Rangeland Ecology & Management 72 (2019) 959–967

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Landowner Perceptions of Legal Liability for Using Prescribed Fire in the Southern Plains, United States☆

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ARTICLE INFO

Article history:
Received 7 June 2019
Received in revised form 6 August 2019
Accepted 8 August 2019

ABSTRACT

Suppression of fire in the Southern Plains has led to proliferation of woody plants and fuel load accumulation that spurs wildfires. These effects have led to calls for widespread application of prescribed fire to reduce fuel loads, but there is substantial landowner resistance to the use of this land management tool. Here we explore factors that affect perceptions of landowners in the Southern Plains about prescribed fire liability and their willingness to apply this land management tool. This region was selected for the study because of the preponderance of private landholdings and widespread woody plant encroachment. The study used a mail survey of 1 853 landowners in 16 counties in Texas and Oklahoma, resulting in a data set from 680 respondents (37% useable response rate). Logistic regression models were developed to test three hypotheses relating to the likelihood that a landowner will apply prescribed fire. The study corroborated that landowners who perceived higher levels of fire-related legal liability were less likely to apply prescribed fire on their land or assist with its application on other properties. In addition, burn bans were found to inhibit landowner willingness to apply fire during periods that result in higher woody plant mortality. Oklahoma respondents, landowners who believed prescribed fire to be an affordable woody plant management tool, and members of prescribed burning associations (PBAs) were more likely to use prescribed fire. These results have important implications for policies aimed at overcoming resistance to the use of prescribed fire to curb woody plant encroachment and reduce fuel load accumulation. Specifically, language in state statutes pertaining to prescribed fire should be modified to reduce landowner concerns over legal liability; PBAs should be established more widely; and public cost-sharing funds for woody plant management should prioritize prescribed fire.

Introduction

Historically, rangelands throughout much of the world were maintained by periodic natural and anthropogenic fires that inhibited the expansion of woody plants in grasslands and savannas (Pyne, 2001). However, vegetative composition in rangelands has undergone substantial changes globally due, in large part, to widespread fire suppression and the subsequent proliferation of woody plants into unburned areas (Archer et al., 1995; Briggs et al., 2005; Archer et al., 2017). Woody plant expansion can alter biophysical characteristics of grasslands and savannas, including biogeochemical and hydrological cycles, forage supply, and wildlife habitat. This has undermined the economic viability of many ranching operations and elevated fuel loads, resulting in more erratic and destructive wildfires (Archer and Stokes, 2000; Archer et al., 2001; Jackson et al., 2002; Luo et al., 2013). Moreover, restoring areas invaded by woody plants to grasslands may be expensive or practically impossible when action to reduce woody plant encroachment is delayed until woody plant density substantially inhibits fire or when the use of fire is disallowed (Fuhlendorf et al., 1996; Van Liew et al., 2012).

In many fire-prone regions of the world there is an effort to promote prescribed fire, planned management fire, in order to reduce the potential for destructive wildfires, especially at the wildland-urban interface. In southern Australia, state and territorial parliaments have enacted legislation aimed at requiring the management of excessive fuel loads and flammable fuel types on privately owned lands (Eburn and Cary, 2018). Similarly, the National Veld and Forest Fire Bill in South Africa (B122B, 1998) requires land owners to actively manage the fuels on their properties and remove flammable invasive vegetation from their land. In the United States, elevated wildfire risk has led to calls for fire management reform,

☆ This work was supported by the National Science Foundation Dynamics of Coupled Human and Natural Systems Program (DEB-1413900).
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https://doi.org/10.1016/j.rama.2019.08.004
1550-7424/

including the systematic use of prescribed fire to reduce fuel loads (North et al., 2015). Periodic application of prescribed fire can also promote high-quality forage and improve wildlife habitat (Ratajczak et al., 2014). Moreover, in Texas it was found that mechanical and chemical woody plant treatments are economically not feasible without public cost-sharing and that prescribed fire is the only economically efficient land management practice for managing woody plant cover at the landscape scale (Van Liew et al., 2012; Twidwell et al., 2015). In addition to its economic advantages, it was shown that even intense fires may not negatively affect perennial grass species and, instead, can enhance herbaceous diversity and ground cover, thereby reducing the potential risks of soil erosion from bare areas under invasive woody plants that are eliminated by fire (Taylor et al., 2012; Twidwell et al., 2012).

