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To Insure or not to Insure? Factors Affecting Acquisition of Prescribed Burning Insurance Coverage

Rajan Parajuli [a,*], Omkar Joshi [b], Neelam C. Poudyal [c], Urs P. Kreuter [d]

[a] Department of Forestry & Environmental Resources, North Carolina State University, Raleigh, NC 27695, USA
[b] Department of Natural Resource Ecology & Management, Oklahoma State University, Stillwater, OK 74078
[c] Department of Forestry, Wildlife & Fisheries, The University of Tennessee, Knoxville, TN 37996, USA
[d] Department of Ecosystem Science & Management, Texas A&M University, College Station, TX 77843-2120, USA

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ABSTRACT

Prescribed burning is a widely used tool in forest and grassland management. However, because fire that escapes from a prescribed burn accidentally may cause property damage, injuries, and even human casualties, purchasing insurance to cover such damages may be beneficial for prescribed burn practitioners. Given that insurance coverage for prescribed fire is recently emerging, factors that determine burners' decisions to purchase such insurance are largely unknown. On the basis of data from a survey of prescribed burn practitioners in 14 southern and midwestern states, we modeled prescribed burners' likelihood of purchasing insurance with respect to demographic characteristics, land management objectives, and importance placed on regulatory compliance and land use practices. Results suggest that prescribed burn practitioners are more likely to obtain such insurance if they are landowners themselves or have a written prescribed burn plan. Age of respondents and the level of importance they place on compliance with environmental laws also had a significant positive effect on the likelihood of obtaining insurance coverage. Respondents were less likely to purchase insurance if their land management objective was to control invasive plants or they considered the availability of lower-cost alternatives for woody plant removal an important factor in deciding whether or not to conduct prescribed burns. These findings shed light on underlying factors influencing insurance coverage for prescribed burning and are potentially beneficial for promoting the acquisition of insurance among burn practitioners.

Introduction

Prescribed burning is an effective rangeland management tool for reducing fuel load accumulation in order to reduce wildfire risks, controlling invasive woody plants, maintaining and restoring native fire-tolerant species, improving forage quality, and enhancing biodiversity (Fuhlendorf and Engle, 2001; Van Liew et al., 2012; Waldrop and Goodrick, 2012; Russell and Lashmet, 2017). Empirical research has shown that prescribed fire applied at 2- to 3-yr intervals in pine forest ecosystems effectively minimizes risks of damage from wildfire (Kobziar et al., 2015; Long and Oxarart, 2017). Therefore, prescribed fire has been hailed as necessary for reducing catastrophic wildfire risk, especially in forest ecosystems (North et al., 2015). In addition, due to its ecological and economic benefits and the establishment of a number of prescribed burn associations[1] (PBAs) that promote the use of prescribed fire, more rural landowners have been applying fire on their land (Twidwell et al., 2013). Even though the nationwide use of prescribed burn decreased from 12.8 million acres in 2011 to 11.3 million acres in 2017, the Western region witnessed increases in acres using prescribed burning, as well as a number of prescribed fire councils (Melvin, 2018). It states that 80% of the 2017 acres were burned to meet forestry objectives and concluded that weather, air quality/smoke management, and lack of capacity to apply fire safely are primary impediments to prescribed fire implementation.

Despite its multiple benefits for hazardous fuel reduction and ecosystem restoration, many private landowners are still reluctant to use prescribed fire because of concerns over legal liability associated with escaped fire (Kreuter et al., 2008; Weir et al., 2019) and other social and legal factors (Yoder et al., 2004; Sun and Tolver, 2012; Toledo et al., 2013; Kobziar et al., 2015; Wonkka et al., 2015). Unintended consequences of escaped fire can lead to property damage and human injury and even casualty. However,

* Correspondence: Rajan Parajuli, Dept of Forestry & Environmental Resources, North Carolina State University, Raleigh, NC 27695, USA. Tel.: +1 919 513 2579.
E-mail address: rparaju@ncsu.edu (R. Parajuli).

[1] A PBA is a group of landowners and other stakeholders who work in partnership sharing their knowledge, man-power and equipment to conduct prescribed burns (Weir, 2010). PBAs can help reduce the barriers to prescribed burning by assisting their members in obtaining insurance, sharing equipment and other resources, and providing peer support to prescribed burns (Diaz et al., 2016).

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evidence overwhelmingly shows that prescribed fire applied using safe burning guidelines is far less risky than many other common practices in rural land management (Twidwell et al., 2015). Evidence indicates that < 1% of prescribed burns have escaped and most resulted in negligible damage (Dether and Black, 2006; Weir et al., 2019). When prescribed burns do escape and cause extensive damage, the consequences for future burning can be serious. For example, major fire events such as the 2000 Cerro Grande in New Mexico and the 2012 Little Fork Fire collectively resulted in the destruction of hundreds of homes and three human deaths, triggering public fear and skepticism over the use of prescribed burning (Ryan et al., 2013). Similarly, a controlled burn conducted by a private contractor in Florida in summer 2018 escaped and burned 800 acres of land including 36 homes, which eventually led to several civil lawsuits against the burner (Adlerstein, 2018; Villafranca, 2018). In addition to the fear of prescribed fire-related damages, smoke emissions from such burns can lead to road safety risks, health risks, and public outcry (Hardy et al., 2001). Other political and operational challenges and conflicts with environmental laws (Endangered Species Act [ESA], Clean Air Act [CAA], Clean Water Act [CWA]) may also hinder the application of prescribed fire treatments (Ryan et al., 2013). In addition, staffing and budgetary limitations have been cited as a major impediment to the application of prescribed fire by public land managers (Kobziar et al., 2015; Melvin, 2018).

