitlists.

Participants were broadly anyone interested in learning more about implementing prescribed fire on private lands through a cooperative extension workshop. As a convenience sample, participants were asked to complete a pre-workshop paper survey upon arrival and before it began. Participants completed 183 surveys, but 11 were excluded because the participants did not manage private property, resulting in 172 relevant responses. All participants included in the study owned, managed, or assisted with management through advice or grants on private lands. Some participants had multiple relationships with private lands. We collected socio-demographic data by asking participants to answer fill-in-the-blank questions for age and gender and multiple-answer multiple-choice with an optional fill-in-the-blank questions regarding their professional and volunteer affiliations, uses of their lands, and their experience with prescribed fire (Tables 1 and 2). Respondents also answered a multiple-answer multiple-choice with an optional fill-in-the-blank question indicating the vegetation types present on the land they managed. Then, broadcast prescribed fire was clearly separated from pile burns in the survey. Participant interest in various land management treatments was measured with a 4-point Likert-type scale (Bryman 2012) (Fig. 2) where participants indicated if they were 0 = not interested, 1 = may be interested, 2 = likely interested, and 3 = definitely interested in a particular treatment option. Participant interest in prescribed fire assistance pathways was measured using check-boxes for (1) if they had heard about it, and (2) if they wanted to use it (Fig. 3). Participant were asked "I am \_\_\_\_\_ interested in using prescribed fire [to]..." for ten different motivations (Fig. 4) and used a 5-point Likert scale to indicate (0) not interested in using prescribed fire, (1) slightly interested, (2) maybe interested, (3) likely interested, or (4) definitely interested. Participants were asked: "What barriers to prescribed fire are there on the lands you manage?" across 17 distinct barriers identified in the prescribed fire literature (Fig. 5); respondents identified along a 5-point Likert scale the extent to which each factor was (0) not a barrier, (1) a slight barrier, (2) a moderate barrier, (3) a significant barrier, or (4) a very significant barrier.

## Results

### Participant characteristics

Approximately 62% of participants identified as male and 38% as female (Table 2). Participant ages ranged

**Table 1** Respondents were asked to describe their familiarity with and desire to use six land management assistance pathways that could include prescribed fire in their region (Fig. 3), including four common agency programs described in the table. Other pathways included “family and friends” and “private contractors”. Respondents ( $N = 172$ ) were surveyed about their perspectives on prescribed fire on private lands before attending one of six workshops in central and northern Sierra Nevada, California, USA (including Amador, Butte, Calaveras, El Dorado, Mariposa, Nevada, Placer, Tuolumne, and Yuba Counties). The “Prescribed Fire on Private Lands” workshops occurred in 2018 and 2019 by the University of California Agriculture and Natural Resources (UCANR)

**CalFire:** California Department of Forestry and Fire Protection, the state forest and fire department

**CalFire Vegetation Management Program (VMP)-** a cost-share program that focuses on prescribed fire use (and some mechanical treatment options) to address wildfire risk concerns and diverse land management objectives in State Responsibility Areas (SRAs). More information can be accessed at: <https://www.fire.ca.gov/programs/resource-management/resource-protection-improvement/vegetation-management-program/>

**CalFire Forest Improvement Program (CFIP)-** a voluntary program meant to incentivize and encourage the improvement of California’s “forest land and resources” for high-quality timber supplies, employment and economic benefits, and long-term management of a resilient and productive forest system. “Improvement” can target all forest resources, including timber, fish, wildlife, soil, and water quality. The program also utilizes a cost-share mechanism and targets private or public lands containing 20–5000 acres of forested land. For more information, visit: <https://www.fire.ca.gov/grants/california-forest-improvement-program-cfip/>

**Natural Resources Conservation Service’s Environmental Quality Improvement Program (EQIP)-** a voluntary conservation program that provides technical and variable amounts of financial assistance to agricultural producers and non-industrial forest owners based on several criteria. The EQIP received directives and funding from the 2018 Farm Bill. Projects can span a range of natural resource concerns and improvement objectives, and often manifest in 5- to 10-year contracts between the landowner and NRCS. More information on EQIP can be found at: <https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/>

**Prescribed Burn Association (PBA)-** span from formalized NGOs to loose connections of individuals; PBAs are a tool proliferating across the nation for sharing resources, knowledge, and liability for private land prescribed fires

from 21 to 77 years old ( $M = 48$ ,  $SD = 16.54$ ). Most participants classified their affiliation as “landowner” (68%) followed by non-governmental organizations (NGOs) (29%). Approximately 10% of participants identified as consultants in the “other” category, which is important to note because they influence management large areas, e.g., they manage many lands for many clients. Approximately 39% of participants indicated that they did not have any previous fire experience. However, some participants reported previous prescribed fire experience(s) through learning about prescribed fire: in a classroom setting (17%); burning with small landowners (20%); and/or burning as a contractor, timber, or range operator (15%). Few participants had experience with prescribed fire-specific organizations or programs such as Prescribed Burn Associations (PBAs) (2%), prescribed fire TRaining EXchanges (TREX) (5%), or Volunteer Fire Departments (VFD) (4%).

Most participants indicated they reside on their land (63%), with conservation (49%), recreation (40%), timber production (38%), and livestock grazing (27%) being other popular land-use types. Participants generally had two or more vegetation types on their property, including forests (76%), oak woodland (70%), grassland (52%), and shrubland (48%). Although the response rate to our fill-in questions related to spatial extent of properties were low compared to the rest of our question responses. Participants who did respond owned or managed between  $< 1$  and  $\sim 100,000$  acres ( $N = 39$ ,  $M = 3813$ ;  $SD = 14,586$ ) with a mode of 10 acres and a median of 60 acres.

Of the 67 responses to the question “Approximately how many acres of your management area would you like to use prescribed fire [on] per decade?”, 34 respondents (54%) indicated that they wanted to burn by responding “yes” to the fill-in question, but did not include a specific number of acres they wanted to burn. Thirty-four participants (77%) wanted to burn more than 20% of their property and 39% wanted to burn more than 50%. Generally, these respondents managed small acreage: 40% of respondents wanted to burn one acre or less per decade ( $N = 23$ , 40%) and 57% of respondents wanted to burn 10 acres or less.

Of the 73 responses to the question “Approximately how many acres of your management area burned during a prescribed fire in the past decade?”, 39 respondents (52%) had not had pile burns or broadcast prescribed fire on their properties. About a quarter burned less than or equal to 10 acres, mostly with friends and family. About a quarter had more than 10 acres burned, mostly by CalFire VMP. A few fires were done by others, such as employees or local or volunteer fire departments.