When making decisions about woody plant management, landowners must weigh the perceived benefits and costs of alternative treatment options, including prescribed fire (Toledo et al., 2012). One of the benefits of applying suitably intensive prescribed fire, especially during dry periods, is the reduction of woody plant density while increasing forbs and maintaining economically important perennial grasses (Twidwell et al., 2012, 2016). Costs associated with the application of prescribed fire include costs of labor, firebreak preparation, and equipment, along with the potential payments for damage and injuries resulting from escaped fire and smoke hazards (Toledo et al., 2012). The decision not to burn obviates those direct costs but incurs other long-term costs, including reduced forage production, wildlife habitat deterioration, and elevated damages from wildfires fed by accumulated fuel loads (Jackson et al., 2002; Luo et al., 2013; Ratajczak et al., 2014). A major challenge for landowners deciding whether or not to apply prescribed fire is the temporal disconnect between the potential costs of damages related to escaped fire and the lagged effect of not burning on forage and wildlife habitat declines. For example, landowners who decide not to apply prescribed fire may continue to obtain wildlife-related benefits from their land when livestock production potential declines, whereas the cost of litigation for damages from escaped fire is likely more immediate (Van Liew et al., 2012). Due to the human tendency to discount the future, the more immediate costs of damages from potential escaped fire, therefore, may weigh more heavily in landowners' decision about applying prescribed fire than the longer-term forage declines associated with woodland expansion.

In addition to economic benefits and costs, the use of prescribed fire on privately owned rangelands can also be influenced by numerous social factors. Lack of knowledge about the safe use of fire and lack of labor and equipment to conduct prescribed fire safely are often cited as key factors for landowner resistance to the use of prescribed fire (Taylor, 2005; Kreuter et al., 2008; Toledo et al., 2012). In addition, social pressure, peer-to-peer mentorship, media coverage, and social norms (community values that motivate individuals) can influence landowner decisions about adopting ecologically important management practices, such as prescribed fire (Jacobson et al., 2001; Taylor, 2005; Kreuter et al., 2008). For example, Toledo et al. (2013) found that the perceptions of family members and neighbors about prescribed fire had an overriding effect on a landowner's decision whether or not to use this woody plant management tool.

Another common factor that affects landowner decisions about applying prescribed fire on their land is the perception that doing so incurs legal liability (Toledo et al., 2012; Weir et al., 2019). Despite few prescribed fires having escaped in the Southern Plains (1.5% in 17 yr, and those that did escape rarely burned substantially beyond their intended target area and caused minimal structural damage and no fatalities), many landowners in that region continue to erroneously consider this management tool as hazardous (Weir et al., 2019). This perception persists despite the finding that risks associated with the application of prescribed fire are far less than many other commonly used management activities on agricultural land (Twidwell et al., 2015). Also, Wonkka et al. (2015) found landowners in states with lower legal liability standards for applying prescribed fire (gross negligence in Florida and Georgia) burned significantly more acreage than landowners in states with more stringent standards (simple negligence in Alabama, South Carolina, and North Carolina). This suggests that landowners in states with gross negligence standards perceive prescribed fire to be less risky and use fire more frequently. By contrast, where legal precedence lays the burden of responsibility for damages caused by escaped fire entirely on the applicators, landowners may be discouraged from using this management tool (Yoder, 2008). For example, in the 1979 Koos versus Roth lawsuit in Linn County, Oregon, the court found field burning to be an "ultrahazardous activity based on testimony from a local fire chief that as many as one out of eight field-burning fires escape in the country" (Yoder et al., 2004, p. 362). This claim is inconsistent with more recent estimates of $< 2\%$ escaped fire in the Southern Plains (Weir et al., 2019), and there is no evidence that it was based on robust records or merely the perception of an individual whose professional duty was to extinguish fire. Regardless, the characterization of prescribed fire as ultrahazardous imposed the burden of damages on the person who applied the fire regardless of reasonable precautions taken, thereby substantially reducing the incentive for using this land management tool in Oregon.

Despite clear evidence of the ecological and economic efficacy of prescribed fire as a woody plant management tool, legal and social barriers to its use have created a lack of understanding about how the interaction between landowners' perceptions of woody plant expansion and legal liability influence their decisions regarding the use of prescribed fire. This lack of understanding pertains to both landowner decisions about the use prescribed fire on their own land and to their assistance with the application of prescribed fire on neighboring properties (Weir et al., 2019).

To address this knowledge gap, we examine the perceptions of landowners who are faced with woody plant expansion about prescribed fire liability (legal dimension) and their willingness to apply prescribed fire on their own land or participate in its application on other landowners' properties (social dimension). This research tests three hypotheses to fill this knowledge gap:

Hypotheses 1. (Legal)

The likelihood that a landowner will apply prescribed fire to their land or participate in its application on others' land is negatively correlated with his or her perception about the legal liability for applying fire. Landowners who perceive prescribed fire to be associated with a high level of legal liability will be less inclined to engage in its use than those with less concern about legal liability (Yoder et al., 2004; Wonkka et al., 2015).

Hypothesis 2. (Social)

Landowner perception of legal liability for applying prescribed fire is positively mediated by their social connectedness, such as membership in a prescribed burning association (PBA). Given that there are more PBAs in Oklahoma than Texas, it is anticipated that, in general, landowners in Oklahoma will express greater willingness to burn (Weir et al., 2016).

Hypotheses 3. (Management)

Landowners who perceive fire to be an effective, affordable, and easy-to-use tool for woody plant management will be more willing to burn than those who do not have this positive perspective of prescribed fire. This is based on the observation that positive perceptions about efficacy, affordability, and ease of use of a land management practice contribute to the widespread adoption of that practice (Kreuter et al., 2001, 2005).