In order to regulate the potential liability associated with prescribed burning damage, several states have codified their statutes. These liability rules attempt to clarify burners' responsibility for their actions when applying a prescribed fire. Strict liability, simple negligence, and gross negligence are three categories of civil liability standards for prescribed fire in the United States (Yoder et al., 2004; Sun, 2006; Wonkka et al., 2015). Under strict or absolute liability requirements, burners are solely responsible for any property damage resulting from an escaped fire regardless of any precautionary or preventive measures taken. Simple negligence standards require burners to take reasonable precautions when conducting prescribed burning. Under gross negligence statutes, liability is imposed only if a burner is found not even slightly diligent in preventing an escape. Hence, gross negligence standards are the most lenient for burners as they entail the lowest level of risk for burning. A recent national survey determined that 5 states have no prescribed fire law, 12 states have strict liability standards, 26 states have simple negligence standards, and 7 states have the highest degree of liability protection in the form of gross negligence laws (Melvin, 2018).

Although not required by law, having insurance coverage for bodily injury and property damage offers a security blanket for burners (Russell and Lashmet, 2017). Most landowners have farm and ranch liability insurance policies that typically do provide coverage to some fire-related damage, but the extent of such coverage is often poorly defined. In response to landowners' request for prescribed fire specific coverage, several insurance companies have started providing such coverage as either a standalone policy or an extended coverage in property insurance (Evans and Busam, 2015).

Fire Risk and Insurance

Wildfires represent a major natural disaster in the United States and are projected to increase in severity due to fuel load accumulations and climate change (Luo et al., 2013). Previous research has evaluated risk of loss from wildfire with and without fuel treatment involving the use prescribed fire and mechanical control or the acquisition of insurance (Amacher et al., 2006; Chen et al., 2014; Gan et al., 2014, 2015; Deng et al., 2015; Sauter et al., 2016). In addition, Hesseln (2000) highlighted the need for benefit-cost analyses and risk-return assessments for the implementation of prescribed fire programs. Gan et al. (2014) explored the factors that determine family forest landowners' propensity to obtain insurance to cover losses resulting from wildfires. They found landowners are more likely to purchase wildfire insurance if they are female, are well educated, inherited their land, or had previously been affected by hurricanes or wildfire. Gan et al. (2015) also analyzed landowners' responses to wildfire risk in terms of "adaptation," "mitigation," and "do nothing" and found that most respondents preferred "do nothing" or use a combination of "adaptation" and "mitigation" strategies to offset wildfire risks. A similar study in Germany found that foresters were willing to pay higher insurance premiums to cover the risk of losses from wildfires than storms (Sauter et al., 2016). The same study recommended that the government should support insurance premiums in order to offset postdisaster recovery costs. Chen et al. (2014) used a spatiotemporal model to understand wildfire risk and its potential impact on insurability of timber products in Mississippi and recommended an insurance scheme that promotes preventive actions to help reduce soaring wildfire suppression costs.

The preceding studies shed light on fire insurance as a risk adaptation strategy for loss exposure to wildfire. Insurance can offset financial losses by providing compensation in an event of catastrophic disaster and serves as an adaptive strategy in responding to inherent risks associated with specified human actions, including damages sustained from the loss of control of a prescribed fire (Kunreuther, 1996; Gan et al., 2014, 2015). Given that prescribed fire is the deliberate application of fire, adoption of prescribed burning insurance may differ from wildfire damage insurance acquisition behavior. However, little is known about prescribed burn practitioners' decision making regarding procurement of prescribed fire insurance.

The objective of this study was to explore the factors that influence burn practitioners' decisions regarding the acquisition of insurance coverage for prescribed burning. Specifically, on the basis of a survey of burn practitioners, we evaluated how factors deemed important in conducting prescribed burns correlated with their likelihood of purchasing insurance coverage.

Methodology

Study Area and Data Collection

The study targeted 452 prescribed burn practitioners located in 14 states in the midwestern, western, and southern regions in the United States where prescribed fire has been most commonly used. These states, shown in Figure 1, included North Dakota, Nebraska, Kansas, Missouri, and Iowa in the Midwest; Utah, Arizona, and New Mexico in the West; and Texas, Oklahoma, Louisiana, Alabama, Georgia, and North Carolina in the South. Data required for developing a model of insurance purchase decision were obtained from a web-based survey of active prescribed burn practitioners in those states. Email addresses for prescribed burn practitioners were obtained from the Extension Service of Oklahoma State University. Respondents were contacted by sending an invitation email that included a link to the survey questionnaire (Appendix 1), which was developed in the Qualtrics program. After 4 waves of email correspondence, a total of 205 responses were obtained, representing a raw response rate of 45%. However, only 126 of the survey participants provided sufficient information for our analysis, representing a 28% usable response rate. The majority (68%) of these respondents were from Texas and Oklahoma, whereas the other 10% were from Nebraska, 5% from Kansas, 3% from Missouri and New Mexico, and remaining 11% (14) evenly divided among North Dakota, Iowa, Utah, Arizona, Alabama, Georgia, and North Carolina. In terms of state liability statutes, 4% of the responses came from states with no prescribed fire statute, 9% from states with strict liability statutes, 87% from states with simple negligence statutes