### Treatments

From the suite of potential treatments, participants indicated the strongest interest in pile burning and broadcast prescribed fire (Fig. 2). Nearly 78% of participants were “definitely” interested in pile burning on the lands they managed, with 12% being “likely” interested, 9% “may” be interested, and 2% being “not” interested ( $M = 3.65$ ,  $SD = 0.73$ ). Nearly 54% of respondents were “definitely” interested in broadcast prescribed fire on their lands,

**Table 2** Characterization of individuals who wanted to learn about prescribed fire planning and implementation in a workshop. Age, gender, acres managed, and number of acres they want to burn per decade or they burned in the previous decade answers were fill-in-the-blank. Prescribed fire included both pile burns and broadcast prescribed fire only in this table. All other questions were multiple-answer multiple-choice with an optional fill-in-the-blank. N=total number of participants who responded to the question, SD=standard deviation, NGO=non-government organization, Rx=prescribed, CalFire=California Department of Forestry and Fire Protection, VFD=volunteer fire department, PBA=Prescribed Burn Association, TREX=prescribed fire TRaining EXchange, NWCG=National Wildfire Coordinating Group. Respondents (N=172) were surveyed about their perspectives on prescribed fire on private lands before attending one of six workshops in central and northern Sierra Nevada, California, USA (including Amador, Butte, Calaveras, El Dorado, Mariposa, Nevada, Placer, Tuolumne, and Yuba Counties). The “Prescribed Fire on Private Lands” workshops occurred in 2018 and 2019 by the University of California Agriculture and Natural Resources (UCANR)

Variable name	Measure	Response options	Responses	
			Value	Percent (%)
<b>Gender</b> (N = 169)	What is your gender?	Male	62	
		Female	38	
<b>Age</b> (N = 165)	What is your age in years?	Fill-in the blank	<b>Range:</b> 21–87 <b>Mean:</b> 48 <b>SD:</b> 17 <b>Median:</b> 65 <b>Mode:</b> 53	
<b>Affiliation</b> (N = 172)	Please circle <u>all</u> affiliations that apply to you:	Landowner	68	
		NGO	29	
		Federal and/or State	8	
		Ranching or timber	7	
		Local government	8	
<b>Land use(s)</b> (N = 172)	How is the land that you manage used ( <i>select all that apply</i> )	Residence	63	
		Conservation	49	
		Timber production	38	
		Recreation	40	
		Livestock grazing	27	
<b>Vegetation type</b> (N = 172)	What types of vegetation occur on the lands you manage? ( <i>select all that apply</i> )	Grassland	52	
		Oak woodland	70	
		Forest	76	
		Shrubland	48	
<b>Previous experience with Rx fire</b> (N = 169)	How much experience do you have with prescribed fire ( <i>circle all that apply</i> )?	I have no experience	38	
		I learned about it in a classroom	17	
		I have experience as a contractor, timber, or range operator	15	
		I have experience as a VFD member	4	
		I've participated in a prescribed fire before via a PBA	2	
		I've participated in a prescribed fire before via a TREX event	5	
		I've participated in a prescribed fire before as a small landowner	20	
		I have/previously had CalFire or NWCG certifications	10	
<b>Acres managed</b> (N = 39)	Approximately how many acres do you manage?	Fill-in the blank	<b>Range:</b> < 1–100,000 <b>Mean:</b> 3813 <b>SD:</b> 14,585 <b>Median:</b> 60 <b>Mode:</b> 10	
<b>Acres want to burn per decade</b> (N = 63)	Approximately how many acres of your management area would you like to use prescribed fire [on] per decade?	Fill-in the blank	<b>Range:</b> 1–27,000 <b>Mean:</b> 759 <b>Median:</b> 5 <b>Mode:</b> 1 <b>SD:</b> 3527	

**Table 2** (continued)

Variable name	Measure	Response options	Responses	
			Value	Percent (%)
<b>Acres burned during prescribed fire during past decade</b> (N = 73)	Approximately how many acres of your management area burned during a prescribed fire in the past decade?	Fill-in the blank	<b>Range:</b> 1–10,000 <b>Mean:</b> 292 <b>Median:</b> 0 <b>Mode:</b> 0 <b>SD:</b> 1295	

with 21% indicating “likely” interest, 22% indicating that they “may” be interested, and 3% indicating they were “not” interested ( $M = 3.25$ ,  $SD = 0.91$ ). Most participants were interested in mechanical treatments (i.e., non-commercial thinning from below ( $M = 3.42$ ,  $SD = 0.94$ ), mastication ( $M = 2.90$ ,  $SD = 1.34$ ), mowing ( $M = 2.93$ ,  $SD = 1.15$ ), commercial thinning from below followed by pile burn ( $M = 2.78$ ,  $SD = 1.19$ ), commercial thin from below followed by lop and scatter ( $M = 2.60$ ,  $SD = 1.24$ )), but these options would not be considered by 18 to 33% of respondents. Participants were least interested in using grazing treatments on their property, with 37 to 61% of participants indicating that they were “not” interested in grazing on their property.

**Pathways**

Approximately half of the participants had heard of CalFire Vegetation Management Program (VMP) (52%), contractors (46%), and CalFire California Forest Improvement Program (CFIP) (44%) (Fig. 3) (Table 1). Fewer participants had heard of using family and friends (38%), the Natural Resource Conservation Service (NRCS) Environmental Quality Improvement Program (EQIP) (25%), and PBAs (25%). Many participants were interested in using public assistance programs (VMP, 39%; CFIP, 39%, EQIP, 37%) and friends and family (39%) to implement prescribe fire on the lands they managed, with PBAs (30%) and contractors (27%) being slightly less popular options. More people were interested in using certain pathways than knew about them, including PBA (25% knew/30% would use) and EQIP (25% knew/37% would use). In contrast, other pathways had dramatically fewer people interested in their use than knew about them, including VMPs (52% knew/39% use) and contractors (46% knew/26% use).