Methodology

Study Area

The study was conducted in the Southern Plains of the United States, which comprises predominantly grassland and savanna

ecosystems. The dominant invasive woody plants are native mesquite *(Prosopis glandulosa),* Ashe juniper *(Juniperus ashei),* redberry juniper *(J. pinchotii),* and eastern redcedar *(J. virginiana)* and exotic Chinese tallow *(Triadica sebiferium).* This region was selected because of the preponderance of private landholdings and extent of woody plant expansion, which makes it possible to address the stated knowledge gap at a large spatial scale. Specifically, the research focused on eight counties in Texas and eight counties in Oklahoma (Fig. 1). The Texas counties are located in the Edwards Plateau ecoregion (San Saba, Llano, Mason, Gillespie, Kimble, Menard, Sutton, and Schleicher), while in Oklahoma the counties are in the Rolling Red Plains ecoregion (Beckham, Comanche, Dewey, Ellis, Roger Mills, Tillman, Pawnee, and Payne). These ecoregions were selected because they are representative of the southern and northern portions of the Southern Plains, and the counties within them were selected primarily on the basis of the presence of an active PBA, allowing comparison of perspectives of PBA member and nonmember landowners. The number of counties was restricted to 16 because of the work load required to extract landowner information from public databases.

Mail Survey Sampling Methods

The study was conducted using a mail survey of landowners in the selected counties. Contact information for landowners in each county was obtained from county tax records. Survey participants were restricted to landowners who owned at least 40 ha (100 acres) in order to minimize small property size sampling bias and because landowners with small properties are generally unlikely to apply prescribed fire on their land (Kreuter et al., 2008). In each county, 100 landowners were randomly selected from the county tax records for inclusion in the study. All 318 members of the PBAs in the selected counties were also included in the study. This resulted in an initial survey sample size of 1 918 landowners. Of the initial mailings, 65 were returned with incorrect addresses, resulting in an effective survey sample of 1 853 landowners.

The study was conducted in October and November of 2015. The survey was administered using a five-phase mailing approach (Dillman et al., 2009): initial letter to inform the selected landowners about the study (d 1); survey questionnaire with postage-paid return envelope (d 7); reminder/thank-you postcard (d 21); replacement questionnaire to nonrespondents (d 42); and a final reminder/thank-you postcard (d 56).

The 12-page questionnaire incorporated five areas of inquiry: attitudes concerning woody plants and fire; use of various land management practices, including prescribed fire; knowledge about prescribed fire; information about prescribed burn associations; and landowner characteristics. Categorical response options were used to obtain quantitative data. Most of the categorical response questions used a seven-point response scale (e.g., strongly disagree = 1, disagree = 2, somewhat disagree = 3, neutral = 4, somewhat agree = 5, agree = 6, and strongly agree = 7). Survey participants were asked to respond to questions they could not answer with D/K = don't know or N/A = not applicable. Binary Yes/No response options were also used in some cases and in others, survey participants were provided space to include short written responses.

A nonresponse bias analysis was not conducted in this study because alternate contact information (i.e., telephone number or email addresses) required for such an analysis (Dilman et al. 2009) was not obtainable from the county tax records. Due to this limitation, we refrain from extrapolating our results to the broader landowner population from which our sample was drawn.

Data Analysis

Survey data were entered into *Microsoft Excel* and analyzed using STATA 12.0 (https://www.stata.com/stata12/). Statistical analyses included descriptive statistics for demographic data and principal components analysis (PCA) to group related variables into functional indices. Logistic regression models were used to test the three hypotheses.

Principal Components Analysis

PCA with varimax rotation was conducted on two sets of variables to test for collinearity (Jackson-Smith et al., 2005). The first set focused on motivations for landownership and the second on prescribed fire liability concerns. Cronbach's alpha (α) values were obtained to test the internal reliability of the aggregated latent variables (or indices). Although ≥ 0.70 generally indicates adequate internal reliability of latent indices (Cortina, 1993), Schmitt (1996)