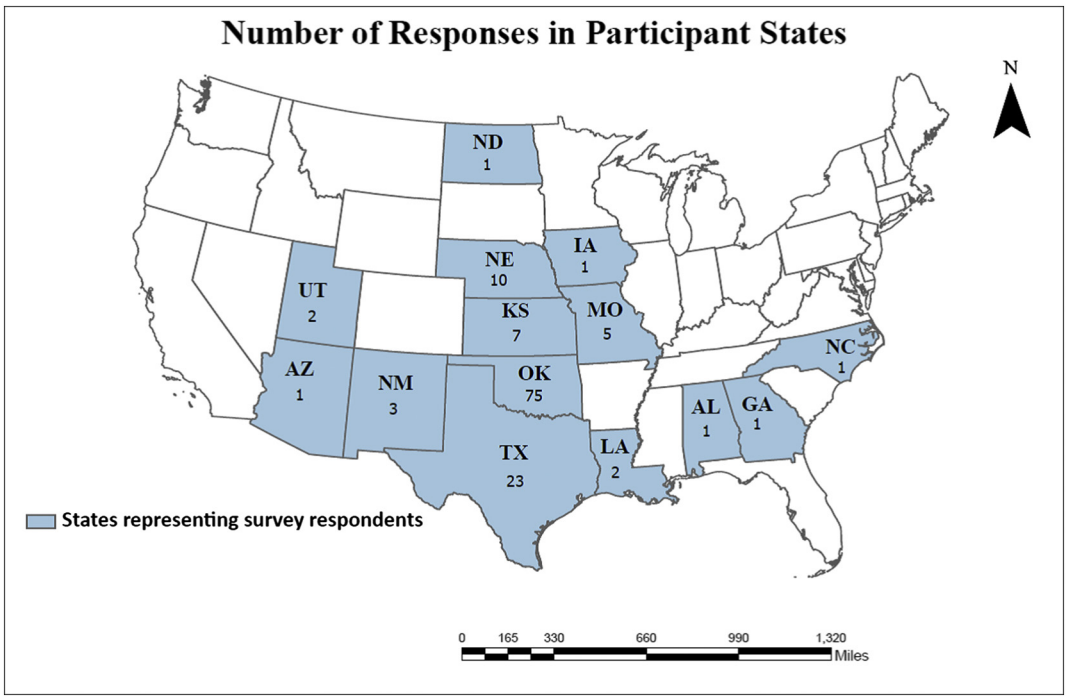

Figure 1. A map highlighting the U.S. states from where survey responses were received.

(primarily from Texas and Oklahoma), and only one from a state with a gross negligence statute (Georgia).

Econometric Model

The study used a binary choice model (purchase or not) to identify statistically significant variables associated with willingness to purchase prescribed fire insurance. The underlying theory of this method is the random utility model (Greene, 2012), which is the most commonly used theoretical framework for modeling consumer choices of products and services (Baltas and Doyle, 2001; Gan et al., 2014). We assume the difference in the utility derived from purchasing or not purchasing prescribed fire insurance is the main determinant of prescribed fire practitioners' decision to acquire insurance. Practitioners acquire prescribed burn insurance only if the utility they derive from having such insurance is greater than that from not having it. The rational choice assumption is based on the notion that people choose to maximize their utility from any products and services, and their choice depends up on attributes of alternatives, attributes of individuals, and random error.

This can be quantified as follows: Let U_a and U_b represent the practitioner's utilities from purchasing and not purchasing the

Table 1
Summary of variables used in the logit regression model to explain factors affecting decisions to purchase insurance for prescribed burning in the United States.

Variable	Description	Mean (standard deviation)
Insurance	Binary variable, 1 if the respondent has insurance coverage for damages while conducting a prescribed burning	0.39 (0.49)
Age	Respondent's age in yr	51.12 (14.67)
Education	Categorical variable, 1 if the respondent has at least bachelor's degree or higher, 0 otherwise	0.45 (0.50)
Income	Binary variable, 1 if respondent's 2016 annual before tax household income was > $75 000, 0 otherwise	0.61 (0.49)
Landownership	Categorical variable, 1 if the respondent is a landowner, 0 otherwise	0.46 (0.50)
BurnPlan	Categorical variable, 1 if the respondent has a written prescription for the planned prescribed burn, 0 otherwise	0.80 (0.40)
LowCostAlt	Influence of availability of lower-cost alternatives on respondent's decision to conduct or planning prescribed burn, ordinal variable 1 to 5	2.22 (1.29)
EnvLaw	Influence of compliance with environmental laws and regulations on respondent's decision to conduct prescribed burn, ordinal variable 1 to 5	2.89 (1.36)
ManageRangePasture	Importance of managing range and pastureland as an objective for the land under prescribed burn, ordinal variable 1 to 5	4.11 (1.18)
InvasiveControl	Importance of controlling invasive shrubs and weeds as an objective for the land under prescribed burn, ordinal variable 1 to 5	4.50 (0.73)
PropertyDamage	Respondent's perceived risks associated with property damage from prescribed burning, ordinal variable 1 to 5	3.42 (0.87)
Injuries	Respondent's perceived risks associated with injuries from prescribed burning, ordinal variable 1 to 5	3.54 (0.82)
Liabilities	Respondent's perceived risks associated with liabilities due to damage of other properties from prescribed burning, ordinal variable 1 to 5	3.65 (0.67)

insurance, respectively. If $Y = 1$, a practitioner purchases insurance, it can be inferred that $U_a > U_b$ (Greene, 2012). Since the random elements in the utility function dictate the outcome, we have:

$$Prob[Y = 1x] = Prob[U_a > U_b] = Prob[x'\beta + \varepsilon > 0x] \quad [1]$$

where $x'\beta$ offers all the observable portions of the difference of the two utility functions and ε denotes the difference between the two random elements. The term x is the set of variables describing the attributes of prescribed burning and its practitioners (Table 1). A vector of coefficient β reflects the effect of changes in x on the probability of buying insurance (Greene, 2012).

