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Forest landowner demand for prescribed fire as an ecological management tool in Pennsylvania, USA

Arun Regmi [*], Melissa M. Kreye, Jesse K. Kreye

Department of Ecosystem Science and Management, Pennsylvania State University, University Park, PA 16802, United States of America

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ABSTRACT

Prescribed burning is important for the ecological health of fire-dependent forests, however, there is little economic research examining landowner preferences for living with fire in the age of the Anthropocene. To understand the value of reintroducing fire on the landscape we assessed forest owner willingness to pay (WTP) for various prescribed fire programs in Pennsylvania, where natural fire occurs infrequently. Survey responses were collected from 243 forest owners using Likert scales and choice experiment questions resulting in a 44% response rate. Most respondents were classified as having limited experience with prescribed fire, but many also had low risk perceptions about prescribed fire and high trust in prescribed fire implementors. A majority (66%) elected to enroll in at least one of 16 proposed burn programs and almost a quarter of landowners were willing to pay up to $200 per acre. Using mixed logistic regression methods, mean WTP was estimated to range from $11 to $19 per acre, but varied significantly under different program alternatives. Respondents overall preferred programs that helped maintain ecosystem health and biodiversity, and offered cost-share, reduced liability, and access to burn bosses. Demographic characteristics were also important predictors of enrollment (i.e., income level, age, and involvement in assistance programs). We conclude that forest owners in Pennsylvania see prescribed fire as potentially helping them meet priority management objectives and supporting cultural values about forest stewardship. Technical and financial assistance for forest owners will be important for expanding the use of prescribed fire in Pennsylvania.

1. Introduction

Humans have been using fire for centuries to shape ecosystems across the world (Bixby et al., 2015). For example, burning by indigenous peoples in North America likely helped improve environmental conditions for hunting and agriculture (Anderson and Moratto, 1996; Delcourt and Delcourt, 1997; Abrams and Nowacki, 2015; Abrams et al., 2022). Widespread fire suppression and changes in land use over the last century have reduced the provision of some important ecosystem services (e.g., habitat services) and increased the risk of wildfire (Westerling, 2016; Kolden, 2019). Natural resource management professionals are now again looking to use prescribed fire to promote the adaptive capacity of long-live species (e.g., trees) and reduce fuels build-up (Stephens et al., 2013; North et al., 2015; Smith et al., 2016; Schoennagel et al., 2017; Kolden, 2019). Prescribed fire is also considered a cost-efficient management tool for meeting long-term forest restoration and management objectives (Brose et al., 2001; Waldrop and Goodrick, 2012; Kobziar et al., 2015). Compared to southeastern and western regions of the United States (US), there is still very little prescribed fire applied to private lands in the northeast region (Yoder et al., 2003; Ryan et al., 2013; Waldrop and Goodrick, 2012; Melvin, 2018). Landowner interest in prescribed fire in this region has not yet been explored and could provide insights into how society may want to live with fire in the future. A better understanding of the economic value of prescribed fire, for meeting ecosystem health and resilience objectives, could be useful for informing policies that seek to restore fire adapted forest ecosystems in this region.

Fire is often naturally prevalent where oak and pine ecosystems dominate. Extended periods of fire exclusion in these systems can lead to significant changes in forest stand structure and species composition (Abrams, 1992; Varner III et al., 2005; Arthur et al., 2012). Fire suppression and other silvicultural practices have pushed forest communities in the northeastern US to become more homogenous and less biologically diverse. For example, many forest stands contain high densities of less valuable mesophytic hardwood species, are more vulnerable to pests and diseases, offer habitat for fewer wildlife species,

* Corresponding author.
E-mail addresses: arun.regmi@psu.edu (A. Regmi), mxk1244@psu.edu (M.M. Kreye), juk1097@psu.edu (J.K. Kreye).

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and have a higher occurrence of nuisance wildlife (e.g., ticks: Gleim et al., 2014). They also contain elevated fuel loads which can increase the risk of severe wildfire during periods of drought, which could occur more often under climate change (Abrams, 2005; Nowacki and Abrams, 2008; Brose et al., 2014). To address these issues, state agency personnel in the northeastern US have begun to use prescribed fire on public lands. However, the total number of acres burned each year in the northeast is still considerably less compared to other regions in the US. Burning on private lands is also needed to help accomplish landscape level management objectives for the region. Most forests in the northeast are owned by non-industrial private landowners (NIPF). These owners vary in their forest management objectives (e.g., wildlife habitat, firewood, recreation, timber production), and their ability to engage in forest management (i.e., knowledge, skills, financial resources; Metcalf et al., 2012; Butler et al., 2020). They also tend to be less proactive in their forest management, which may have implications for reintroducing fire to the landscape. For example, 30% of owners have conducted a harvest in the last 10 years, but only about 4 % of family forest owners in Pennsylvania have a forest management plan (Metcalf et al., 2012).

The stewardship of private forest lands would likely be improved if prescribed burning was more achievable, and landowners were informed as to the proper application of fire from an ecosystem management perspective. Since forest management on private lands is strongly dependent on both the willingness and abilities of the landowners, it is important to understand what may motivate NIPF owners to use prescribed fire (Kreye et al., 2021). A growing body of research has already identified psychological, societal, legal, and economic barriers to landowner acceptance and use of prescribed fire. Landowner knowledge of prescribed fire and associated liability laws and regulations tend to play an important role in shaping perceptions of risk (Yoder et al., 2004; Blanchard and Ryan, 2007; Kreuter et al., 2008; Morton et al., 2010; Piatek and McGill, 2010; Harr et al., 2014; Twidwell et al., 2015). Perceived risk of liability is often listed as the primary reason behind landowners' reluctance to use prescribed fire on their land (Blanchard and Ryan, 2007; Jarrett et al., 2009; Fischer, 2011; Toledo et al., 2012; Wonkka et al., 2015; Melvin, 2018; Weir et al., 2019; Kreuter et al., 2019). Trust in the person or institution responsible for administrating the burn can also influence the acceptability of prescribed fire use and associated assistance programs (Winter et al., 2004; McCaffrey, 2006; Vaske et al., 2007). Other important barriers to prescribed fire use are functional and economic, such as proximity to forestlands, property size, landowner income, narrow burn windows, and lack of adequate personnel (Kreuter et al., 2008; Quinn-Davidson and Varner, 2011; Evans et al., 2017; Melvin, 2018). In places where prescribed fire is infrequently used, policy efforts to increase burning will need to address both functional and economic barriers as well as landowner capacity and motivation through financial and technical assistance.