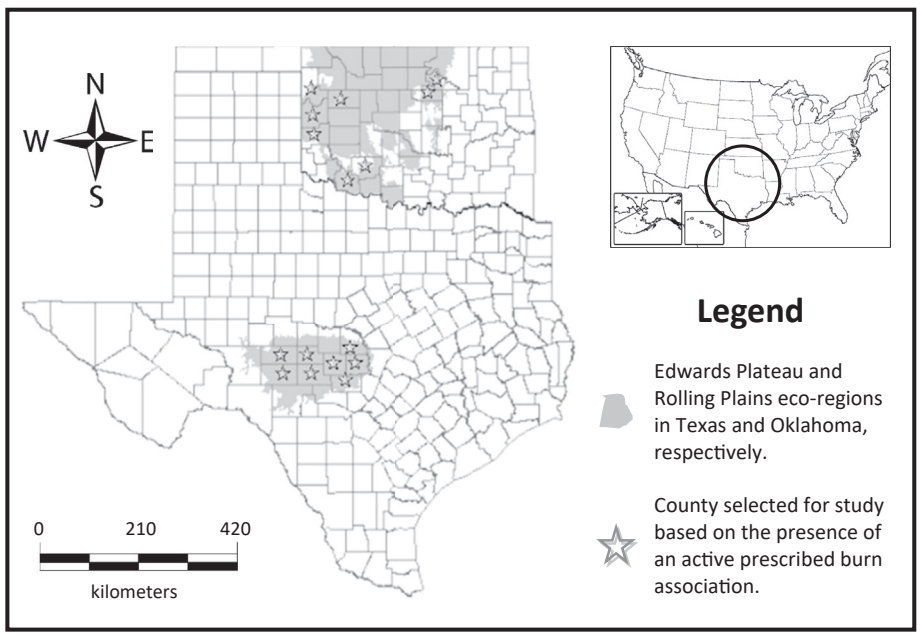

Figure 1. Landowner mail survey area in eight counties in the Texas Edwards Plateau and eight counties in the Oklahoma Rolling Plains ecoregions of the Southern Plains, United States.

Table 1
Rotated factor loading results of principal components analysis of independent variables concerning liability and prescribed fire with Cronbach's α measuring internal scale reliability. (Bold values highlight the factors that load onto each of three latent variables.)

Independent variables	Rotated factor loadings		
	Reduced concern α = 0.8965	Influence α = 0.7938	Liability α = 07498
Burn plans reduce escape	**0.9011**	0.1198	0.0007
New tech reduces injury	**0.9107**	0.0866	0.0548
Affordable liability insurance access	**0.8672**	0.1453	0.0901
State laws affecting liability	**0.7896**	0.1319	0.1197
Influence on state legislation	0.1421	**0.8474**	−0.0475
Influence on affordable insurance	0.1107	**0.8525**	0.0822
Influence over county officials	0.1748	**0.7911**	−0.0022
Concern over personal liability on own land	0.1013	−0.1012	**0.8439**
Concern over personal liability on others' land	0.0377	0.0402	**0.8570**
Concern that burns reduce access to insurance	0.0795	0.1472	**0.7246**
Insurance protection[1]	0.3191	0.5565	−0.0889
State liability standards[1]	0.4518	0.4615	−0.0431
Influence of burn bans[1]	0.3425	0.0457	0.2256

[1] Variable did not load on any particular factor.

argued that lower α levels may still be quite useful for exploratory research. Accordingly, in this study we relaxed the internal reliability standard to $\alpha > 0.60$. The resulting latent variables were then included in the logistic regression models for hypothesis testing.

Three latent indices, Reduced concern, Influence, and Liability, were created from 10 variables (Table 1). Three additional variables did not load onto the other variables and were retained as single-item independent variables.

In addition, five latent indices were created from 17 response items relating to landownership motivations (Table 2) and were used as independent variables in the regression models. They include: Recreation, Ranching, Heritage, Hunting, and Farming.

Regression Model Development

Logistic regression models were developed to address the three stated hypotheses. We used binary choice (Logit) regression models to identify statistically significant variables associated with willingness to use prescribed fire. The methodological foundation is the random utility model, which is the most commonly used framework for studying consumer choices of products and services (Greene, 2012; Gan et al., 2014). This type of econometric regression model accommodates binomial dependent variables and a mix of continuous, binomial, and ordinal scale variable values for dependent variables. In these models, the binary responses to landowner willingness to burn on their own land or on another person's land are the dependent variable (Table 3). In addition to the PCA-derived latent variables, Table 3 also provides a list of other independent variables used in the regression models. Correlation coefficients for independent variables that are statistically significant ($P < 0.05$) are considered to be potential predictors of landowner willingness to burn their own land or another person's land.

Results

Response Rate

Of the initial sample of survey mailings ($n = 1\,918$), 65 were returned with incorrect addresses, resulting in survey sample 1 853 landowners. We received 771 responses, with 680 completed survey questionnaires and 91 respondents declining to participate in the study. Therefore, the raw and useable response rates were 42% and 37%, respectively. In both Texas and Oklahoma, the response rates of PBA members were higher (67%) than for nonmember landowners (29%).

Respondent Characteristics

The demographic characteristics of survey respondents are presented in Table 4. Over half (57%) of the respondents were from

Table 2
Principal components analysis of five landowner motivation response variables, with Cronbach's α measuring internal scale reliability. (Bold values highlight the factors that load onto each of the five latent variables.)