Since the stochastic component ε can take any functional form and the decision variable Y takes only binary choice values, Equation [1] can be represented as:

$$Prob[Y = 1x] = F(x, \beta) \text{ and } Prob[Y = 0x] = 1 - F(x, \beta) \quad [2]$$

Two of the common probability distribution functions considered to solve $F(x,\beta)$ are probit and logit models. Whereas the probit model takes normal distribution into consideration, the logit model considers the logistic probability (Gumbel) distribution function. Given these two distributions generally result in similar outcomes and there is no theoretical basis for choosing one distribution over the other (Greene, 2012), we adopted the logit model in this study because it offers desirable statistical properties including minimum sufficiency and computational and interpretational simplicity (Gan et al., 2014). The logistic probability function is specified as:

$$Prob[Y = 1x] = \frac{exp(x'\beta)}{1 + exp(x'\beta)} = \Lambda(x'\beta) \quad [3]$$

On the basis of Equation [3], the empirical specification of the logit model is:

$$\begin{aligned} Prob[Y = Insurance] &= \Lambda(\beta_0 + \beta_1 Age + \beta_2 Education + \beta_3 income \\ &+ \beta_4 Landownership + \beta_5 BurnPlan + \beta_6 LowCostAlt \\ &+ \beta_7 EnvLaw + + \beta_8 ManageRangePasture \\ &+ \beta_9 InvasiveControl + \beta_{10} PropertyDamage \\ &+ \beta_{11} Injuries + \beta_{12} Liabilities) \end{aligned} \quad [4]$$

where *Insurance* is a binary choice (1 = yes and 0 = no) variable indicating whether or not respondents purchased prescribed burning insurance. Definitions, descriptive statistics, and a priori expected signs for each variable in Equation [4] are presented in Table 1 and described below.

Age

This denotes the respondent's age in years. While the level of risk aversion generally increases with age (Gómez-Limón et al., 2003), previous research on wildland and prescribed fire did not find significant influence of age on risk aversion or insurance purchase behavior (Gan et al., 2015; Joshi et al., 2019). Therefore, the sign of the regression coefficient for this variable was unclear.

Education

The highest educational attainment of the respondent was denoted as 1 with at least a bachelor's degree and 0 otherwise. On the basis of previous research by (Gan et al., 2014), a positive sign was expected for the regression coefficient on this variable.

Income

This variable characterized 2016 annual household income before tax, which was denoted as 1 for those having > $75 000 (Kreuter et al., 2008; Joshi et al., 2019) and 0 otherwise. Because respondents having a higher income are likely to have higher affordability (Gan et al., 2015), a positive sign was expected for this variable.

Landownership

This categorical variable captures the current affiliation of respondents, with 1 indicating that the respondent is the owner of the land and 0 indicates otherwise. Given landownership is associated with an inherent sense of responsibility of any liability and damage (France-Hudson, 2017), a positive sign was expected on the coefficient of this variable.

BurnPlan

This binary variable (1 = yes and 0 = no) represents whether or not respondents have a written plan for prescribed burning. On the basis of the findings of Gan et al. (2015) that landowners with a written forest management plan are more likely to adopt a wildfire response strategy and given that possession of a burn plan implies a landowner is cognizant of the timing and potential risk of applying prescribed fire, we predict this variable to be positively related with the likelihood of purchasing prescribed burning insurance.

LowCostAlt

On the basis of a 5-point ordinal response scale (1 = no influence … 5 = great influence), this variable captures how availability of lower-cost alternatives for removing woody plants may impact respondents' decisions to plan and/or conduct a prescribed burn. Van Liew et al. (2012) found prescribed fire to be economically superior to other commonly applied mechanical and chemical woody plant treatments. Respondents who chose to use prescribed fire instead of other treatments due to its cost-effectiveness may view insurance as an additional financial burden. Hence, we predict that the sign of this variable is negative with respect to respondents' likelihood of purchasing prescribed burn insurance.

EnvLaw

This variable represents respondents' perception of the influence of compliance with environmental laws and regulations in planning and conducting prescribed burns. This variable was also quantified using a 5-point ordinal scale (1 = no influence … 5 = great influence). The application of prescribed burning is regulated by various laws including the CAA, CWA, ESA, forest fire control law, and general tort law concerning property damage and personal injury (Haines and Cleaves, 1999). While some government agencies and programs promote the use of prescribed burning, several environmental laws and state-specific liability laws and statutory reforms substantially influence prescribed burning activities (Yoder et al., 2004; Sun, 2006; Wonkka et al., 2015). On the basis of these considerations, we predict that respondents' perceptions of legal and regulatory compliance effects on the use of prescribed fire will be positively associated with their willingness to acquire prescribed burn insurance.

ManageRangePasture

This variable represents respondents' perception of managing range and pastureland as an important activity on the land they intend to burn and was measured on a 5-point ordinal response scale (1 = not important … 5 = extremely important). Emergence of the livestock industry and ranchers' preference for more homogenous landscapes resulted in the widespread utilization of fire as a landscape management tool (Taylor, 2003; Becerra et al., 2013; Joshi et al., 2017). Given a general lack of experience with prescribed fire among other types of land users, respondents with well-defined range or pastureland management goals may be more likely to buy insurance in order to alleviate concerns over escaped fire. Accordingly, the coefficient of this variable is expected to have a positive sign.

Table 2
Logit regression results highlighting the factors influencing decisions to purchase insurance coverage for prescribed burning in the United States.

Variable	Full model ($N = 115$)		Reduced-form model ($N = 122$)		
	Coefficient (standard error)	P value ($P > \|z\|$)	Coefficient (standard error)	P value ($P > \|z\|$)	Odds ratio
Age	0.04 (0.02)	**0.02**	0.04 (0.02)	**0.04**	1.04
Education	−0.53 (0.46)	0.25			
Income	−0.55 (0.54)	0.31			
Landownership	1.06 (0.55)	**0.05**	1.01 (0.51)	**0.05**	2.75
BurnPlan	1.20 (0.61)	**0.05**	1.16 (0.58)	**0.04**	3.18
LowCostAlt	−0.43 (0.22)	**0.05**	−0.36 (0.19)	**0.07**	0.70
EnvLaw	0.34 (0.18)	**0.06**	0.32 (0.17)	**0.05**	1.37
ManageRangePasture	0.55 (0.23)	**0.01**	0.51 (0.22)	**0.02**	1.67
InvasiveControl	−0.71 (0.40)	**0.07**	−0.65 (0.36)	**0.07**	0.52
PropertyDamage	0.49 (0.46)	0.29	0.48 (0.29)	**0.09**	1.62
Injuries	−0.04 (0.43)	0.93			
Liabilities	−0.06 (0.59)	0.91			
Constant	−4.20 (2.57)	0.10	−4.84 (2.26)	**0.03**	0.01
Specification tests					
Linear predicted value (_hat from *linktest*)			0.97	0.00	
Linear predicted value (_hat-square from *linktest*)			−0.05	0.76	
Hosmer and Lemeshow's goodness of fit (chi2 [8])			6.11	0.63	

Bold numbers indicate statistical significance.