Non-market valuation methods offer a strategic way of looking at how society wants to live with fire, as an economic consideration. To date, most non-market valuation studies focus on homeowners' willingness to pay (WTP) for prescribed fire on public lands to reduce wildfire hazards (Loomis et al., 2002; Walker et al., 2007; Kaval et al., 2007; Loomis and González-Cabán, 2009; Shrestha et al., 2021). For example, Loomis and González-Cabán (2010) found that residents in California, Florida, and Montana were willing to pay $323 to $838 annually per household for prescribed burning programs on public lands to help protect their properties. A recent paper by Shrestha et al. (2021) examined forest owner WTP for prescribed fire to reduce risk of wildfire hazard on timber production. To our knowledge, no studies have focused on how forest owners may value prescribed fire as a way of achieving ecological management goals (e.g., wildlife habitat, ecosystem health) and obtaining cultural benefits (e.g., recreational experiences, identity of a good land steward). The goal of this study is to explore the potential for establishing a prescribed fire economy in Pennsylvania by examining a wide range of factors that may influence landowner demand for prescribed fire services. Factors expected to influence WTP for prescribed fire include knowledge, psychological barriers, management objectives, implementation strategy (e.g., landowner training), and price. To help support prescribed fire application, findings are presented in a range of policy scenarios with associated economic impact estimates. Findings are expected to broaden understanding of the ecological and cultural benefits associated with prescribed burning in regions with little wildfire risk.

2. Data, materials, and methods

2.1. Study area

The Commonwealth of Pennsylvania is located in the northeastern US (Fig. 1). About 16.9 million acres (58%) of the state is covered by forestland, of which 70% are privately owned (Albright et al., 2017). Wildfires occur infrequently in PA. For example, in 2021, only 2981 acres of forests were burned due to wildfires (PFC-PA, 2022). Pennsylvania enacted the Prescribed Burning Practices Act in 2009 largely to support forest health objectives and manage wildlife habitats. The Act provides standards for fire implementors who want to acquire from the state simple negligence liability protection. This has since resulted in increased burning, but mostly on public lands. For example, in 2021 a total of 21,901 acres of public lands were prescribed burned by state agencies whereas only 476 acres of private forests were burned (PFC-PA, 2022). Since 2010, prescribed burning has occurred on only 2219 acres of private forest lands and there are still a limited number of qualified fire implementors in the state.

2.2. Theoretical approach

Following the approach used by Kreye et al. (2018) an attribute-based choice experiment (CE) method was used in combination with psychometric scales to understand landowner motivation and WTP for conservation programs. The CE has been used extensively in environmental research to understand the value of goods and services not

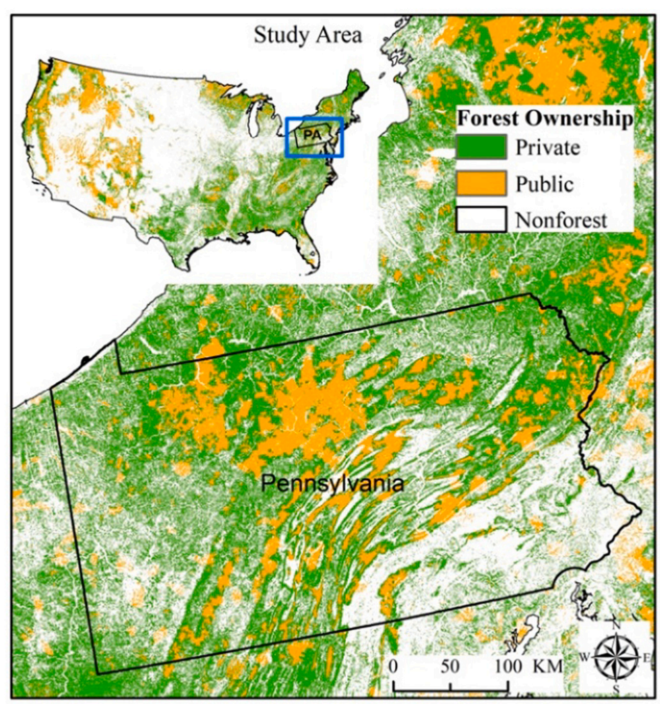


Fig. 1. A map showing private forests and geographical location of Pennsylvania in the United States map. (Data Source: Hewes et al., 2014).

represented in markets by asking consumers to make choices across a series of hypothetical alternatives (Hanley et al., 1998; Hensher et al., 2015). The CE approach is based on random utility theory which provides the necessary link between the statistical model (i.e., observed landowners behavior) and an economic model of utility maximization. The theoretical explanation of random utility theory is presented in Appendix A.

Correlation procedures can be used to generate estimates of the part-worth value, or marginal utility of any given attribute which can then be used to quantify the overall indirect utility of any particular combination of attributes (Hanley et al., 1998; Rolfe et al., 2000). A mixed logit model (MLM) estimates the unconditional probabilities of discrete choices and is based on random utility maximization (Train, 2009). Structurally, the mixed logit probability of alternative j being chosen is the integrals of standard logit probabilities over a density function of parameters (Eq. (1)). This can be written in the linear parameter form such that $V_{ij} = \beta_i X_{ij}$.

$$P_i(j|\theta) = \int P_i(j|\beta) f(\beta|\theta) d\beta = \int \cdot \frac{exp(\beta_i X_{ij})}{\sum_{k=1}^{K} exp(\beta_i X_{ik})} f(\beta|\theta) d\beta \quad (1)$$

Where $P_i(j|\beta)$ is the standard logit probability conditional on β, β_i is a vector of coefficients that varies across individuals with density $f(\beta|\theta)$ where θ is a vector of the true parameters of the taste distribution of βi, and X_{ij} is a vector of observable attributes.