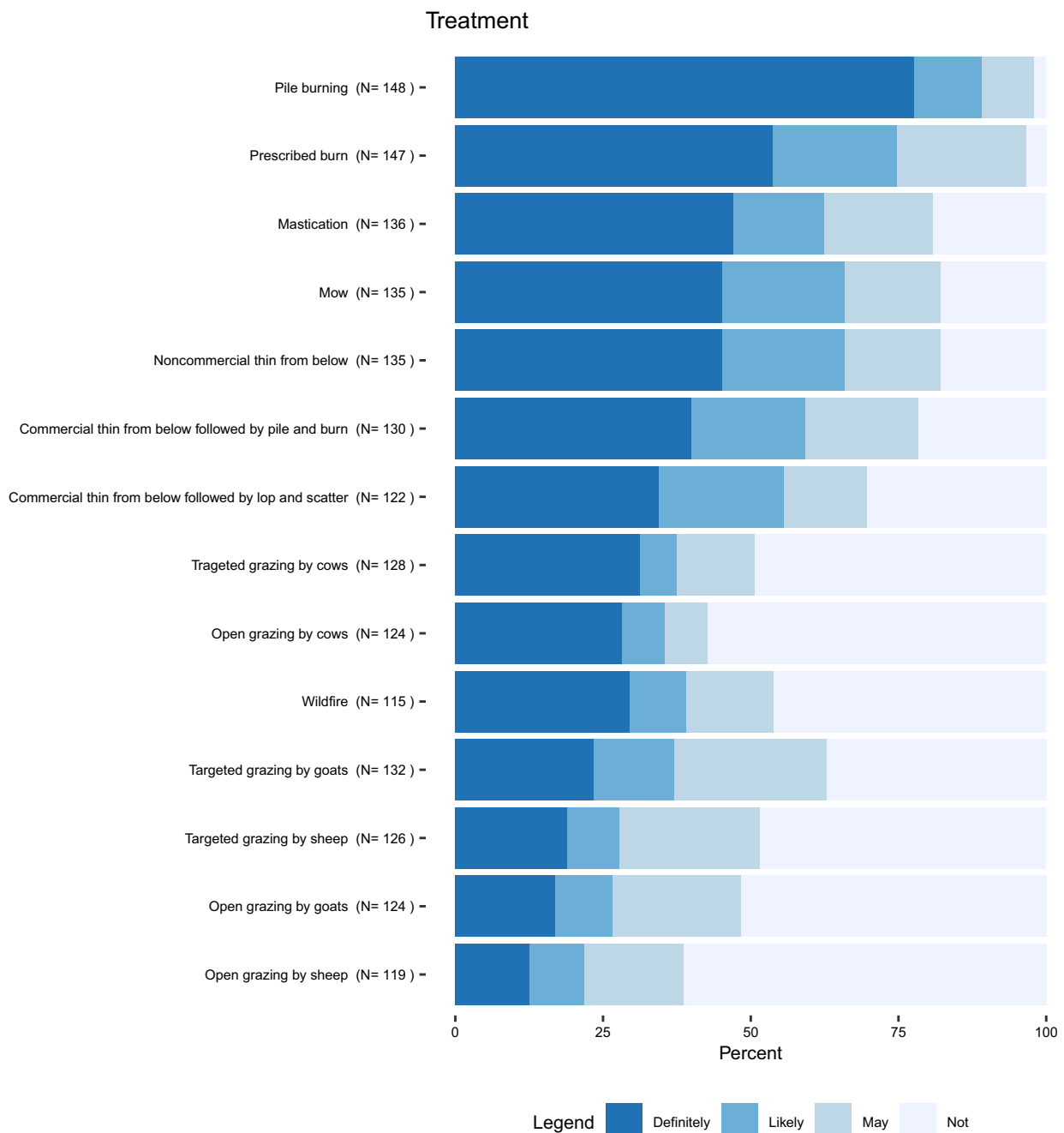
**Motivators**

Participants indicated multiple motivators for their interest in broadcast prescribed fire on their lands (Fig. 4). The majority of participants were “definitely” interested in using broadcast prescribed fire to “reduce fuel hazards” (89%,  $M = 4.83$ ,  $SD = 0.53$ ) and to “improve natural lands health” (71%,  $M = 4.54$ ,  $SD = 0.87$ ). Most

participants were “definitely” interested in using broadcast prescribed fire to reduce invasive species (55%,  $M = 4.07$ ,  $SD = 1.29$ ), reduce woody encroachment (52%,  $M = 3.98$ ,  $SD = 1.34$ ), improve wildlife habitat (50%,  $M = 4.12$ ,  $SD = 1.10$ ), reduce insect and disease issues (49%,  $M = 3.84$ ,  $SD = 1.43$ ), and improve scenic quality (44%,  $M = 3.77$ ,  $SD = 1.37$ ). Overall, participants were least interested in using broadcast prescribed fire to prepare a site for reforestation ( $M = 2.84$ ,  $SD = 1.59$ ), improving traditional cultural resources ( $M = 3.22$ ,  $SD = 1.54$ ), and improving recreational opportunities ( $M = 2.98$ ,  $SD = 1.57$ ).

**Barriers**

Participants indicated several barriers to broadcast prescribed fire on the lands they managed (Fig. 5). Approximately 42% of participants indicated that liability insurance was a “very significant” barrier ( $M = 3.89$ ,  $SD = 1.23$ ). Narrow burn windows (weather, fuel moisture) ( $M = 3.66$ ,  $SD = 1.14$ ), the costs of burning (i.e., hiring crews ( $M = 3.61$ ,  $SD = 1.34$ ), cost of planning ( $M = 3.53$ ,  $SD = 1.27$ )), and having a residential area near the burn ( $M = 3.47$ ,  $SD = 1.41$ ) were also listed as “very significant” or “significant” barriers. Respondents also indicated concerns about having the resources to conduct a fire on the lands they managed, particularly lacking personnel ( $M = 3.33$ ,  $SD = 1.35$ ), knowledge ( $M = 3.27$ ,  $SD = 1.32$ ), and equipment ( $M = 3.20$ ,  $SD = 1.33$ ). While there were some concerns about obtaining permits, permits were often listed as lesser barriers. Of the permits, air quality permits were a more problematic barrier ( $M = 3.34$ ,  $SD = 1.29$ ) than acquiring a CalFire burn permit ( $M = 2.80$ ,  $SD = 1.39$ ) or riparian or listed species permit ( $M = 2.43$ ,  $SD = 1.16$ ). Social or support barriers (e.g., a lack of support from co-workers or supervisors ( $M = 2.11$ ,  $SD = 1.39$ ) or the general public ( $M = 2.86$ ,  $SD = 1.35$ )) were ranked relatively low. Notably, 52% of participants reported that a lack of support from supervisors and co-workers to conduct burns was “not” a barrier ( $M = 2.11$ ,  $SD = 1.39$ ), which potentially hints at the ability private managers have to make decisions about prescribed burning in the spaces they live and/or work.



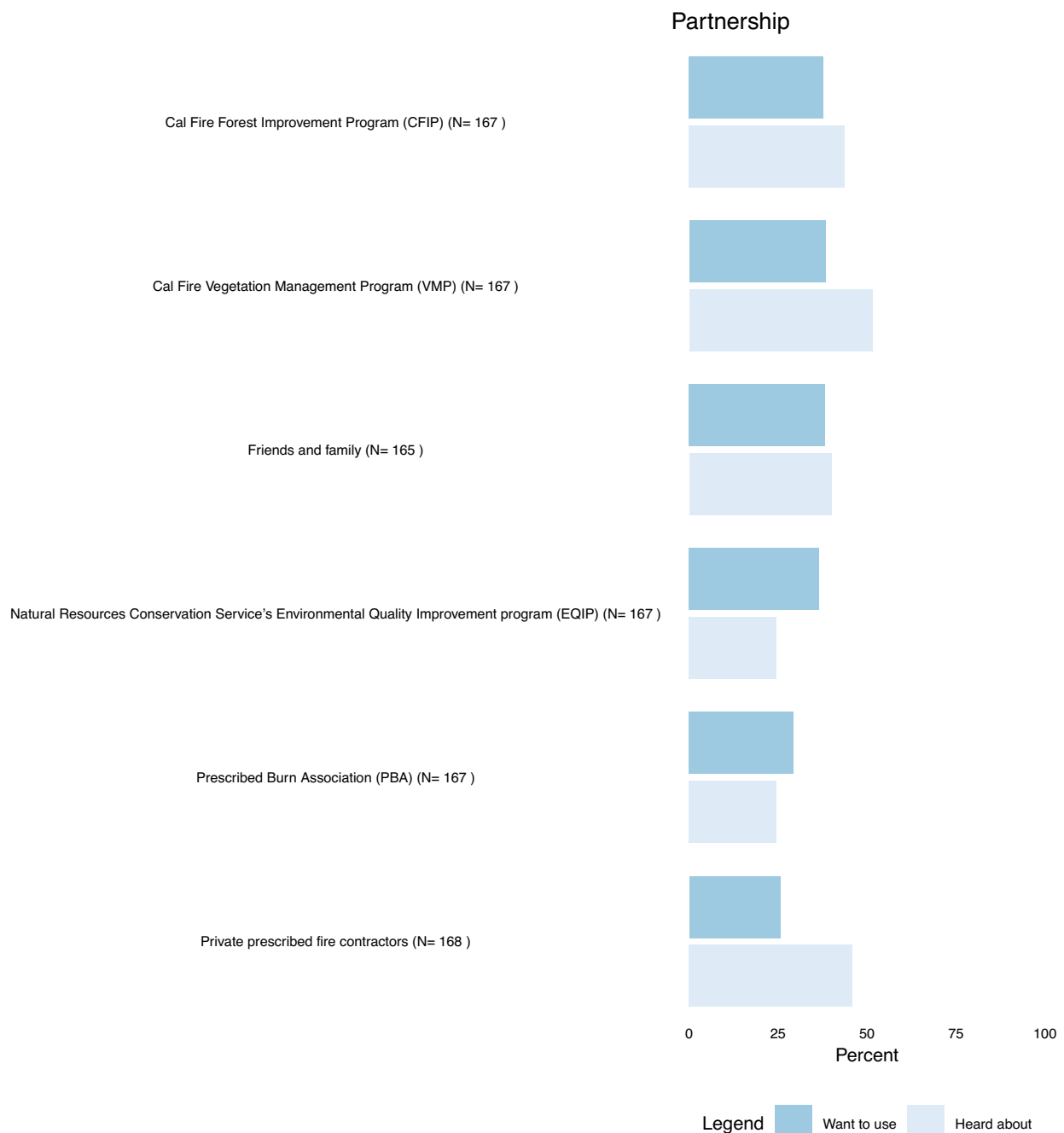
**Fig. 2** Count of participants’ experiences and perceptions of each treatment on their land. Participants were asked to indicate their experiences with or interest in using a treatment in their land management completing the statement “I would/have \_\_\_use(d) (management technique) on my lands.” Potential response were a 4-point Likert scale including “definitely,” “likely,” “may,” and “not”. N is the total number of participants who responded to the specific questions