InvasiveControl

This variable refers to the importance landowners place on controlling invasive shrubs and weeds on the land they plan to burn, and it was also quantified using a 5-point ordinal response scale (1 = not important … 5 = extremely important). Given that prescribed fire is economically superior to mechanical and chemical brush management treatments (Van Liew et al., 2012), land managers who prefer using this less expensive option to control invasive species may also be disinclined to incur the extra cost of obtaining insurance for prescribed fire. Therefore, we predict a negative sign on the coefficient of this variable.

PropertyDamage

This variable used a 5-point Likert scale (1 = is not important … 5 = most important) to capture respondents' perceptions of risk associated with property damage while conducting prescribed burning. Since risk averse respondents prefer to obtain prescribed burn insurance as a risk premium (Joshi et al., 2019; Weir et al., 2019), we predict the coefficient of this variable to be positive.

Injuries

This variable, measured using a 5-point ordinal response scale (1 = is not important … 5 = most important), characterized respondent's perceived risks associated with injuries while conducting prescribed burning. Because respondents who worry about bodily injuries while conducting prescribed fire tend to be risk averse, we predict a positive sign of its coefficient.

Liabilities

This variable, measured using a 5-point ordinal response scale (1 = is not important … 5 = most important), estimates respondents' perceived risks associated with liabilities due to damages caused to the property of others while conducting prescribed burning. Because concern for personal liability also characterizes risk-averse behavior (Maguire and Albright, 2005), we similarly predict a positive sign for this variable.

Results

Survey results revealed that only 39% of the respondents had insurance coverage for prescribed burning (see Table 1). In terms of demographic characteristics, the average age of the respondents was 51 yr and 45% had a bachelor's degree education. In terms of respondents' affiliations, 46% of the respondents were landowners themselves and 61% had annual household income > $75 000. Approximately 80% of the respondents had a written burn plan. The use of prescribed burning to control invasive shrubs and weeds was scored most highly (mean score of 4.50 on the 5-point response scale) as an objective for applying prescribed fire. Of the three liability factors, legal liability for property damages from escaped fire was perceived to be the greatest risk of prescribed burning (mean score of 3.65). The lowest scoring factors with respect to level of importance when considering the use of prescribed were compliance with environmental laws and regulations and availability of lower-cost woody plant treatment alternatives (mean scores of 2.89 and 2.22, respectively).

Table 2 presents results from the logit regression models of factors influencing respondents' decisions to purchase insurance. The full model incorporates all the variables from the model specification (see Equation [4]). Since education, income, and two variables representing perceived risks associated with prescribed burnings were statistically insignificant, the regression was rerun without those variables and is presented as a reduced-form model in Table 2. We accepted $P < 0.10$ as the statistical significance threshold because of the exploratory nature of the study and the relatively small sample size. In terms of specification tests, the linear predicted values from the *linktest*, hat and hat-squared were statistically significant and insignificant, respectively, indicating that the link function is properly specified and there is no omitted variable bias problem (STATA, 2019; UCLA, 2019). Similarly, the insignificant estimate from the Hosmer and Lemeshow's goodness-of-fit test (UCLA, 2019) suggests that the specified model fits the data well. The variance inflation factor (VIF) associated with independent variables in the model was far below the acceptable threshold of 10 (Gujarati, 2004), inducing that no multicollinearity is present.

The logit regression results suggest that among socioeconomic variables, *age* is the only significant positive factor affecting decision to purchase insurance. On the basis of the odds ratio, each year increase in respondent age will likely result in an about 4% increase in the odds of purchasing insurance coverage for prescribed burning. The positive coefficient associated with *landownership* suggests that respondents who conduct prescribed burning on their own land were 175% more likely to purchase insurance than respondents who were not landowners. Similarly, respondents who had a written burn plan were 218% more likely to purchase insurance than those who did not have a burn plan. In addition, the positive coefficient estimate associated with *EnvLaw* suggests that respondents who perceived regulatory environmental laws and regulations to be an important

factor in conducting prescribed burn were 37% more likely to purchase insurance than those who considered laws and regulations to be less important. Although the goal of using prescribed fire to manage range and pastureland *(ManageRangePasture)* was positively associated with the propensity to purchase insurance, the use of this land management tool to control invasive plants *(InvasiveControl)* was negatively associated with this insurance acquisition propensity. The negative coefficient estimate associated with *LowCostAlt* indicates that respondents who considered the availability of lower-cost alternatives for woody plant removal an important factor in deciding whether or not to conduct prescribed burning also have a lower propensity to purchase prescribed burning insurance coverage. Finally, respondents who reported higher perceived risks associated with property damage from prescribed burning were more likely to purchase insurance coverage.