The empirical model for individual i, with choices j was specified as follows.

$$V_{ij} = \beta_0 + \beta_1 \ldots + \beta_i \quad (2)$$

Where V is the binary voting decision (yes/no), β_0 refers to the constant term, and β_1 to β_i represents coefficients of independent variables including the cost variable.

Mean WTP across all model variables was calculated using the equation provided by Hanemann (1989):

$$Mean\ WTP = \frac{1}{\beta_{price}} * ln(1 + e^{\beta_0}) \quad (3)$$

where β_0 is the estimated constant without other independent variables. Confidence intervals around the mean WTP were calculated using the Delta method.

The part-worth value (PWV), also known as WTP or marginal utility of each attribute was estimated using the ratios of attribute and price coefficients given by Hanemann (1984) and Parsons and Kealy (1992) in the simplified form (Eq. (4)):

$$WTP\ (or\ PWV) = -1\left(\frac{\beta_{attribute}}{\beta_{price}}\right) \quad (4)$$

The Krinsky-Robb simulation method as introduced by Hole (2007)[1] was used to estimate WTP standard errors and 95% confidence interval. Following Rolfe et al. (2000) value differences between programs were estimated for the selected combinations of variables (see Table 7). For example, the overall WTP for program 1 can be represented as a function of the assigned program attributes such as in the following equation.

$$Value\ of\ program\ 1 = -\frac{1}{\beta_{price}} \ (\beta_1 + \ldots + \beta_i) \quad (5)$$

where β_{price} is the coefficient for the price per acre variable and $\beta_{1\ldots i}$ represents the features of the program on offer.

The potential demand for different program alternatives was estimated by multiplying the mean WTP per acre for the proposed program obtained from eq. 5 with the target number of acres impacted by the program (Table 9). A target number of acres may include goals for acres burned in a year or the parcel size of important categories of forest owners. An equivalent annual annuity (EAA) assessment provides an average annual value and is used to compare policy scenarios with unequal burning timelines.

2.3. Survey design

A multi-stage process was used to design, test, validate, and distribute a survey to private forest owners in Pennsylvania (Dillman et al., 2014). To identify attributes and levels for use in the choice sets, a comprehensive literature review, an early survey, and semi-structured interviews were conducted with 25 participants representing diverse stakeholder groups including landowners. The final survey contained 63 questions and consisted of four sections: 1) information on land ownership and management objectives, 2) questions to measure knowledge, perceived risk, and trust, 3) choice experiment questions, and 4) landowner demographic questions. Pre-testing was conducted with 20 participants including forest owners and state agencies and other research professionals.

To understand the influence of knowledge, trust, and risk on choice, validated[2] psychometric scalar tools were used with five choice options ranging from 1 = "strongly disagree" to 5 = "strongly agree". Using questions similar to those constructed by Blanchard and Ryan (2007), respondents were asked about their past experiences and training in prescribed fire using six statements (Cronbach's α = 0.86). Similarly, landowners perceived risk of using prescribed fire was measured using a set of nine scalar questions (Cronbach's α = 0.89; adapted from Elmore et al., 2009 and Busam and Evans, 2015). Trust in landowners, professionals, and the organizations that oversee and implement prescribed fire on private lands were measured using a set of four scalar questions (Cronbach's α = 0.79; adapted from Blanchard and Ryan, 2007 and Busam and Evans, 2015). To help save space, the statements used in the scalar tools are presented in the results section (Table 4).

2.3.1. Choice experiment design

In the full factorial design, five factors with four levels each can be combined in 4^5 ways to form 1024 possible combinations. To make it easier to apply, 16 choice sets were selected using the Taguchi orthogonal array (OA) which is widely used to create balanced designs (Kechagias et al., 2020; Tanco et al., 2009). To reduce respondent fatigue the 16 choice sets were split into two blocks of 8 choice sets. Fifty percent of respondents were randomly presented with either one of the block sets.

Preliminary surveys, interviews, and focus groups revealed forest owner interest in a wide range of possible program options and benefits. The final factors and levels used here were considered representative of what most forest owners may consider when deciding to adopt fire as a new management tool (Table 1). The factors describe broader categories of consideration ranging from possible outcomes on the landscape to opportunities to build capacity. The levels on offer represent specific outcomes or program features. Similar studies assessing public preferences for government programs also use a holistic decision-making framework when designing factors and levels (Kreye et al., 2016, 2017). Forest owner choices about Ecological Outcomes and Management Benefits are expected to be dependent on the respondent's stewardship values and management objectives. Preferences for Support Resources are expected to be dependent on perceived personal barriers to burning. Preferences for Institutional Factors may depend on perceived economic/policy barriers to burning. A price attribute was also included in the design to estimate a marginal WTP for the other attributes. According to interviews and focus groups, the price of

[1] Hole (2007) introduced a STATA command "*wtp*" based on the simulation of variance and co-variance matrix.

[2] Cronbach's alpha is often used to validate scales by assessing the reliability and internal consistency of scaler statement sets.

Table 1
Factors and levels used in the choice experiment.

Factors	Levels
Ecological Outcomes	Promote oak regeneration Improve wildlife habitat Restore rare vegetation communities Maintain forest health, resilience, and diversity
Management Benefits	Reduce management costs Control invasive plant species Reduce ticks Reduce tree and plant pests
Support Resources	Landowner training to enhance prescribed fire skills Associations that train and coordinate owners interested in burning State coordination in burning activities (e.g., crews, equipment) Financial assistance (e.g., cost-share)
Institutional Factors	Reduce legal liability of an escaped fire Access to qualified consultants Access to qualified burn bosses Relaxed standards
Price of burning ($ per acre)	$20, $50, $125, $200

burning in Pennsylvania can be highly variable ranging from $20 to $400 per acre. These values informed the prices on offer in this study.