Landowner motivations	Rotated factor loadings				
	Recreation α = 0.8574	Ranching α = 0.8526	Heritage α = 0.9206	Hunting α = 0.6289	Farming α = 0.6693
Enjoy the outdoors	**0.8132**	0.1247	0.1615	0.0798	-0.0706
Place to relax	**0.8883**	0.0195	0.0572	0.0747	0.0117
Recreational fishing	**0.8020**	−0.0949	0.0590	0.2146	0.0697
Recreational hunting	**0.8386**	0.0450	−0.0060	0.2309	0.0412
Operate farm/ranch	0.0702	**0.8709**	0.1704	0.0710	0.0980
Maintain family ranch/farm tradition	0.0004	**0.6943**	0.5299	0.0843	0.1167
Produce grazing livestock	0.0185	**0.8561**	0.1962	0.0040	0.0942
Earn a profit	−0.0270	**0.6702**	0.1280	0.0774	0.3765
Keep land in family	0.0669	0.2411	**0.9176**	0.0169	0.0608
Leave land for family	0.1050	0.1664	**0.9184**	0.0655	0.0738
Operate hunting enterprise	0.0177	0.2631	0.0877	**0.8071**	-0.0769
Manage large wildlife (deer)	0.2923	−0.0128	−0.0010	**0.8657**	-0.0793
Manage other wildlife	0.2770	−0.0773	0.0799	**0.7387**	0.1939
Produce hay/forage	0.0599	0.3569	0.1370	−0.2315	**0.6425**
Cultivate crops	−0.0216	0.1995	0.1282	−0.0159	**0.7628**
Obtain income from minerals	−0.0988	0.0775	0.1841	0.1023	**0.6747**
Have financial investment	0.2230	0.1096	−0.1402	0.0359	**0.6175**

Table 3
Dependent and independent variables used in the two logit regression models for willingness to apply prescribed fire on one's own land and willingness to participate in the application of prescribed fire on another person's land.

Variable name	Variable descriptions
Dependant variables	
Apply prescribed fire on own land	Binary response to question, "Have you ever conducted a prescribed fire on your land"? (1 = yes, 0 = no)
Participate in prescribed fire on others' land	Binary response to question, "Have you ever participated in a prescribed fire on someone else's land"? (1 = yes, 0 = no)
Independent variables	
Hypothesis 1—liability issues	
General/personal liability	Latent variable for liability issues with prescribed fire[1]
Risk reduction	Latent variable for prescribed fire risk reduction[1]
Influence	Latent variable for influences on landowner use of prescribed fire[1]
Burn bans	Ordinal response for, "I have been prevented from using prescribed fire due to burn bans imposed by county commissioners."[2]
Prescribed fire insurance	Ordinal response for, "Prescribed fire insurance effectively protects burners from liability in case of escape fires."[2]
State liability standards	Ordinal response for, "State-legislated lower liability standards for prescribed burning protects burners from liability in case of escaped fires."[2]
Hypothesis 2—social connectedness	
PBA membership	Membership in prescribed burn association. Binary single item variable.
State	State of residence (0 = Oklahoma, 1 = Texas)
Hypothesis 3—fire as a management tool	
Fire affordability	Ordinal response for, "Prescribed fire is less costly than other methods for controlling woody plant encroachment."[2]
Fire ease	Ordinal response for, "Prescribed fire is easier to implement than other methods for controlling woody plant encroachment"[2]
Fire efficacy	Ordinal response for, "Prescribed fire is more effective than other methods for controlling woody plant encroachment"[2]
Landowner characteristics	
Gender	1 = male, 0 = female
Age (yr)	Landowner's age in 2015 (continuous single item variable)
Education	Landowner's level of education: high school (reference category), some postsecondary/bachelor degree, graduate/professional degree
Yr of ownership	Number of yr since land ownership (continuous single item variable)
Property size	Ordinal response for property size: 100-500 acres (reference category), 501-2500 acres (medium acreage) and > 2500 acres (larger acreage).
Residency	Categorical response used for place of residence: full-time resident, occasional resident, and absentee resident (reference category)
Income from property	Ordinal response for, "In 2014, approximately what percent of your total annual income was generated from activities on your rural property?" 0% (reference category), 1 – 25%, 26 – 50%, 51 – 75%, 76 – 100%
Hunting	Latent variable for hunting as primary ownership motivator[3]
Farming	Latent variable for farming as primary ownership motivator[3]
Ranching	Latent variable for ranching as primary ownership motivator[3]
Recreation/amenity	Latent variable for recreation as primary ownership motivator[3]
Heritage	Latent variable for leaving land to family as primary ownership motivator[3]

[1] < 3 = negative … > 3 = positive.
[2] Scale response (1 = strongly disagree … 7 = strongly agree).
[3] < 3 = unimportant … > 3 = important.

Texas, and almost a third (32%) indicated they were a member of a PBA. The large majority of respondents (81%) were male, and their average age was 66 yr. The average yr of property ownership was 26.4, and a third of respondents reported their property had been in their family for > 100 yr. About half (54%) reported they live on their property full-time, and the greatest proportion of respondents (40%) reported they generated 26 – 50% of their 2015 household income from their property.

Table 4
Demographic characteristics of mail survey respondents in Texas and Oklahoma.