Discussion and Conclusions

The result of this study suggests that prescribed fire practitioners who have a stronger sense of the need for regulatory compliance are more likely to obtain prescribed fire insurance than others. Regulatory compliances relating to the National Environmental Policy Act (NEPA), CAA, and ESA require burn practitioners to take precautionary actions when applying prescribed fire, including smoke management and protection of endangered species habitat (Ryan et al., 2013), which should encourage burners to adopt risk mitigation strategies including the acquisition of prescribed fire insurance (Gan et al., 2014). This observation reveals a need for further study on the increase in compliance costs of burners with the purchase of prescribed burning insurance. If the compliance costs increase substantially, encouraging the broader adoption of prescribed burning insurance may be challenging. This warrants a provision of financial incentives (e.g., public cost sharing or tax breaks) to offset such insurance costs in order not to disproportionately impact less affluent landowners and burning practitioners.

Similarly, respondents who had obtained a written burn plan were more likely to have insurance coverage because written burn plans stipulate the precautions and appropriate actions necessary for the safe application of a prescribed fire. Burn plans outline appropriate fuel and weather conditions for the preferred type of burn (low or high intensity), as well as proper fire ignition, smoke management, risk management and public safety practices, among others (Weir et al., 2013). This finding also has a broad implication for burn practitioner collaboration, which is facilitated by PBA membership. PBA members can obtain assistance with the compilation of written burn plans (Kreuter et al., 2008), alerting them to regulatory compliance and safe fire practices, which in turn, may encourage them to acquire prescribed burning insurance. It is not clear whether any prescribed fire insurance policies provide a premium discount for having a written burn plan. If this practice is prevalent in the insurance market, our finding that having a written plan is associated with a greater propensity to buy insurance warrants further investigation to confirm this causality.

Our results suggest that preference for insurance coverage varied by land management objectives that led respondents to conduct a prescribed burning. Practitioners who valued the use of prescribed fire as an effective range or pastureland management tool may be more willing to minimize risk exposure by obtaining insurance. Also, those who own the land where prescribed fire is to be applied also appear to be more willing to obtain insurance coverage than those who are associated with government agencies, university extension services, or nongovernment organizations. This can be attributed to the likelihood that landowners feel a greater sense of risk or loss exposure while applying prescribed fire on their land than other practitioners.

Despite its acceptance as a management tool (Joshi et al., 2019), perceived risks and liability concerns are major obstacles in prescribed burn adoption decisions (Elmore et al., 2009; Joshi et al., 2019). Becuase insurance serves as an adaptive premium to offset risk (Gan et al., 2014), our results showing the interest of risk-averse respondents in obtaining insurance plan make intuitive sense.

Although prescribed fire is an ecologically and economically more efficient option than mechanical and chemical woody plant treatments (Van Liew et al., 2012; Weir and Scasta, 2014), practitioners who seek to minimize the cost of invasive species control may prefer to forgo the cost of buying liability insurance. Burn insurance served as a risk premium for respondents who were concerned about potential property damage from escaped fire. These results are consistent with broader risk theory (Nicholson and Snyder, 2008) and corroborate previous findings (Joshi et al., 2019; Weir et al., 2019).

Finally, our finding that respondent age is positively correlated with willingness to buy prescribed burn insurance corroborates previous research findings that age is a stronger predictor than other sociodemographic attributes of wildfire risk sensitivity (Paveglio et al., 2018).

Although prescribed burning is a cost-efficient land management option and has been documented to be less risky than other common land management activities (Twidwell et al., 2015), applying fire does carry some amount of risk of escape when weather and other factors are beyond human control. Regardless of the land management objectives, prescribed burning may have numerous cobenefits (e.g., wildlife habitat enhancement, invasive species suppression, forage quality improvement). Such cobenefits could offset the cost of obtaining insurance to minimize the risk of exposure from escaped fire. Therefore, greater accessibility of inexpensive prescribed fire liability insurance may encourage more landowners to purchase insurance.

Another possibility for obtaining insurance coverage for the application of prescribed fire is PBA membership. Although not all PBAs provide insurance coverage for their members, some do and others could do so if such insurance policies are affordable. The majority of respondents in our study are located in the Great Plains states, a region that has strong PBA presence. PBA membership may not only facilitate access to insurance but also mitigate the risk of applying prescribed fire because these associations generally provide safe-fire training, assistance with burn plan development, and access to labor and fire management equipment to their members (Taylor, 2005; Toledo et al., 2014). In addition, with their growing credibility and connectedness to county and state officials, PBAs may also catalyze modifications to prescribed fire statues and regulations that reduce landowners' risks when applying prescribed fire. In turn, reduced level of landowner risk should encourage insurance companies to provide more affordable prescribed fire insurance policies.

Our study is a novel effort to examine factors that influence demand for prescribed burning insurance coverage. In particular, it suggests that the decision to purchase insurance appears to be driven more by cognitive variables, such as importance placed on regulatory compliance, importance of certain land use and management practices, and landownership, than practitioner demographics. These factors should be considered important predictors for insurance demand models. They should also be important for outreach efforts aimed at expanding the use of prescribed fire as a land management practice that provides multiple ecosystem benefits and as a fuel load mitigation tool to reduce the risk of catastrophic wildfires.

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Appendix 1. Questionnaire form used in the Qualtrics survey

Questionnaire form used in the Qualtrics survey

Dependent Variable

Do you currently have insurance coverage for damages incurred while conducting a prescribed burn?

- Yes
- No

Independent Variables

1. Which of the following best describes your current affiliation (select one)?
   - Government
   - Non-governmental organization
   - Landowner
   - University/Cooperative Extension Service
   - Others (please specify _____)

2. A burn plan is a written prescription for the planned prescribed burn. Have you obtained a burn plan(s) for each prescribed burn?
   - Yes
   - No

3. How important are the following objectives for the land that you are conducting or planning prescribed burns. (Please mark one number for each objective).

	Is not important⇒⇒ ⇒⇒Most important				
Control invasive shrubs and weeds (Cedar, Juniper etc.)	1	2	3	4	5
Manage range and pastureland	1	2	3	4	5

4. How do each of the following factors influence the decision in conducting or planning prescribed burns? Please rate each factor below.