To assess the possibility of hypothetical bias, a 10-point certainty scaler question was included after each WTP question, with response options ranging from 1 = "Extremely uncertain" to 10 = "Extremely certain" (Fig. 2; Vossler et al., 2003).

2.4. Data collection and response

The survey was administered one time in September 2019 by mail and was sent to 551 private landowners in Pennsylvania following a slightly modified version of the Dillman method[3] (Dillman et al., 2014). Mailing addresses were obtained from the Center for Private Forests-Pennsylvania State University and the Pennsylvania Forestry Association. Of the 551 mail surveys sent out, 20 questionnaires were not delivered while 243 were returned for an adjusted response rate of 44%. Of the total 243 surveys returned, 224 surveys were classified as useable for the choice experiment analysis.[4] Table 2 contains a summary of the respondent demographic profiles compared to a 2010 census of PA forest owners (Metcalf et al., 2012).

Most respondents were male (86%) and older than 45 years in age (90%). About 54% of respondents had annual household income levels above $80,000. Most respondents (76%) had either a bachelor's degree or equivalent or a higher level of education. A majority of respondents reported that they enrolled in government assistance programs in the past (62%) and were part of a private landowner association (69%). When our findings were compared to landowner census data, we found women and younger owners were likely undersampled and owners with larger holdings, greater incomes, and higher education levels were likely oversampled (Metcalf et al., 2012).

2.5. Data analysis

Likert scale responses were analyzed by calculating a mean response to individual statements and grand means for the whole set of statements. The grand means are reported as descriptive statistics and used as covariates in the model. To help control bias, two different treatments were applied to the final dataset. A raking procedure was used to generate custom weights for individual observations to help address response bias. The weights were constructed using STATA 15.1 software and calibrated using socio-demographic distributions from the 2010 landowner survey (Metcalf et al., 2012) (see Appendix A). The potential for hypothetical bias was addressed using the certainty score associated with each WTP question. Respondents who accepted the program on offer at the proposed price and had a certainty score of ≤5, had their responses changed to reject the program, because of their lack of certainty about the purchase (Vossler et al., 2003). Effect coding[5] was used to parameterize program attributes and avoid confounding the *Opt-Out* coefficient (Bech and Gyrd-Hansen, 2005).

Mixed logistic regression models were used to establish a relationship between the dependent variable (i.e., willingness to enroll in a prescribed fire program at the offered price per acre) and the independent variables listed in Table 3. Sequential runs of the model were set to retain variables significant at $p < 0.01$, $p < 0.05$, and $p < 0.10$ levels. Model selection was also based on goodness-of-fit measures including the likelihood ratio test and McFadden's Pseudo R-squared (Rolfe et al., 2000).

3. Results

Findings reveal that respondents are heterogenous in their management objectives and activities, which is similar to other forest owners in the region (Metcalf et al., 2012). Still, most worked to control invasive plant species and enhance habitats through harvesting, thinning, and making other stand improvements (see Table B2 in Appendix B). These activities are often associated with enhanced recreational experiences and other cultural values about forest stewardship (e.g., aesthetics, sense of place, seclusion, and preserve natural heritage). Few (9%) respondents reported that they already use prescribed burning as a management tool, and these burns were often limited to small areas mainly to manage warm-season grass, reduce understory fuel, and improve browse for deer.

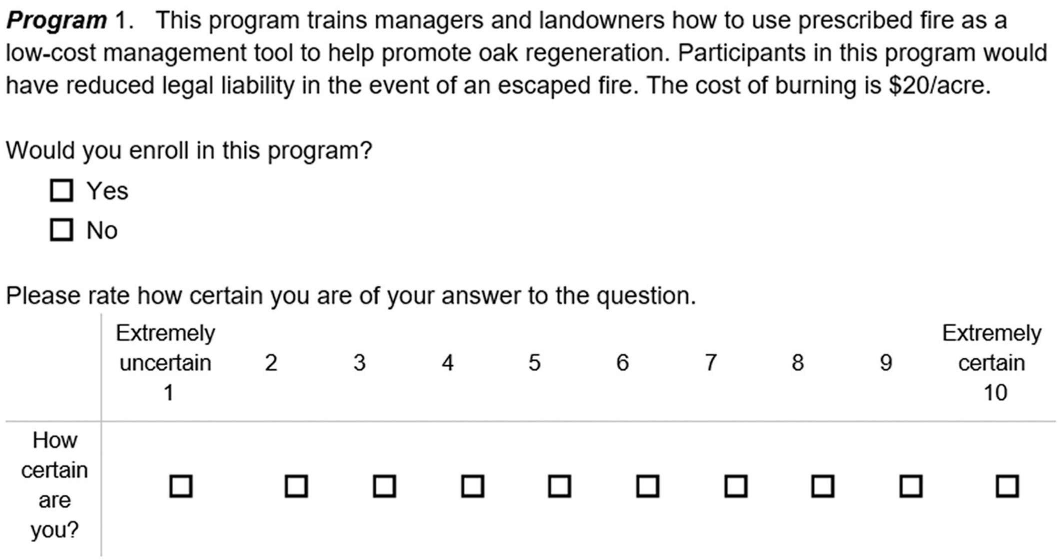
3.1. Knowledge, perceived risk, and trust

The grand mean score on the knowledge scale was relatively low (*grand mean 1.91, SD 1.31*) indicating most respondents have limited experience or formal knowledge about prescribed fire (Table 4). To get information about prescribed fire, many respondents referred to hunting and trade magazines which often promoted the use of fire to improve wildlife habitats (48%). Less than one-third of respondents referred to science-based information delivered by academia (e.g., extension) or government programs. The grand mean for risk perceptions was also low (*grand mean 2.25, SD 1.07*) indicating that most respondents do not consider prescribed fire a potential hazard or harm. More specifically, respondents expressed greater concern about potential harm to PA's native plants and trees than harm to human health due to smoke and poor air quality. The grand mean for trust was comparatively high (*grand mean 3.87, SD 1.03*) indicating most respondents generally trusted the people and organizations who implement prescribed fire. Expressions of trust were also somewhat higher for professional fire implementers (e.g., state agencies and consultants) compared to landowners who implement prescribed fire (Table 4).