Demographic variable	Descriptor	Statistic
Age (yr)		M = 65.9; SD = 10.9, Range 30-93
Yr property owned		M = 26.4, SD = 16.9, Range 0-100
Yr family ownership		M = 71.4, SD = 44.1, Range 0-400
Gender	Male	81.0%
Prescribed burning association member	Yes	32.0%
State of residence	Texas	56.5%
	Oklahoma	43.5%
Education	High school	15.0%
	Postsecondary/bachelor degree	50.0%
	Graduate/professional degree	35.0%
Property size	100-500 acres	29.4%
	501-1 000 acres	19.8%
	1 001-2 500 acres	25.0%
	2 500 acres +	25.8%
Live on property	Full-time resident	54.0%
	Weekend/occasional resident	19.0%
	Do not reside on property	27.0%
% Income from property	0 – 25%	15.6%
	26 – 50%	39.9%
	51 – 75%	15.9%
	76%+	14.9%

Regression Results

The results of two logistic regression models are presented in Table 5. These models were developed to identify statistically significant determinants of landowner willingness to apply prescribed fire for woody plant management on their own land and their willingness to participate in this activity on neighboring land. Statistical significance for explanatory variables was determined by $P < 0.05$.

Hypothesis 1 stated *"The likelihood that a landowner will apply prescribed fire to their land or participate in its application on others' land is negatively correlated with his or her perception about the legal liability for applying fire."* Our results corroborate this hypothesis. Survey respondents who perceived a higher level of fire-related legal liability were 26% less likely to apply prescribed burns to their own land and 38% less likely to assist with the application of prescribed burns on another person's land than respondents who perceived legal liability for doing so to be lower. In addition, a burn ban, which restricts the use of prescribed fires during hot dry periods, was a significant barrier to respondents' willingness to burn their own property (43% of respondents agreed with the statement that "I have been prevented from using prescribed fire due to burn bans imposed by county commissioners") but was not significant with respect to willingness to assist with burns on other people's properties. This difference may be due to perceptions that other

Table 5
Logistic regression models of factors influencing willingness to apply prescribed fire on one's own and another person's land. (Bolded values indicate statistical significance at $P < 0.05$.)

	Burn own land Pseudo $R^2 = 0.2491$; $P < 0.001$		Burn another's land Pseudo $R^2 = 0.3163$; $P < 0.001$	
Independent variables	%Δ odds	*P* value	%Δ odds	*P* value
Hypothesis 1: legal liability				
General/personal liability (risk)	**−25.7**	**0.025**	**−38.0**	**0.000**
Burn ban inhibits burning	**22.4**	**0.001**	7.1	0.263
Reduced concern	19.4	0.228	19.2	0.228
Influence	10.2	0.461	−6.7	0.613
Prescribed fire insurance	3.0	0.691	9.8	0.223
State-legislated liability standards	10.6	0.140	−1.8	0.798
Hypothesis 2: social connectedness				
Prescribed burning association member	**280.6**	**0.000**	**577.5**	**0.000**
Oklahoma residency	**60.1**	**0.003**	−7.1	0.813
Hypothesis 3: fire as a management tool				
Prescribed fire is less expensive	**30.7**	**0.004**	9.7	0.309
Prescribed fire is easier	0.6	0.936	−3.3	0.651
Prescribed fire is effective	7.9	0.373	−13.1	0.227
Landowner characteristics				
Gender (male)	−27.3	0.375	62.8	0.056
Age	−2.1	0.071	−2.2	0.073
Some undergraduate/bachelor's degree[1]	41.9	0.325	−26.4	0.384
Some graduate/graduate degree[1]	28.6	0.506	**−52.9**	**0.050**
Yr of property ownership	1.6	0.067	0.8	0.375
Medium acreage	−5.4	0.873	−28.9	0.332
Large acreage	40.0	0.292	−4.3	0.895
Full-time resident[2]	**128.7**	**0.005**	−22.8	0.393
Occasional resident[2]	93.9	0.069	**−65.1**	**0.005**
1–25% income[3]	30.5	0.500	**136.1**	**0.043**
26–50% income[3]	49.1	0.420	**293.1**	**0.009**
51–75% income[3]	15.4	0.791	**365.4**	**0.008**
76% to full income[3]	67.0	0.360	**218.1**	**0.052**
Hunting	5.4	0.710	**58.8**	**0.002**
Farming	−11.0	0.412	**−22.7**	**0.074**
Ranch/profit	−9.3	0.508	−7.6	0.608
Recreation/amenities	4.3	0.734	7.6	0.556
Heritage	−15.9	0.179	−13.1	0.297

[1] High school is reference category.
[2] Nonresident on property is reference category.
[3] 0% annual income from rural property is reference category.

landowners would not ignite fire on their land when burn bans are in place. Interestingly, other factors that could influence the application of prescribed fire were statistically not significant with respect to willingness to apply prescribed fire. Specifically, our study did not find evidence that landowners concerns about insurance or state liability standards influence their willingenss to conduct a prescribed fire on their land or anyone else's property.