	Does not influence ⇒ ⇒ ⇒ ⇒ Great Influence				
Availability of lower cost alternatives	1	2	3	4	5
Compliance with environmental laws and regulations	1	2	3	4	5

5. How do you perceive following risks associated with prescribed burning?

	Is not important⇒⇒ ⇒⇒Most important				
Property damage	1	2	3	4	5
Liabilities due to damage of others property	1	2	3	4	5
Injuries	1	2	3	4	5

6. Please check the highest level of education that you have completed. (Please check one)
   - Some high school
   - High school graduate
   - Some College
   - College Graduate
   - Graduate Degree
   - Technical Degree
   - Other (Please specify)……

7. How old are you?
_____Years

References

Adlerstein, D., 2018. Burn contractor fights civil suits. Panama City News Herald. Available at: https://www.apalachtimes.com/news/20180921/burn-contractor-fights-civil-suits. Accessed August 15, 2019.

Amacher, G.S., Malik, A.S., Haight, R.G., 2006. Reducing social losses from forest fires. Land Economy 82, 367–383.

Baltas, G., Doyle, P., 2001. Random utility models in marketing research: a survey. Journal of Business Research 51, 115–125.

Becerra, T.A., Engle, D.M., Elmore, R.D., Fuhlendorf, S.D., 2013. Contrasting preference for grassland landscapes among population groups in the central and southern Great Plains. Rangeland Ecology & Management 66, 529–538.

Chen, X., Goodwin, B.K., Prestemon, J.P., 2014. Is timber insurable? A study of wildfire risks in the U.S. forest sector using spatio-temporal models. American Journal of Agriculture and Economy 96, 213–231.

Deng, Y., Munn, I.A., Coble, K., Yao, H., 2015. Willingness to pay for potential standing timber insurance. Journal of Agriculture Applied Economy 47, 510–538.

Dether, D., Black, A., 2006. Learning from escaped prescribed fires—lessons for high reliability. Fire Management Today 66, 50–56.

Diaz, J., Fawcett, J.E., Weir, J.R., 2016. The value of forming a prescribed burn association. Southern Fire Exchange 2, 2–4.

Elmore, R.D., Bidwell, T.G., Weir, J.R., 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. Tall Timbers Research Station, Tallahassee, FL, USA, pp. 55–65.

Evans, J., Busam, J., 2015. Prescribed fire liability coverage: 2015-2016 insurance options for landowners and consultants in the Southeast. North Carolina State University. Survey questions, Raleigh, NC, USA.

France-Hudson, B., 2017. Surprisingly social: private property and environmental management. Journal of Environmental Law 29, eqw032.

Fuhlendorf, S.D., Engle, D.M., 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. Bioscience 51, 625–632.

Gan, J., Jarrett, A., Gaither, C.J., 2014. Wildfire risk adaptation: propensity of forestland owners to purchase wildfire insurance in the southern United States. Canadian Journal of Forestry Research 44, 1376–1382.

Gan, J., Jarrett, A., Gaither, C.J., 2015. Landowner response to wildfire risk: adaptation, mitigation or doing nothing. Journal of Environmental Management 159, 186–191.

Gómez-Limón, J.A., Arriaza, M., Riesgo, L., 2003. An MCDM analysis of agricultural risk aversion. European Journal of Operational Research 151, 569–585.

Greene, W.W.H., 2012. Econometric analysis. Prentice Hall, Upper Saddle River, NJ, USA, p. 1228.

Gujarati, D.N., 2004. Basic econometrics. McGraw-Hill, New York, NY, USA, p. 1032.

Haines, T.K., Cleaves, D.A., 1999. The legal environment for forestry prescribed burning in the south: regulatory programs and voluntary guidelines. Southern Journal of Applied Forestry 23, 170–174.

Hardy, C.C., Ottmar, R.D., Peterson, J.L., Core, J.E., Seamon, P., 2001. Smoke management guide for prescribed and wildland fire, 2001 edition. PMS, Boise, ID, USA, pp. 420–422.

Hesseln, H., 2000. The economics of prescribed burning: a research review. Forest Science 46, 322–334.

Joshi, O., Becerra, T.A., Engle, D.M., Fuhlendorf, S.D., Elmore, R.D., 2017. Factors affecting public preferences for grassland landscape heterogeneity in the Great Plains. Environmental Management 60, 922–930.

Joshi, O., Poudyal, N.C., Weir, J.R., Fuhlendorf, S.D., Ochuodho, T.O., 2019. Determinants of perceived risk and liability concerns associated with prescribed burning in the United States. Journal of Environmental Management 230, 379–385.

Kobziar, L., Godwin, D., Taylor, L., Watts, A., Kobziar, L.N., Godwin, D., Taylor, L., Watts, A.C., 2015. Perspectives on trends, effectiveness, and impediments to prescribed burning in the southern U.S. Forests 6, 561–580.

Kreuter, U.P., Woodard, J.B., Taylor, C.A., Teague, W.R., 2008. Perceptions of Texas landowners regarding fire and its use. Rangeland Ecology & Management 61, 456–464.

Kunreuther, H., 1996. Mitigating disaster losses through insurance. Journal of Risk and Uncertainty 12, 171–187.

Long, A., Oxarart, A., 2017. What the research says: prescribed fire and wildfire risk reduction. SFE Factsheet 2017-1, p. 2. Available at: http://www.southernfireexchange.org/SFE_Publications/factsheets/2017-1.pdf. Accessed August 15, 2019.

Luo, L., Tang, Y., Zhong, S., Bian, X., Heilman, W.E., Luo, L., Tang, Y., Zhong, S., Bian, X., Heilman, W.E., 2013. Will future climate favor more erratic wildfires in the western United States? Journal of Applied Meteorology and Climatology 52, 2410–2417.