[3] The survey instrument consisted of a cover letter, questionnaire, and a pre-paid return envelope. Following the main survey, one week later, a reminder/thank-you post-card was sent to those who didn't respond and already responded. A unique ID system was used to tract and manage the surveys that were sent and received by mail.

[4] Non usable surveys include incomplete surveys (10), responses from non-landowners (e.g., wildlife managers, biologists, government professionals, etc.; 7), and landowners with <10 acres forests (2).

[5] The effects coded variable for an attribute level is set equal to 1 when that level is present in the choice set, and equal to −1 if the reference level is present in the choice set and equal to 0 otherwise, see the coding illustration in the supplementary table.


Program 1. This program trains managers and landowners how to use prescribed fire as a low-cost management tool to help promote oak regeneration. Participants in this program would have reduced legal liability in the event of an escaped fire. The cost of burning is $20/acre.

Would you enroll in this program?

☐ Yes

☐ No

Please rate how certain you are of your answer to the question.

	Extremely uncertain 1	2	3	4	5	6	7	8	9	Extremely certain 10
How certain are you?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Fig. 2. Example choice experiment question with a certainty scale measuring willingness to pay for prescribed fire programs.

Table 2
Summary of demographic profiles compared with woodland owner census (Metcalf et al., 2012; NWOS, 2018).

Characteristics	Census		Sample	
	Count	Percent (%)	Count	Percent (%)
Gender				
Male	494,492	67	189	86
Age				
18–24 years	7380	1	2	1
25–34 years	18,451	3	9	4
35–44 years	121,778	16	11	5
45–54 years	214,034	29	51	23
55–64 years	169,751	23	86	39
65–74 years	206,653	28	45	21
75 years and above			15	7
Acres owned				
10–19 acres	98,160	41	8	4
20–49 acres	86,352	36	35	16
50–99 acres	33,950	14	54	24
100–199 acres	15,499	6	55	25
200–499 acres	5166	2	44	20
500–1000 acres	738	<1	18	8
1000 acres and above	295	<1	7	3
Annual household income	*	*		
Less than $20,000	*	*	4	2
$20,000 - $49,999	*	*	27	14
$50,000 - $79,999	*	*	55	29
$80,000 - $99,999	*	*	39	21
$100,000 - $149,999	*	*	30	16
$150,000 - $ 249,999	*	*	22	12
$250,000 and more	*	*	10	6
Education				
Less than high school	*	2	1	0.5
High school	*	31	28	13
Associates degree	*	10	24	11
Bachelor's degree	*	22	73	33
Master's degree	*	18	65	30
Postgraduate degree	*	*	27	12
Assistance program (yes)	*	51	128	62
Association member (yes)	*	*	152	69

*Census data not available.

3.2. Willingness to pay

On the certainty scale, respondents had a mean score of 7.56 (out of 10) indicating respondents were frequently confident in their WTP responses. Most respondents (59%) with a confidence level > 5 were willing to enroll in at least one prescribed fire program. Fifty-two percent preferred the lowest cost program ($20 per acre), but almost a quarter of respondents (22%) were still willing to pay upwards of $200 per acre (Fig. 3).

An equal number of respondents completed choice sets from both blocks resulting in a total of 1718 WTP observations. Out of this dataset, 38% were yes votes. Of the three models fitted, based on the number of statistically significant program attributes (12 out of 16) and improved pseudo-R squared, *AIC, and BIC* values, Model 2 was considered the most robust and was used to generate estimates of statewide demand.

Table 5 presents the results of mixed logistic regression analysis. Initial runs of the model demonstrated important variation in robustness under different weighting and correction procedures, so three models are reported here. Model 1 is the base model using raw data without any treatments. Model 2 utilized certainty corrected data (i.e., yes responses with a certainty score ≤ 5 were recoded as "no"). Model 3 utilizes a raked, and certainty corrected dataset. The demographic variable representing past participation in a landowner assistance program was significant, positive, and had the greatest overall influence on choice. The demographic variable for income had a similar impact in models 2 and 3. Coefficients for price, risk, and age were negative indicating WTP decreased as levels within these variables increased. Gender was not significant in predicting WTP in these models, however, we expect that the sampling of female landowners was problematic and not effectively corrected with the raking procedure.

Program attribute coefficients for forest health, cost-share assistance, and reduced liability variables were positive indicating their presence increased the mean value of prescribed fire. Coefficients for oak regeneration, rare vegetation, landowner training, and relaxed standards variables were negative indicating their presence decreased the mean value of prescribed fire.

Mean WTP ranged from $11.16 to $18.63 per acre across weighted and unweighted models (Table 6). Part worth values (PWV) for model variables were also estimated and ranged from -$57.52 to $124.04 per acre. Estimates from model 2 show previous experience with landowner assistance programs increased WTP value an average of $96.93 per acre. Likewise, respondents with an annual household income greater than $80,000 were willing to pay an average of $69.77 more per acre. Respondents in younger age categories were willing to pay an average of $52.43 more per acre. Higher trust increased the value of prescribed burn programs by $15.40 per acre on average, but higher risk perceptions reduced the value of prescribed burn programs by $4.75 per acre on average.

Table 3
Description of variables used in mixed logistic regression models.