Hypothesis 2 stated: *"Landowner perception of legal liability for applying prescribed fire is positively mediated by their social connectedness, such as membership in a prescribed burning association."* The regression models show that respondents who belonged to PBAs were, in fact, 281% more willing than respondents who were not PBA members to apply fire on their own property and 578% more willing to assist in burns on another person's property. Also, respondents who reside in Oklahoma were 60% more likely than Texas respondents to apply prescribed burns on their land likely due to a greater profire culture that is correlated with more PBAs in Oklahoma than Texas (19 and 11, respectively) (GPFSE, 2019).

Hypothesis 3 stated: *"Landowners who perceive fire to be an effective, affordable, and easy-to-use tool for woody plant management will be more willing to burn than those who do not have this positive perspective of prescribed fire."* The regression models corroborated this hypothesis in only one instance; respondents who reported they believed prescribed fire to be an affordable woody plant management tool were 30.7% more willing than those who felt otherwise to apply prescribed fire, but only on their own property and not on someone else's property. By contrast, landowner willingness to use this management tool on either their own or another's property was not statistically associated with perceptions about efficacy and ease of use of fire.

Numerous demographic control factors were also significantly correlated with respondent willingness to apply prescribed fire. In particular, respondents with some level of graduate education were 53% less likely to assist with a prescribed burn on another person's land. Compared with nonresident (absentee) landowners, full-time resident respondents were 129% more likely to burn on their own property. By contrast, part-time resident respondents were 65% less likely than absentee landowners to assist with prescribed burns on another person's property. Some property ownership motivations were also correlated with willingness to assist with prescribed fire on another person's land; farming as a primary ownership motivation was negatively associated (23%) with willingness to assist with the application of prescribed fire, whereas hunting was positively associated (59%) in this regard. Finally, respondents who obtained any proportion of income from their property were 136–365% more willing to assist other property owners with prescribed burns but were not statistically more willing to apply fire on their own land.

Discussion and Conclusion

Woody plant encroachment is a global phenomenon, in part, due to widespread fire suppression in ecosystems that were historically subjected to periodic fires, some of high intensity (Wilcox et al., 2018). Although the increased application of prescribed fire has been

recommended to contain woody plant encroachment and reduce wildfire risk associated with fuel load accumulation in the western United States, private landowners are often reluctant to use this tool because of concerns about legal liability for igniting fire that could escape onto neighboring properties (Yoder et al., 2004; Kreuter et al., 2008).

The negative correlation between willingness to apply prescribed fire and perceived legal liability for doing so suggests that the public benefits provided by periodic prescribed fire in reducing fuel loads may be outweighed on private land by landowners' undue concerns about legal liability for igniting fires that burn out of control. The weaker correlation when burning one's own land than when participating in prescribed fire on another person's land is consistent with the notion that the private benefits of burning one's own land are greater than those of helping burn another person's land, and those assisting with a burn on another property may be unsure of the adequacy of insurance on that property to cover such liability.

Our research also emphasized that burn bans negatively affect landowner willingness to apply prescribed fire on their land. In the Southern Plains, high-intensity fires maximize the probability of mortality of nonresprouting invasive woody plants, such as pervasive Ashe juniper trees. However, such fires often occur under conditions when risk averse public officials are more likely to impose a burn ban due to increased concerns over escaped fire (Twidwell et al., 2012, 2016). Restricting burn bans to serious fire hazard conditions or allowing exceptions to burn bans are important considerations to encourage the broader application of prescribed fire under conditions that produce high-intensity restorative burns. This suggests that those who have authority to implement burn bans should be provided with salient information about the ecological and wildfire risk reduction benefits of periodically applying prescribed fire in the Southern Plains.

The perceived danger of escaped fire has led many policymakers to adopt precautionary stances regarding the use of prescribed fire, while at the same time there are calls for increased use of prescribed fire to reduce wildfire risk (North et al., 2015). Legal statutes relating to land management tools influence both public perception about land management options and land managers' concerns about the riskiness of adopting affected management tools (Haimes et al., 2002). This has led some to argue for less onerous legal statutes for the use of prescribed fire on private land (Wonkka et al., 2015). Others have stated that because insurance can reduce the "cost" of liability from an escaped fire, the total net benefit of applying a prescribed fire increases with insurance protection (Yoder et al., 2004). However, some have questioned whether insurance policies covering escaped fire damages actually lead to greater use of prescribed fire (Weir et al., 2019). We found that neither a potential shift in legal liability standards nor liability insurance for applying prescribed fire significantly affected landowner willingness to apply prescribed fire in the Southern Plains. This is inconsistent with findings in the southeastern United States where landowners in states with gross negligence statutes burned significantly more land than those in adjacent states with simple negligence statutes (Wonkka et al., 2015). Perhaps the reason for our null results was that both Texas and Oklahoma have simple negligence statutes for prescribed fire and, therefore, survey respondents may have been unclear about how a change in the statute from simple to gross negligence might reduce their legal exposure for escaped fires. There is some evidence that, even under similar legal statutes, perceptions of liability for applying prescribed fire vary (Weir et al., 2019). For example, in Oklahoma landowners appear to be less concerned about using prescribed fire than in Texas, possibly due to interstate differences in language included in the statute, interpretation of the language by County Court Judges, or the greater occurrence of PBAs whose members are more likely to embrace a fire culture than nonmembers. This issue needs further investigation to determine if changes in language in statutes pertaining to prescribed fire may enhance the use of prescribed fire.