### Discussion

Recent high-activity and disastrous wildfire seasons have galvanized renewed interest in reducing wildfire hazards across fire-prone landscapes in the western USA and world (Schoennagel et al. 2017; Cattau et al. 2020; Hanes et al. 2019). In California, forests have been decimated

by both wildfire and drought-related mortality (Axelson et al. 2020), leading residents and land managers to explore ways to address risk reduction and ecological restoration. The UCANR “Prescribed Fire on Private Lands” workshops were hosted to promote prescribed fire as a partial antidote to the regional “fire deficit” and “forest



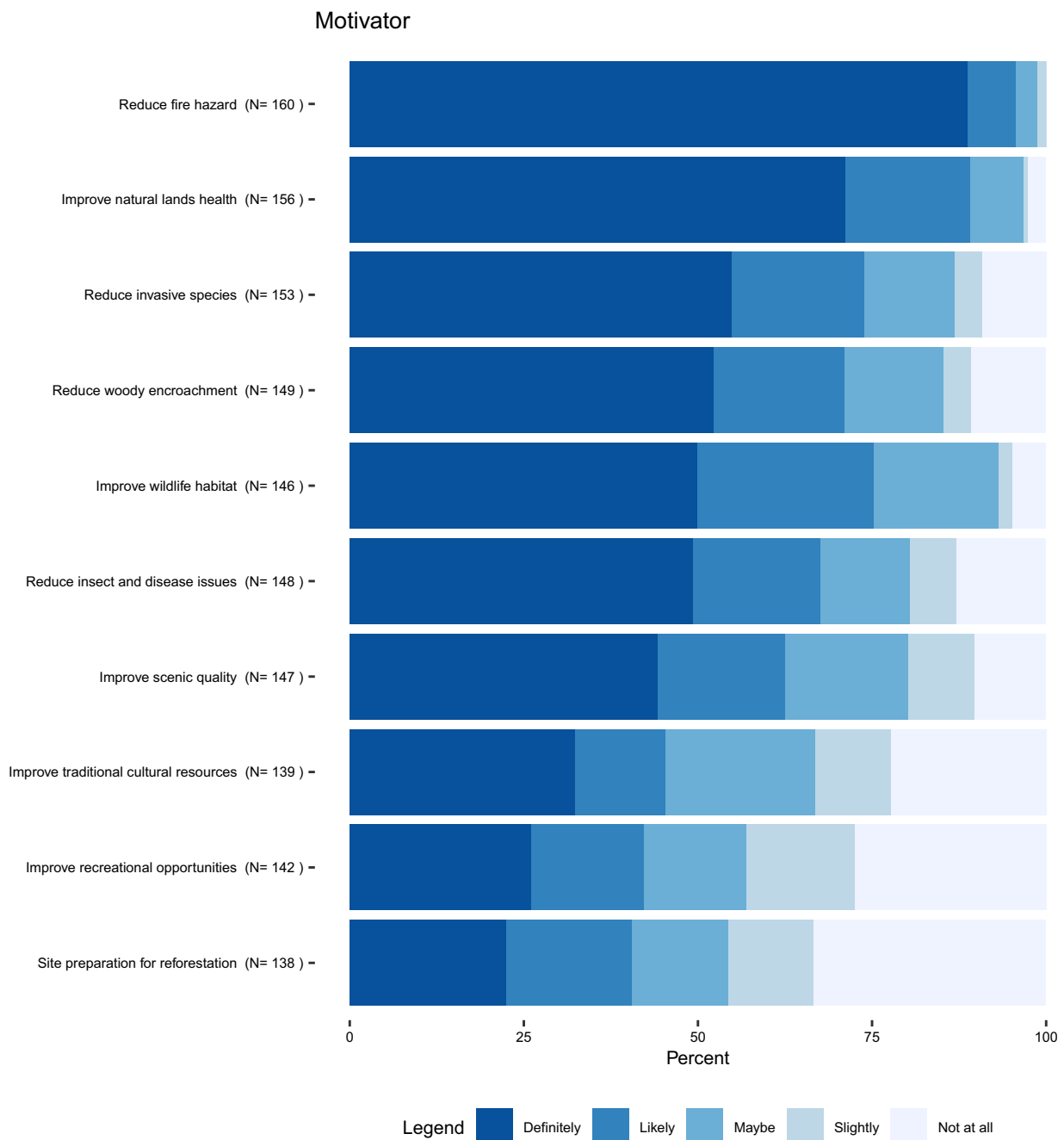


**Fig. 3** Count of participants' knowledge of ("heard about," light blue bar) and desire to use ("want to use," darker blue bar) each prescribed fire assistance opportunity or program. Participants were able to indicate via a checkbox whether they (1) had heard of the option/program being used for prescribed fire before and (2) wanted to use pile burn or broadcast prescribed fire on their property. Participants were not given any additional information about the programs apart from the names below. Descriptions of the programs can be found in Table 1. N is the total number of participants who responded to the specific questions

health" problems. We begin to address a literature gap around prescribed burning on private lands in the western USA, particularly in California. We also assist with characterizing the populations that are interested in

expanding their prescribed fire knowledge and engaging in programming.