Name	Description	Data Type	Coding
Choice	Dependent variable	Binary*	1 = Accept the program on offer 0 = Reject the program on offer
Ecological Outcomes	Promote oak regeneration	Effect code	1 = EO_0, −1 = EO_3 (reference level), and 0 = otherwise
	Improve wildlife habitat	Effect code	1 = EO_1, −1 = EO_3 (reference level), and 0 = otherwise
	Restore rare Vegetation	Effect code	1 = EO_2, −1 = EO_3 (reference level), and 0 = otherwise
Management Benefits	Reduce Management Costs	Effect code	1 = MB_0, −1 = MB_3 (reference level), and 0 = otherwise
	Control invasive plant species	Effect code	1 = MB_1, −1 = MB_3 (reference level), and 0 = otherwise
	Reduce ticks that harm humans	Effect code	1 = MB_2, −1 = MB_3 (reference level), and 0 = otherwise
Support Resources	Landowner training to enhance prescribed fire skills	Effect code	1 = RL_0, −1 = RL_3 (reference level), and 0 = otherwise
	Prescribed fire associations to coordinate landowners	Effect code	1 = RL_1, −1 = RL_3 (reference level), and 0 = otherwise
	State agency coordination	Effect code	1 = RL_2, −1 = RL_3 (reference level), and 0 = otherwise
Institutional Factors	Reduce legal liability of an escape fire	Effect code	1 = RB_0, −1 = RB_3 (reference level), and 0 = otherwise
	Access to qualified consultants	Effect code	1 = RB_1, −1 = RB_3 (reference level), and 0 = otherwise
	Access to qualified burn bosses	Effect code	1 = RB_2, −1 = RB_3 (reference level), and 0 = otherwise
Price	Cost of burning per acre	Categorical	\$20, \$50, \$125, \$200
Trust	Trust in people and organizations who implement prescribed fire (total score)	Continuous	1 = low trust, 5 = high trust
Risk	Perceived risk of prescribed fire (total score)	Continuous	1 = low risk, 5 = high risk
Assistance Program	Past use of government assistance	Binary	1 = enrolled in an assistance program in the past, 0 = otherwise
Income	Annual household income	Binary	1 = >80 k, 0 = otherwise
Age	Age of respondent (years)	Ranked Categories	1 = 18 to 24, 2 = 25 to 34, 3 = 35 to 44, 4 = 45 to 54, 5 = 55 to 64, 6 = 65 to 74, 7 = 75 to 84, and 8 = 85 or older

* Observations were recoded to 0 if the associated response on the ten-point confidence scale was ≤5.

Table 4
Mean response to statements on the knowledge, risk, and trust scales (1 = extremely low, 5 = extremely high).

Measurement items	Mean	SD
Knowledge		
I know people who have used prescribed burning	2.81	1.65
I have taken higher education classes on ecosystem management and prescribed burning	1.96	1.43
I have taken a training course on ecosystem management and prescribed burning	1.90	1.35
I have experience conducting a prescribed burn	1.72	1.29
I have been trained to conduct a prescribed burn	1.69	1.22
I have enough experience and qualifications to be a burn boss	1.39	0.91
Grand Mean	*1.91*	*1.31*
Risk Perceptions		
Prescribed fire could harm PA's native plants and trees	2.48	1.15
Prescribed fire and wildfires are equally dangerous to the public's safety	2.45	1.37
Prescribed fire can cause soil erosion	2.35	1.05
Prescribed fire often harms human health (e.g., smoke and air quality)	2.30	1.06
Prescribed fire often harms wildlife and destroys their habitat	2.22	1.10
Prescribed fire can reduce water quality	2.16	0.94
Prescribed fire reduces aesthetic/recreational benefits important to me	2.15	0.99
Animals are usually unable to find safety during prescribed fires	2.08	0.98
Prescribed fire typically causes damage to private property	2.05	1.01
Grand Mean	*2.25*	*1.07*
Trust in Implementors		
I trust that trained resource management professionals have the skills needed to conduct a burn safely	4.20	0.89
I trust state agencies in PA will do a good job setting the prescribed fire standards	4.07	0.97
I trust state agencies to run programs that promote the use of prescribed fire on private lands	4.02	0.97
I trust that trained landowners have the skills needed to conduct a burn safely	3.18	1.28
Grand Mean	*3.87*	*1.03*

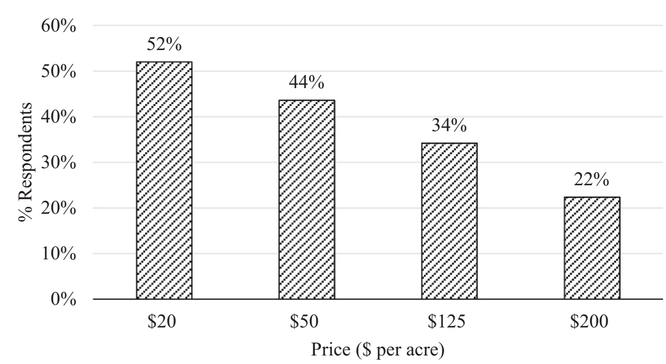


Fig. 3. Percent enrollment in proposed prescribed fire programs based on price.

Programs that promoted burning to achieve forest health and resilience were valued at an average of \$33.48 more per acre. Programs that promoted oak regeneration and restoring rare vegetation reduced mean WTP by \$16.05 and \$22.61 per acre, respectively. Programs that used cost-share assistance and reduced liability on landowners increased mean WTP by an average of \$29.70 and \$15.72 per acre, respectively. Programs that offer landowner training and relaxed standards decreased mean WTP by an average of \$26.34 and \$23.06 per acre, respectively. Model 3 was the only model where variable for burn bosses was significant, and burn bosses provided an additional \$19.25 per acre to prescribed fire programs.

3.3. Policy scenarios and statewide demand

The total value of potential programs was estimated using eq. 5 (Table 7). Forest health and resilience was seen as an overarching benefit of prescribed fire, so this alternative was included in all the programs. It was assumed that enrollment in any program could also provide benefits in the form of reduced liability, so this alternative was also included in all proposed programs. The strategies used in each program include cost-share, landowner training, and access to burn bosses. The value to forest owners with prior experience with landowner assistance programs in the past was also estimated.

The total amount of income that landowners may allocate to a

Table 5
Estimates from a mixed logistic regression analysis illustrating factors affecting private forest owners willingness to pay (WTP) for using prescribed fire in Pennsylvania, USA.