The finding that PBA members are almost three times more willing than nonmember landowners to apply prescribed fire on their own land and almost six times as willing to participate in prescribed fire on another person's property corroborates the contention that social networks that support prescribed fire can switch subjective norms from antifire to profire. (Jacobson et al., 2001; Toledo et al., 2013; Twidwell et al., 2013). Moreover, such landowner associations can act as a catalyst for the use of prescribed fire on private land. One reason that supportive social networks, such as PBAs, enhance the use of prescribed fire is that they pool community skills and resources that help reduce the risk of escaped fire by promoting safe burning practices that include proper planning and preparation and adequate expertise, equipment, and labor when the fire is applied (Taylor, 2005; Twidwell et al., 2012). The PBA concept also promotes communication between neighbors and application of fire simultaneously across property boundaries, thus reducing liability through collaboration. In addition, assisting with the application of a prescribed fire on a neighbor's property, as is required by several PBAs, represents a social investment that increases trust and sustains cooperation among neighboring landowners (Siegrist et al., 2000; Wagner et al., 2007; Sutherland and Burton, 2011; Toledo et al., 2014). Our finding that survey respondents who were members of a PBA were far more willing than nonmembers to apply fire on another person's property may be explained by there being potentially valuable benefits to aiding in the application of prescribed fire. These include increased trust, knowledge, and skills gained through active participation in the application of fire, as well as land management benefits such as reduced woody plant proliferation and lower risk of wildfire spreading across landscapes (Toledo et al., 2013). Although PBAs were first established in the Texas section of the Southern Plains, they have proliferated across the central and western United States (Twidwell et al., 2013) and are a potentially important vehicle for reducing the risk of applying prescribed fire and, therefore, promoting broader use of this tool for combatting woody plant encroachment in fire-dependent ecosystems.

Our finding that affordability of fire as a woody plant management and/or fuel reduction tool was an important determinant of landowner willingness to apply fire on their own land implies that, when promoting the use of prescribed fire, economic efficacy should be more strongly emphasized. In addition, public cost-sharing funds for woody plant management could be preferentially directed to the preparation of land that is to be burned (including preparation of fire breaks) instead of targeting "less risky" but costlier and potentially less effective mechanical and chemical woody plant treatments.

While our study focused on willingness to apply prescribed fire subject to perceived liability of using this land management practice, the study did not explore the point where concern over woody plant encroachment outweighs the perceived risk of using prescribed fire. This issue should be addressed in future research. And our study was restricted to Texas and Oklahoma, both of which apply simple negligence liability standards to the use of prescribed fire. Future research should also compare landowner willingness to apply prescribed fire in other regions with simple and gross negligence standards.

Implications

The application of prescribed fire in fire-adapted ecosystems is critical for containing the expansion of invasive woody plants and for fuel load management to reduce risks of catastrophic wildfire.

Our finding that landowners' risk perception regarding liability for escaped fire damage deters them from engaging in the use of prescribed fire suggests the need to mitigate potentially unfounded landowners' perceptions that using prescribed fire is highly risky. Less stringent liability standards have been suggested as an important measure to accomplish this. This recommendation should be further researched elsewhere where more frequent and widespread application of periodic fire may help maintain open grasslands and savanna ecosystems and reduce fuel load accumulations. Especially important is a broader understanding of the potential effect of converting liability standards from simple to gross negligence or at least to reexamine language within existing statutes that discourage landowners from using prescribed fire as a management tool. Also, burn bans should be limited to periods when wildfire risks are most extreme because such bans deter the application of prescribed fire under conditions that lead to substantial invasive woody plant mortality. While well-meaning, excessively restrictive burn bans may undermine their intended purpose of reducing wildfire fire risk by promoting buildup of fuel loads that exacerbate wildfires.

A major policy implication of our finding that PBA membership leads to substantially greater willingness to apply prescribed fire on private land is that the establishment of more PBAs should be encouraged and membership of such associations should be actively promoted. Finally, the economic efficacy of using prescribed fire should be broadly publicized and cost-sharing programs that promote the use of prescribed fire, rather than potentially less effective and costlier mechanical and chemical woody plant treatments, should be prioritized.

Our findings have important implications for the formulation of polices aimed at changing landowners' perceptions that applying prescribed fire is legally risky. Profire polices that shift the burden of liability for using fire more equally among landowners who burn their land and neighbors who should take actions to reduce their exposure to wildfire will encourage the wider use of this important environmental management tool for stemming woody plant invasion, reducing accumulated fuel loads, and decreasing the risk of catastrophic wildfire.

Acknowledgments

The authors thank all 680 landowners who graciously agreed to provide data for this study, approved under protocol IRB2015-0516D.

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