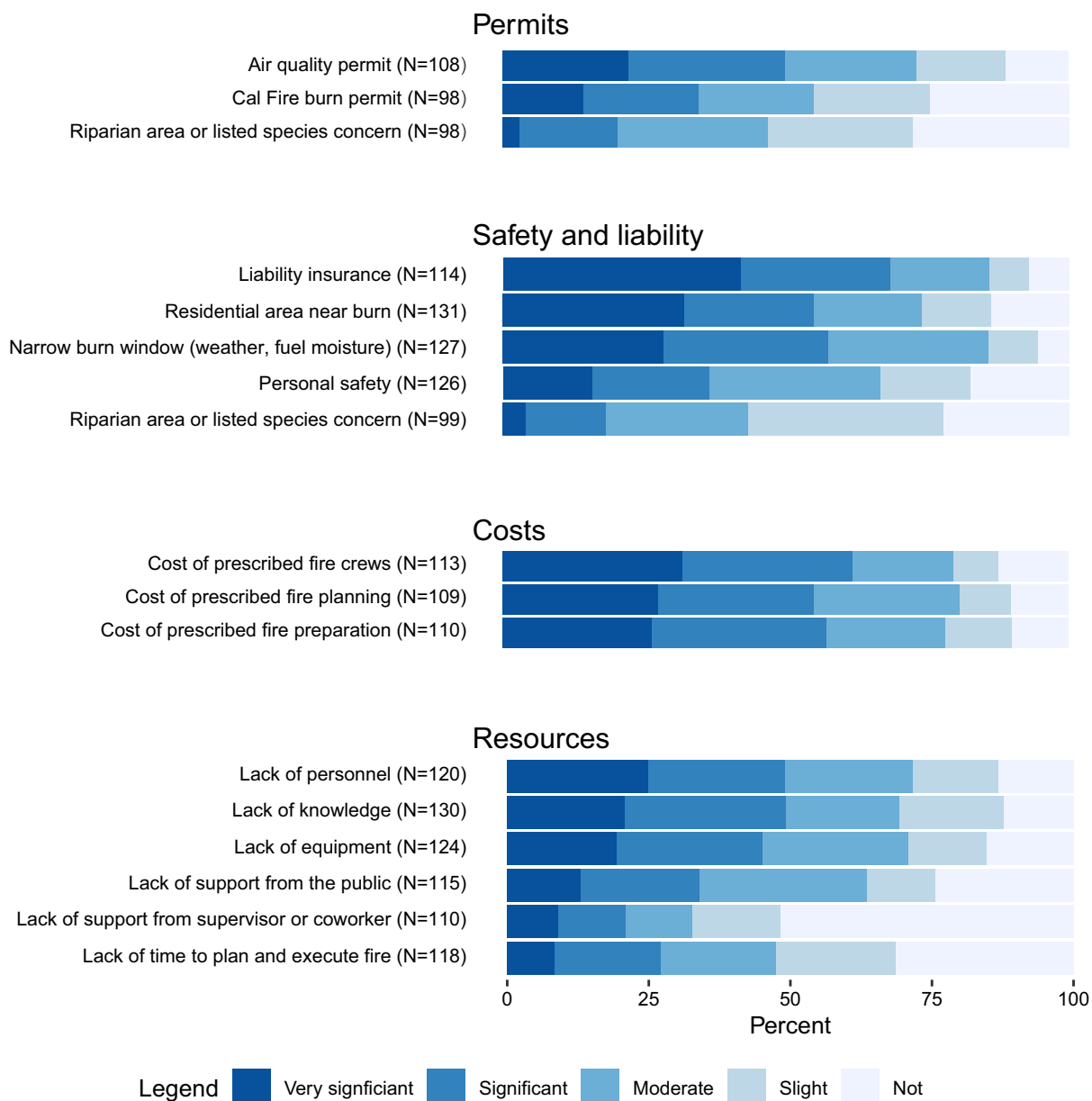
Our study of a relatively large convenience sample verifies and expands upon other research. Our results



**Fig. 4** Count of participants' who were motivated by each value for using broadcast prescribed fires on their land. Respondents were asked to complete the statement "I am \_\_\_\_\_ interested in using prescribed fire [to]..." to address a list of natural resource and wildfire management issues. Potential responses were a 5-point Likert scale including "definitely," "likely," "maybe," "slightly," and "not at all." N is the total number of participants who responded to the specific questions

somewhat mirror prescribed fire trends highlighted in other regions of the USA (e.g., Wood and Varner 2023; Kobziar et al. 2015; Bendel et al. 2020; Wilbur et al. 2021; Haines et al. 2001) and in California (e.g., regional, multi-landowner studies, Quinn-Davidson

and Varner 2011). Most importantly, we expand recent California-specific literature beyond public lands and NGOs to include more variety in private lands perspectives, such as residents, individually owned, family-owned, industrial-owned, and lease-holders (e.g., Miller et al. 2020).



**Fig. 5** Count of participants' who perceived different factors as barriers to broadcast prescribed fire on their land. Respondents were asked "What barriers to prescribed fire are there on the lands you manage?" and then provided with a table filled with known barriers to prescribed fire implementation. Respondents were asked to indicate how much of a barrier each prompt provided using a 5-point Likert scale of "definitely," "likely," "maybe," "slightly," and "not at all." N is the total number of participants who responded to the specific questions

**Participant characteristics**

Despite a large-scale trend of increasing landowner age in the USA from 2006 to 2018 (Sass et al. 2023), our participants mean age was much lower than a previous study in our region (Ferranto et al. 2011). In 2008, the mean landowner age was 62 while our mean age of landowners and managers was 42 in 2018 and 2019. These differences may be due to differences in the population attracted to our workshop (e.g., younger people are in early career

positions that support them attending workshops) or due to differences in those surveyed (e.g., landowners in 2008 versus landowners and managers in 2018–2019).

**Treatments**

Wildfire social science literature robustly demonstrates that there is relatively widespread support for thinning and prescribed fire on public lands, especially in high-risk areas (McCaffrey et al. 2013). We demonstrate that

a similar sentiment may exist among segments of California's population for prescribed fire in private-land contexts. A cumulative 98% of participants were "definitely" interested (78%), "likely" interested (11%), or "may" be interested (9%) in burning piles as a management tool on their private lands. This trend may highlight growing acceptance of intentional fire as a wildfire risk reduction and land-clearing tool among our participants.

Despite increased interest, our participants were not yet using pile burns or broadcast prescribed fire, which reflects findings in other studies. Butler et al. (2021) found that only 5% of California forestland owners surveyed ( $N=178$ ) had used prescribed fire in the last 5 years, while 10% wanted to do so in the next 5 years. Similarly, a 2008 survey of private forest and rangeland owners in California (most from the Sierra Nevada and central coast) ( $N=615$ ) (Ferranto et al. 2011) found that ~22% of respondents already used prescribed fire and 38% "might" (although it appears that pile burning and prescribed fire are potentially combined in this study). This is much less than the 78% "definitely" interested in pile burning and 54% "definitely" interested in broadcast prescribed fire in our study. Our results may reflect (1) a potential divergence from the general population of the Sierra Nevada and/or (2) overriding societal and market trends such as growing recognition of fires' ecological role on landscapes (Kolden 2019), market shifts and challenges (e.g., Nicholls et al. 2018; Anderson and Mitchell 2016), and high tree removal costs (Penman et al. 2017). However, it is important to note that our participants were interested enough in prescribed fire to pay \$20 USD, ask for financial assistance, and dedicate at least 8 h to accessing knowledge. Consequently, our results may reflect that our population is predisposed to view pile burns and broadcast prescribed fire favorably.

### Pathways

About half of participants were familiar with state programs for private land management that may incorporate or support pile burns and broadcast prescribed fire, which suggests about half our attentive public heard about these programs (and most options) for the first time at the workshop. This demonstrates how workshops may be important opportunities for spreading wildfire risk mitigation opportunities to residents, especially in the wake of a wildfire event or near miss. Distinctly, only some of the participants that knew about the CFIP, VMP, and private contractors options wanted to use those options. The gap between interest and wanting to use state-supported programs may reflect noted trends that resource-dependent and rural community members may be wary of government agency partnerships due to distrust in extra-local government or not wanting

the oversight that may come with accepting grant monies or support (Paveglio et al. 2018; Olsen and Schindler 2010; Vaske et al. 2007). VMP burns are also generally not available to private lands managers; one VMP project occur in each county per year on average (Fire and Resource Assessment Program 2021). NRCS may be viewed more favorably as compared to the CalFire programs, with more individuals open to using EQIP than had heard about it. This suggests that participants perceive a difference in what the programs have to offer (and therefore their utility to the private land manager) and/or the relationships between the public and NRCS versus CalFire differ.