Variables	Model 1		Model 2		Model 3	
	Unweighted (choice)		Unweighted (choice≥ 6)		Weighted (choice≥ 6)	
	Coeff.	se	Coeff.	se	Coeff.	se
Constant	1.614	−2.179	0.498	−2.052	0.986	−1.785
Price	−0.0165***	−0.0014	−0.0156***	−0.0014	−0.0119***	−0.0012
Trust	0.218***	−0.084	0.240***	−0.081	0.129*	−0.076
Risk	−0.087**	−0.040	−0.074*	−0.038	−0.052	−0.036
Assistance Program	1.715***	−0.524	1.508***	−0.492	1.476***	−0.447
Income	0.625	−0.529	1.085**	−0.495	0.977**	−0.454
Age	−0.733***	−0.213	−0.815***	−0.200	−0.685***	−0.154
Oak regeneration	−0.196	−0.141	−0.250*	−0.144	−0.287**	−0.128
Rare vegetation	−0.196	−0.143	−0.352**	−0.148	−0.332**	−0.129
Forest health	0.327**	−0.139	0.521***	−0.140	0.481***	−0.124
Landowner training	−0.451***	−0.144	−0.410***	−0.148	−0.495***	−0.130
Cost share	0.459***	−0.141	0.462***	−0.144	0.277**	−0.128
Reduced liability	0.022	−0.142	0.244*	−0.142	0.255**	−0.125
Access to consultants	0.273*	−0.147	0.138	−0.147	−0.082	−0.128
Access to burn bosses	−0.062	−0.147	−0.024	−0.146	0.229*	−0.124
Relaxed standards	−0.233	−0.145	−0.359**	−0.150	−0.403***	−0.132
lnsig2u	2.309***	−0.181	2.085***	−0.189	1.828***	−0.180
AIC	1425.5		1371		1628.1	
BIC	1534.5		1479.9		1737.1	
Pseudo R-squared	0.16		0.17		0.01	
LL [null; full model]	[−828.39; −692.74]		[−800.28; −665.48]		[−800.28; −794.07]	
LR test [$\chi^2(19)$]	555.26***		427.81***		423.55***	

Note: "choice" refers to WTP responses without certainty correction and "choice>=6" refers to WTP responses with certainty scores < 6 were being converted to "no" response.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 6
Part-worth value (PWV) and 95% confidence interval* estimates for significant variables.

Variables	Model 1		Model 2		Model 3	
	PWV	(95% C.I.)	PWV	(95% C.I.)	PWV	(95% C.I.)
Trust	$13.22	(3.22; 23.52)	$15.40	(5.17; 25.95)	$10.82	(−1.67; 23.75)
Risk	−$5.28	(−9.94; −0.21)	−$4.75	(−9.37; 0.40)	–	–
Assistant Program	$104.22	(42.09; 172.96)	$96.93	(35.17; 165.87)	$124.04	(52.71; 207.91)
Income	–	–	$69.77	(9.33; 131.26)	$82.05	(11.65; 159.84)
Age	-$44.56	(−71.21; −18.6)	−$52.43	(−79.42; −26.65)	−$57.52	(−86.03; −31.47)
Oak regeneration	–	–	−$16.05	(−34.49; 2.03)	−$24.14	(−45.81; −3.27)
Rare vegetation	–	–	−$22.61	(−41.61; −4.54)	−$27.88	(−49.84; −7.1)
Forest health	$19.87	(4.7; 37.27)	$33.48	(17.23; 52.17)	$40.45	(21.5; 62.61)
Landowner training	−$27.41	(−45.38; −10.16)	−$26.34	(−45.54; −8.09)	−$41.63	(−64.44; −20.05)
Cost share	$27.87	(12.3; 46.06)	$29.70	(12.77; 49.61)	$23.28	(3.47; 46.35)
Reduced liability	–		$15.72	(−2.19; 33.87)	$21.46	(0.95; 43.12)
Access to consultants	$16.57	(−1.41; 34.38)	–	–	–	–
Access to burn bosses	–	–	–	–	$19.25	(−1.67; 40.73)
Relaxed standards	–	–	-$23.06	(−42.98; −4.32)	−$33.83	(−56.88; −12.05)
Mean WTP ($ per acre)	$18.63	(15.52; 21.74)	$11.16	(9.22; 13.11)	$14.59	(11.83; 17.35)

* Lower and upper limits of 95% confidence intervals in parentheses using Krinsky and Robb method.

Table 7
Attribute levels and total WTP per acre for different prescribed fire programs.

Program attributes	Program 1	Program 2	Program 3	Program 4
Forest health/resilience	✓	✓	✓	✓
Reduced liability	✓	✓	✓	✓
Cost share	✓			
Landowner training		✓		✓
Access to burn boss			✓	
Past enrollment, landowner assistance programs				✓
WTP ($ per acre)	$78.90	$22.86	$68.45	$119.79

proposed program was calculated by multiplying the values in Table 7 with number of acres or different parcel sizes (Table 8).

Estimates of potential statewide demand were also generated, with different acreage goals and timelines, which could be used to inform

Table 8
Total WTP per landowner for different prescribed fire programs based on the minimum number of acres enrolled.*

Parcel size	Program 1	Program 2	Program 3	Program 4
At least 20 acres	$1578	$457	$1369	$2396
At least 100 acres	$7890	$2286	$6845	$11,979
At least 500 acres	$39,450	$11,430	$34,225	$59,895

* Estimates generated by multiplying WTP per acre for each program from Table 7 with 20, 100, and 500 acres.

Table 9
The potential annual value of proposed policies [i.e., Equivalent Annual Annuity (EAA) at a 4% discount rate].