Maguire, L.A., Albright, E.A., 2005. Can behavioral decision theory explain risk-averse fire management decisions? Forestry Ecology & Management 211, 47–58.

Melvin, M.A., 2018. 2018 National prescribed fire use survey report, technical report 03-18.

Nicholson, W., Snyder, C., 2008. Microeconomic theory: basic principles and extensions, 10th ed. Thomson South-Western, Mason, OH, USA, p. 768.

North, M.P., Stephens, S.L., Collins, B.M., Agee, J.K., Aplet, G., Franklin, J.F., Fulé, P.Z., 2015. Reform forest fire management: agency incentives undermine policy effectiveness. Science 349, 1280–1281.

Paveglio, T.B., Edgeley, C.M., Stasiewicz, A.M., 2018. Assessing influences on social vulnerability to wildfire using surveys, spatial data and wildfire simulations. Journal of Environmental Management 213, 425–439.

Russell, M.L., Lashmet, T.D., 2017. Prescribed burning: liability and insurance considerations. Texas A&M Agrilife Extension Publication. ERM-035, College Station, TX, USA. Available at: https://agrilifecdn.tamu.edu/texasaglaw/files/2017/08/click-here.pdf. Accessed June 18, 2019.

Ryan, K.C., Knapp, E.E., Varner, J.M., 2013. Prescribed fire in North American forests and woodlands: history, current practice, and challenges. Frontiers in Ecology and the Environment 11, 15–24.

Sauter, P.A., Möllmann, T.B., Anastassiadis, F., Mußhoff, O., Möhring, B., 2016. To insure or not to insure? Analysis of foresters' willingness-to-pay for fire and storm insurance. Forest Policy and Economics 73, 78–89.

STATA, 2019. Linktest—specification link test for single-equation models. Available at: https://www.stata.com/manuals13/rlinktest.pdf. Accessed June 18, 2019.

Sun, C., 2006. State statutory reforms and retention of prescribed fire liability laws on U.S. forest land. Forest Policy and Economics 9, 392–402.

Sun, C., Tolver, B., 2012. Assessing administrative laws for forestry prescribed burning in the southern United States: a management-based regulation approach. International Forestry Review 14, 337–348.

Taylor, C.A., 2003. Rangeland monitoring and fire: wildfires and prescribed burning, nutrient cycling, and plant succession. Arid Lands Resource Management 17, 429–438.

Taylor, C.A., 2005. Prescribed burning cooperatives: empowering and equipping ranchers to manage rangelands. Rangelands 27, 18–23.

Toledo, D., Kreuter, U.P., Sorice, M.G., Taylor, C.A., 2014. The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems. Journal of Environmental Management 132, 323–328.

Toledo, D., Sorice, M.G., Kreuter, U.P., 2013. Social and ecological factors influencing attitudes toward the application of high-intensity prescribed burns to restore fire adapted grassland ecosystems. Ecological Society 18, 9.

Twidwell, D., Rogers, W.E., Fuhlendorf, S.D., Wonkka, C.L., Engle, D.M., Weir, J.R., Kreuter, U.P., Taylor, C.A., 2013. The rising Great Plains fire campaign: citizens' response to woody plant encroachment. Frontiers in Ecology & the Environment 11, e64–e71.

Twidwell, D., Wonkka, C.L., Sindelar, M.T., Weir, J.R., 2015. First approximations of prescribed fire risks relative to other management techniques used on private lands. PLoS One 10, e0140410.

UCLA, 2019. Lesson 3 logistic regression diagnostic. UCLA Institute of Digital Research Education. Available at: https://stats.idre.ucla.edu/stata/webbooks/logistic/chapter3/lesson-3-logistic-regression-diagnostics/. Accessed June 18, 2019.

Van Liew, D., Conner, J.R., Kreuter, U.P., Teague, W.R., 2012. An economic comparison of prescribed extreme fire and alternative methods for managing invasive brush species in Texas: a modeling approach. Open Agriculture Journal 6, 17–26.

Villafranca, O., 2018. "Controlled burn" in Florida accidentally torches dozens of homes across 800 acres. CBS Evening News. Available at: https://www.cbsnews.com/news/eastpoint-fire-contro. Accessed June 18, 2019.

Waldrop, T.A., Goodrick, S.L., 2012. Introduction to prescribed fire in Southern ecosystems. In: Science Update SRS-054.

Weir, J.R., 2010. Prescribed burning associations: landowners effectively applying fire to the land. In: Robertson, K.M., Galley, K.E.M., Masters, R.E. (eds.), Proceedings of the 24th Tall Timbers Fire Ecology Conference: The Future of Prescribed Fire: Public Awareness, Health, and Safety. Tall Timbers Research Station, Tallahassee, Florida, USA, pp. 44–46.

Weir, J.R., Kreuter, U.P., Wonkka, C.L., Twidwell, D., Stroman, D.A., Russell, M., Taylor, C.A., 2019. Liability and prescribed fire: perception and reality. Rangeland Ecology & Management 73, 533–538.

Weir, J.R., Scasta, J.D., 2014. Ignition and fire behaviour of Juniperus virginiana in response to live fuel moisture and fire temperature in the southern Great Plains. International Journal of Wildland Fire 23, 839.

Weir, J.R., Scasta, J.D., Stevens, R., Bidwell, T.G., 2013. Burn plan for prescribed burning. Oklahoma Cooperative Extension Service NREM-2893, Stillwater, OK, USA.

Wonkka, C.L., Rogers, W.E., Kreuter, U.P., 2015. Legal barriers to effective ecosystem management: exploring linkages between liability, regulations, and prescribed fire. Ecology Applications 25, 2382–2393.

Yoder, J., Engle, D., Fuhlendorf, S., Yoder, J., Engle, D., Fuhlendorf, S., 2004. Liability, incentives, and prescribed ecosystem management. Frontiers in Ecology & the Environment 2, 361–366.