Using friends and family to assist with pile burn and broadcast prescribed fire projects had somewhat stable interest across the "heard of" and "want to use" responses, potentially reflecting an affinity for self-sufficiency and neighbors-helping-neighbors documented in more rural or remote communities (Stasiewicz and Paveglio 2017; LaLone 2012; Carroll et al. 2005). Despite some attrition in responses between "heard about" and "want to use" for the CalFire programs, the CFIP, VMP, EQIP, and friends and family options still garner the most support for "want to use." PBAs attracted more interest in use than had "heard about." Lack of familiarity with PBAs may influence the lower levels of interest, especially because PBAs are celebrated as a mechanism for formalizing neighbors-helping-neighbors to perform pile burn and broadcast prescribed fire in other parts of the USA (e.g., Wonkka et al. 2015; Toledo et al. 2014). In the 5 years since these outreach and data collection efforts, additional PBAs developed to serve the entire study area in part due to these workshops. UCANR also expanded their Fire Advisor employees at the state and local levels to help facilitate prescribed fire education, fires, and policies.

### Motivations

The literature on public perceptions of treatments and motivations for using them is expansive and largely inconclusive (McCaffrey et al. 2013). Participants were primarily motivated to use broadcast prescribed fire in order to promote ecosystem health (e.g., reduce wildfire hazards, improve natural lands health), followed by managing undesirable species (i.e., invasives, woody encroachment). Recent catastrophic fire history and tree mortality in California may have presented a window of opportunity where individuals were more receptive to new land management techniques (McGee et al. 2009). Site preparation likely had limited motivation because many people were not harvesting timber and thus did not plan on planting. However, these workshops occurred in areas recently impacted by wildfires (e.g., Butte County

had 2018 Camp Fire 1 year prior to workshop) and extensive tree mortality (e.g., throughout the focal region) where broadcast prescribed fire would be helpful to reduce activity fuel and limit shrub competition.

### Barriers

Similar to Kobziar et al. (2015), we found that private landowners viewed liability concerns as one of the biggest barriers to broadcast prescribed fire on private lands. Although liability was not as high of a concern in cross-boundary studies (e.g., Quinn-Davidson and Varner 2011), it represents a recurring theme in many research efforts exploring prescribed fire application on private lands (Haines et al. 2001; Yoder et al. 2004; Elmore et al. 2009; Toledo et al. 2012; Wonkka et al. 2015). Recent California legislation dramatically altered liability law from a simple negligence to a gross negligence standard for burns with a Certified Burn Boss and included a Prescribed Fire Claims Fund that would help offset the cost a Certified Burn Boss might face if a prescribed fire escaped under the new liability law (see California Legislative Information 2021a, b). Narrow burn windows were also frequently cited by participants as a challenge they faced prescribing fire, which echoes findings from other studies (Quinn-Davidson and Varner 2011; Haines et al. 2001) as well as recent calls to develop strategies to deal with narrow burn window frustrations in prescribed fire councils (Wilbur and Scasta 2021). Costs and resource constraints (lack of knowledge, personnel) associated with plans for and actually prescribing fire also appear to be barriers. Several authors have explored mechanisms for addressing some of our top barriers (e.g., liability, costs of planning, and costs of burning) via PBAs (e.g., Toledo et al. 2012; Wonkka et al. 2015) through training, knowledge and resource sharing, and liability insurance. PBAs are a burgeoning program in California, with several new PBAs arising in our study regions since these data were collected (CalPBA 2021). Participants had low engagement with these programs when our workshops were conducted.

Also of interest is the relatively low ranking that participants gave to permitting as a barrier to broadcast prescribed fire on private lands compared to liability, including air quality ( $M=3.34$ ,  $SD=1.29$ ) and CalFire permits ( $M=2.80$ ,  $SD=1.39$ ). In the workshop region, air quality permits are required throughout the entire year while CalFire requires permits during declared fire season (York et al. 2020). Our participants' perceptions are in contrast to the workshop organizers who demonstrated live burns during these and other workshops (York et al. 2020). Organizers documented the difficulties they had getting permits for workshop burns despite their long experience with burning, available burn

windows, resources and personnel, and low concern for liability (York et al. 2020); they suggest that CalFire's lack of willingness to issue burn permits is "a reality that constrains burning on private lands" and make suggestions for improving the permit process. Recommendations made by Wood and Varner (2023) could also help provide rationales and pathways to reduce bureaucratic aspects of permitting in California and beyond.

### Definitions of prescribed fire

During our synthesis of literature, agency reports, and our own data collection efforts, we noted a distinct need for consistent prescribed fire terms, especially those contributing to or focused on synthesizing data across agencies and/or the private sector. Many studies appear to *not* define "prescribed fire" for survey instruments (e.g., our survey distinguishes between pile and broadcast burns on page 3). We have found that participants and some agencies conflate broadcast burns and pile burns into one metric or the same construct, which has important implications for construct validity and data interpretation. For example, we have seen orange "Prescribed Burn Ahead Do Not Report" traffic signs used when agencies are conducting pile burns in the study region, which conflates the two terms to the public. Through observations of our participants, we found that some people were pile burning, but very few were completing broadcast burning (e.g., our results for prescribed burned acres during the past decade likely reflect both pile and broadcast fires).

Conflating pile and broadcast burning has important implications. First, there are important ecological differences between pile and broadcast burns (e.g., pile concentration of heat influences soil sterility and reduction of seed bank (Korb et al. 2004), while broadcast burns reduce fine fuels and potentially pathogens across the landscape). Second, it leads to issues with data validity and interpretation when looking across studies or synthesizing data sets. As researchers, managers, and politicians seek to aggregate data across agencies and the private-public sector to assess achieving goals for prescribed fire goal application (e.g., the Wildfire Crisis Implementation Plan (2022)), it is imperative that all studies and/or reports define their prescribed fire-related terms. For autonomous survey instruments and focus group facilitators utilizing pre-post surveys (as our study did), terms like "prescribed fire," "pile burning," and "broadcast fire" need to be defined.

### Conclusion

In the face of increasing wildfire and forest health risks, more private landowners may consider broadcast prescribed fire as a viable land management tool. Nearly 20% of our participants heard of prescribed fire for the first

time at our workshops, which suggests that workshops may be an important mechanism for increasing exposure to broadcast prescribed fire use and addressing the needs of individuals looking to take responsibility for management of their lands (Bendel et al. 2020). It is important to have the capacity to provide educational and technical services to these populations, especially as at-risk areas expand under the changing climate. Extension programs, like UCANR, represent one such mechanism for disseminating scientific and technical knowledge to the public, although demands for these services (and those provided by other organizations such as defensible space inspectors, Firewise evaluations) can outpace the trained workforce available following a hazard event. Other novel tools, like PBAs, may present viable avenues for addressing barriers to broadcast prescribed fire on private lands in California because they address some of the most significant private land manager-perceived barriers. Finally, while the number of acres most private landowners wanted to burn was not significant by federal or state agency standards, our results indicate that these smaller burn sizes (e.g., < 1 acres) can be a significant proportion of the lands many of our participants have decision-making power over. In addition, when many private landowners each burn a small acreage, it can add up to a significant increase in broadcast prescribed fire acres overall. It is also important to note that novel land management techniques often require trials at smaller scales before the public is comfortable scaling up to larger acreage treatment goals (e.g., Pannell et al. 2006; Gregory et al. 2006). There is a window of opportunity in many regions of the western US to use outreach and education to increase broadcast prescribed fire literacy and capacity by providing opportunities for exploring broadcast prescribed fire on private lands.

## Appendix

### Workshop advertisement

The workshops were advertised through email listservs and Facebook posts from community and special interest groups (e.g., Resource Conservation District and Fire Safe Council in each county, UC ANR staff. UC ANR county-based listserv, UC ANR Forestry and Range listserv in each county and statewide, Cal Fire Forestland Steward Newsletter, California Licensed Foresters Association, Society of American Foresters California Chapter, Forest Landowners of California, California Fire Science Consortium, regional Prescribed Fire Councils, regional California Native Plant Societies, local fire departments, the regional Sierra Forest Legacy radio stations, and local and

regional news (Chico Enterprise-Record, Camptonville Courier, YubaNet, Appeal-Democrat, El Dorado News, Union Democrat).

The workshop advertisements included target audience and topics covered in the workshop with the following descriptive title: “A two day workshop designed for landowners and managers looking to gain skills in prescribed fire plans and implementation.” The first day was classroom-based and consisted of information about local fire history, prescribed fire permitting and legal considerations, Cal Fire’s Vegetation Management Program, Fire weather forecasting and tools, air quality and smoke management, prescribed burn associations, fire terms and behavior, burn plan development, burn unit preparation, and tools and equipment. The second day was a prescribed fire demonstration and training session weather permitting.

### Abbreviations

CalFire	California Department of Forestry and Fire Protection
VMP	California Department of Forestry and Fire Protection Vegetation Management Program
CFIP	California Department of Forestry and Fire Protection Forest Improvement Program
CQIP	Natural Resources Conservation Service’s Environmental Quality Improvement Program
M	Mean
N	Total number of participants who responded to the question
NRCS	Natural Resources Conservation Service
NGO	Non-government organization
NWCG	National Wildfire Coordinating Group
PBA	Prescribed Burn Association
SD	Standard deviation
TREX	Prescribed fire TRaining EXchange
UCANR	University of California Agriculture and Natural Resources
VFD	Volunteer Fire Department

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### Authors’ contributions

KW co-conceived the project, e.g., workshop series and research project, led design, co-led data acquisition, and substantially analyzed data, interpreted data, and drafted the work. SK co-conceived the project, advised on survey design, co-led data acquisition, and substantially interpreted data and revised the work. AS substantially analyzed data, interpreted data, and drafted the work. All authors read and approved the final manuscript.

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**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations****Ethics approval and consent to participate**

The lead authors' Institutional Review Board determined in Summer 2018 that this research was exempt from review.

**Consent for publication**

Na.

**Competing interests**

The authors declare that they have no competing interests.

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**References**

- Anderson, M.K. 2006. The use of fire by Native Americans in California. In *Fire in California's ecosystems*. University of California Press, Berkeley, California, USA, 417–430.
- Anderson, N., and D. Mitchell. 2016. Forest operations and woody biomass logistics to improve efficiency, value, and sustainability. *Bioenergy Research* 9: 518–533.
- Ascher, T.J., R.S. Wilson, and E. Toman. 2012. The importance of affect, perceived risk and perceived benefit in understanding support for fuels management among wildland–urban interface residents. *International Journal of Wildland Fire* 22 (3): 267–276.
- Axelson, J., J.J. Battles, A.J. Das, and P.J. van Mantgem. 2020. Coming to terms with the new normal: Forest health in the Sierra Nevada. *Fremontia* 47 (2): 50–56.
- Bendel, C., D. Toledo, T. Hovick, and D. McGranahan. 2020. Using behavioral change models to understand private landowner perceptions of prescribed fire in North Dakota. *Rangeland Ecology & Management* 73 (1): 194–200.
- Biswell, H.H. 1999. *Prescribed burning in California wildlands vegetation management*, 274. Berkeley: University of California Press.
- Bryman, A. 2012. *Social Research Methods*, 4th ed. New York: Oxford University Press.
- Butler, B.J., S.M. Butler, J. Caputo, J. Dias, A. Robillard, and E.M. Sass. 2021. Appendix 1 of the Family forest ownerships of the United States, 2018: Results from the USDA Forest Service, National Woodland Owner Survey. Gen. Tech. Rep. NRS-199, 52 [plus 4 appendixes]. Madison, WI: Department of Agriculture, Forest Service, Northern Research Station. <https://doi.org/10.2737/NRS-GTR-199-Appendix1>.
- CalPBA. 2021. California PBAs. <https://calpba.org/>. Accessed 17 Mar 2023.
- California Legislative Information. 2021a. SB-332 Civil liability: Prescribed burning operations: Gross negligence. [https://leginfo.ca.gov/faces/billTextClient.xhtml?bill\\_id=2021202205B332](https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=2021202205B332). Accessed 27 Jan 2023.
- California Legislative Information. 2021b. AB-642 Wildfires. [https://leginfo.ca.gov/faces/billNavClient.xhtml?bill\\_id=202120220AB642](https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB642). Accessed 27 Jan 2023.
- Carroll, M.S., P.J. Cohn, D.N. Seesholtz, and L.L. Higgins. 2005. Fire as a galvanizing and fragmenting influence on communities: The case of the Rodeo-Chediski fire. *Society and Natural Resources* 18 (4): 301–320.
- Cattau, M.E., C. Wessman, A. Mahood, and J.K. Balch. 2020. Anthropogenic and lightning-started fires are becoming larger and more frequent over a longer season length in the USA. *Global Ecology and Biogeography* 29 (4): 668–681.
- Cisneros, R., E. Alcalá, D. Schweizer, and N. Burke. 2018. Smoke complaints caused by wildland fire in the southern Sierra Nevada region, California. *International Journal of Wildland Fire* 27 (10): 677–683.
- Cleaves, D.A., J. Martinez, and T.K. Haines. 2000. *General Technical Report SRS-37: Influences on Prescribed Burning Activity and Costs in the National Forest System*. Asheville: USDA Forest Service Southern Research Station.
- Elmore, R.D., T.G., Bidwell, and J.R. Weir. 2009. Perceptions of Oklahoma residents to prescribed fire. In *Proceedings of the 24th tall timbers fire ecology conference: the future of prescribed fire: public awareness, health, and safety*. Tallahassee, Florida, USA: Tall Timbers Research Station (pp. 000–000).
- Ferranto, S., L. Huntsinger, C. Getz, G. Nakamura, W. Stewart, S. Drill, Y. Valachovich, M. DeLasaux, and N. Kelly. 2011. Forest and rangeland owners value land for natural amenities and as financial investment. *California Agriculture* 65 (4): 184–191.
- Fire and Resource Assessment Program. 2021. *Fire Perimeters*. Sacramento: California Department of Forestry and Fire Protection.
- Gregory, R., D. Ohlson, and J. Arvai. 2006. Deconstructing adaptive management: Criteria for applications to environmental management. *Ecological Applications* 16 (6): 2411–2425.
- Haines, T.K., R.L. Busby, and D.A. Cleaves. 2001. Prescribed burning in the South: Trends, purpose, and barriers. *Southern Journal of Applied Forestry* 25 (4): 149–153.
- Hanes, C.C., X. Wang, P. Jain, M.A. Parisien, J.M. Little, and M.D. Flannigan. 2019. Fire-regime changes in Canada over the last half century. *Canadian Journal of Forest Research* 49 (3): 256–269.
- Kobziar, L.N., D. Godwin, L. Taylor, and A.C. Watts. 2015. Perspectives on trends, effectiveness, and impediments to prescribed burning in the southern US. *Forests* 6 (3): 561–580.
- Kolden, C.A. 2019. We're not doing enough prescribed fire in the Western United States to mitigate wildfire risk. *Fire* 2 (2): 30.
- Korb, J.E., N.C. Johnson, and W.W. Covington. 2004. Slash pile burning effects on soil biotic and chemical properties and plant establishment: Recommendations for amelioration. *Restoration Ecology* 12 (1): 52–62.
- Laband, D.N., A. Hussain, and A. González-Cabán. 2008. The impact of Forest Service litigation success on administrative appeals of proposed fuels reduction actions. *Forest Policy and Economics* 10 (7–8): 444–449.
- LaLone, M.B. 2012. Neighbors helping neighbors: An examination of the social capital mobilization process for community resilience to environmental disasters. *Journal of Applied Social Science* 6 (2): 209–237.
- Madley, B. 2016. *An American Genocide: The United States and the California Indian Catastrophe, 1846–1873*. New Haven, Connecticut, USA: Yale University Press.
- McCaffrey, S., E. Toman, M. Stidham, and B. Schindler. 2013. Social science research related to wildfire management: An overview of recent findings and future research needs. *International Journal of Wildland Fire* 22: 15.
- McGee, T.K., B.L. McFarlane, and J. Varghese. 2009. An examination of the influence of hazard risk experience on wildfire risk perceptions and adoption of mitigation measures. *Society and Natural Resources* 22 (4): 308–323.
- Miller, R.K., C.B. Field, and K.J. Mach. 2020. Barriers and enablers for prescribed burns for wildfire management in California. *Nature Sustainability* 3 (2): 101–109.
- Nicholls, D.L., J.M. Halbrook, M.E. Benedum, H.S. Han, E.C. Lowell, D.R. Becker, and R.J. Barbour. 2018. Socioeconomic constraints to biomass removal from forest lands for fire risk reduction in the western US. *Forests* 9 (5): 264.
- Norgaard, K.M. 2014. The politics of fire and the social impacts of fire exclusion on the Klamath. *Humboldt Journal of Social Relations* 36: 77–101.
- Olsen, C.S., and B.A. Schindler. 2010. Trust, acceptance, and citizen-agency interactions. *Fire* 19: 137–147.
- Paveglio, T.B., M.S. Carroll, A.M. Stasiewicz, D.R. Williams, and D.R. Becker. 2018. Incorporating social diversity into wildfire management: Proposing “pathways” for fire adaptation. *Forest Science* 64 (5): 515–532.
- Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* 46 (11): 1407–1424.
- Penman, T.D., C. Eriksen, D. Horsey, A. Green, D. Lemcke, P. Cooper, and R.A. Bradstock. 2017. Retrofitting for wildfire resilience: What is the cost? *International Journal of Disaster Risk Reduction* 21: 1–10.

- Quinn-Davidson, L.N., and J.M. Varner. 2011. Impediments to prescribed fire across agency, landscape and manager: An example from northern California. *International Journal of Wildland Fire* 21 (3): 210–218.
- Sass, E.M., B.J. Butler, J. Caputo, and E.S. Huff. 2023. Trends in United States Family Forest Owners' Attitudes, Behaviors, and General Characteristics from 2006 to 2018. *Forest Science* 69 (6): 689–697.
- Schoennagel, T., J.K. Balch, H. Brenkert-Smith, P.E. Dennison, B.J. Harvey, M.A. Krawchuk, N. Mietkiewicz, P. Morgan, M.A. Moritz, R. Rasker, M.G. Turner, and C. Whitlock. 2017. Adapt to more wildfire in western North American forests as climate changes. *Proceedings of the National Academy of Sciences* 114 (18): 4582–4590. <https://doi.org/10.1073/pnas.1617464114>.
- Schultz, C.A., S.M. McCaffrey, and H.R. Huber-Stearns. 2019. Policy barriers and opportunities for prescribed fire application in the western United States. *International Journal of Wildland Fire* 28 (11): 874–884.
- Shrestha, A., R.K. Grala, S.C. Grado, S.D. Roberts, J.S. Gordon, and R.K. Adhikari. 2021. Nonindustrial private forest landowner willingness to pay for prescribed burning to lower wildfire hazards. *Forest Policy and Economics* 127: 102451.
- Stasiewicz, A.M., and T.B. Pavaglio. 2017. Factors influencing the development of Rangeland Fire Protection Associations: Exploring fire mitigation programs for rural, resource-based communities. *Society & Natural Resources* 30 (5): 627–641.
- Statista. 2021. Number of fires and acres burned due to U.S. prescribed fires in 2017, by state. <https://www.statista.com/statistics/204014/highest-number-of-prescribed-fires-in-the-us-by-states/>. Accessed 27 Nov 2021.
- Stephens, S.L., R.E. Martin, and N.E. Clinton. 2007. Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands. *Forest Ecology and Management* 251 (3): 205–216.
- Stephens, S.L., J.W. van Wagtenonk, J.K. Agee, and R.H. Wakimoto. 2021. Introduction to the article by Harold Biswell: Prescribed burning in Georgia and California compared. *Fire Ecology* 17: 1–4.
- Toledo, D., U.P. Kreuter, M.G. Sorice, and C.A. Taylor. 2012. To burn or not to burn: Ecological restoration, liability concerns, and the role of prescribed burning associations. *Rangelands* 34 (2): 18–23.
- Toledo, D., U.P. Kreuter, M.G. Sorice, and C.A. Taylor. 2014. The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems. *Journal of Environmental Management* 132: 323–328.
- van Wagtenonk, J.W. 1995. Dr. Biswell's influence on the development of prescribed burning in California. In *The Biswell symposium: fire issues and solutions in urban interface and wildland ecosystems; February 15–17, 1994; Walnut Creek, California. Gen. Tech. Rep. PSW-GTR-158*, ed. David R. Weise, Robert E. Martin, Technical coordinators, 11–16. Albany: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.
- Vaske, J.J., J.D. Absher, and A.D. Bright. 2007. Salient value similarity, social trust and attitudes toward wildland fire management strategies. *Human Ecology Review*. 14: 223–232.
- Wilbur, R., and J.D. Scasta. 2021. Participant motivations for the Wyoming Prescribed Fire Council (PFC): Emergence from a regional void. *Rangelands* 43 (3): 93–99.
- Wilbur, R., C. Stanley, K.A. Maczko, and J.D. Scasta. 2021. Perceptions of NRCS assistance with prescribed fires on US private lands: a regionally stratified case study. *Fire* 4 (3): 47.
- Williams, J.N., H.D. Safford, N. Enstice, Z.L. Steel, and Z. L., and A.K. Paulson. 2023. High-severity burned area and proportion exceed historic conditions in Sierra Nevada, California, and adjacent ranges. *Ecosphere* 14 (1): e4397.
- Williamson, M.A. 2007. Factors in United States Forest Service district rangers' decision to manage a fire for resource benefit. *International Journal of Wildland Fire* 16 (6): 755–762.
- Wonkka, C.L., W.E. Rogers, and U.P. Kreuter. 2015. Legal barriers to effective ecosystem management: Exploring linkages between liability, regulations, and prescribed fire. *Ecological Applications* 25 (8): 2382–2393.
- Wood, J., & M. Varner. 2023. Burn Back Better: How Western States Can Encourage Prescribed Fire on Private Lands. *Property and Environmental Research Center: Tall Timbers* :40. Last accessed at: <https://perc.org/2023/01/10/burn-backbetter/>.
- Yoder, J., D. Engle, and S. Fuhlendorf. 2004. Liability, incentives, and prescribed fire for ecosystem management. *Frontiers in Ecology and the Environment* 2 (7): 361–366.
- York, R., A. Roughton, R. Tompkins, and S. Kocher. 2020. Burn permits need to facilitate – not prevent – “good fire” in California. *California Agriculture* 74 (2): 62–66. <https://calag.ucan.edu/Archive/?article=ca.2020a0014>.

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