Specification	Policy scenarios				
	Policy A	Policy B	Policy C	Policy D	Policy E
WTP ($ per acre)	$78.90	$22.86	$68.45	$119.79	$11.16
Acres burned	2.5 million	2.5 million	2.5 million	330,000	2.5 million
EAA for 5-year plan	$39,844,500	$11,544,300	$34,567,250	$60,493,950	$5,635,800
EAA for 10-year plan	$19,922,250	$5,772,150	$17,283,625	$30,246,975	$2,817,900

investment decisions (Table 9). Acreage goals were set at either 25% of private forest lands in the state (2.5 million acres) or 25% of acres from forest owners who have been enrolled in a government assistance program in the past (approx. 330,000 acres). To understand how project timelines may affect the value of a multiyear program or policy, an Equivalent Annual Annuity (EAA) value was estimated for each scenario using 5- and 10-year time horizons (4% discount rate) (Table 9). The EAA assessment provides adjusted annual values for alternatives with different timelines and acreage goals. Policies A, B, C, and D use mean WTP for programs 1, 2, 3, and 4 respectively from Table 7. Demand for policy E was generated using mean WTP ($11.16 per acre) from model 2.

4. Discussion

Systematic variation in landowner demand for prescribed fire programs can be explained by both the expected ecological benefits of using prescribed fire and the strategies used to promote burning on private forest lands. The social conditions necessary for expanding prescribed fire onto private lands appears to be present, as suggested by overall low-risk perceptions and relatively high trust in the implementors of prescribed fire. These findings are in agreement with a recent census of woodland owners in Pennsylvania which found only half of the forest owners are either concerned or strongly concerned about wildfire hazard (NWOS, 2018). The PWVs for risk and trust also suggest that at present, key psychological factors are of marginal value compared to other program factors. State agencies have been conducting burning on state lands for over a decade, which may signal to landowners that competent prescribed fire implementors are available. This may change, however, once more fire is introduced to the landscape and the reality of living with fire becomes more tangible. Continued outreach and education about prescribed fire will be needed to help maintain the trust already placed in state agencies and organizations that oversee prescribed fire activities (Winter et al., 2004).

Most respondents in this study were classified as having a low level of knowledge about prescribed fire, because most had little experience using prescribed fire. Moreover, the variable representing knowledge was not correlated with WTP for prescribed fire programs. In the southeastern US, where prescribed fire is more common, landowners tend to have a better understanding of fire safety and ecological response (Gordon et al., 2020). This understanding is based on past experiences with fire and information passed down from natural resource managers and other landowners (Johnson and Hale, 2002). The general openness of respondents in this study towards prescribed fire could be the influence of some trade and hunting magazines that describe the benefits of burning. Unfortunately, most media resources offer an incomplete understanding of prescribed fire. Science based education and training programs for landowners are needed to support the smart application of fire, especially if they plan to conduct a burn themselves. Practices include timing of fire and methods for controlling fire intensity, as this can have a significant influence on forest structure and biological functions (Block et al., 2016: Yaussy and Waldrop, 2010). Helping forest owners be successful in their burning activities will be important for fostering the safe and sustained use of fire.

The percent of respondents willing to enroll in at least one program was similar to a study conducted in West Virginia which found that 64% of private owners supported prescribed fire as a management tool (Piatek and McGill, 2010). However, a study conducted in Mississippi found only 26% of respondents were interested in enrolling in a prescribed fire program specifically aimed to reduce the risk of wildfire (Shrestha et al., 2021). The mean WTP estimates in our study ranged from $11.16 to $18.63 per acre (see Table 6), but total values increased or decreased significantly depending on which program attributes were included in the analysis (see Table 7). Variation in WTP within this study, and across related studies, points to the important influence of a wide range of factors such as ecosystem type, stand conditions, landowner goals and perceptions as well as policy design, which are discussed more in the following sections (Kreye et al., 2017).

Based on the number of significant variables, the expected benefits of using prescribed fire include both targeted benefits (i.e., oak regeneration, enhance rare vegetation) and more generalized benefits (i.e., forest health and resilience). The greater preference for meeting the generalized benefit of maintaining forest health is reasonable since the desire to protect forest health is common among forest owners in Pennsylvania (Metcalf et al., 2012; Albright et al., 2017). Respondents were more mixed in response towards targeted benefits, suggesting owners may see prescribed fire as the solution to some management problems, but not others. In the professional world, Pennsylvania is viewed as a leading example of the oak regeneration failure problem, for many reasons including lack of fire (Brose et al., 2014). Outside of Pennsylvania landowners often use prescribed fire use to help oak regeneration (Piatek and McGill, 2010). Forest owner response in this study suggests oak regeneration may be a relatively low priority. Controlling tree regeneration was ranked 9th out of the 9 management activities listed. Managing invasive species and making stand improvements were ranked highest and were likely perceived as important for achieving priority management objectives, including enhanced wildlife habitat and recreational hunting opportunities (DeCalesta and Stout, 1997; Lashley et al., 2011). Landowner education programs may consider using a curriculum that links wildlife habitat with oak regeneration, as a way to encourage the strategic application of fire on private lands to benefit oaks.

Respondent's preferences for protecting forest health and maintaining recreational benefits suggests that many see their forest as a natural heritage with aesthetic value (Majumdar et al., 2008). Prescribed fire could help forest owners maintain important cultural benefits associated with unique groundcover characteristics (Gordon et al., 2020; Pereira et al., 2021). However, the lower preference for using fire to enhance rare vegetation suggests uncertainty about how fire may affect preferred types of vegetation (e.g., wild leeks, ginseng). Moreover, the interpretation of the "rare vegetation" attribute may have been confusing to some respondents since half of the respondents actively plant native species, but half of respondents also plant food plots (e.g., fruit trees, berries) to support game species. Education programs are needed to help landowners understand the real opportunities for groundcover that can come from reintroducing fire in Pennsylvania (e.g., forage from oaks and acorns) and the importance of being strategic when applying fire to meet different management objectives (Yaussy and Waldrop, 2010).

Respondents who participated in a landowner assistance program in the past (e.g., cost-share assistance, technical assistance, or landowner education) assigned the most value to prescribed burning. Because of the support that comes from assistance programs, they may also be more likely to implement priority management activities (Butler et al., 2014; Kilgore et al., 2015; Andrejczyk et al., 2016). In the case of prescribed fire, cost-share contracts tended to enhance the value of burning programs by $30 per acre on average. The motivation to accept cost-share opportunities in private forest management is often multifaceted (Ma et al., 2012; Kreye et al., 2021). In some cases, the cost-share may be seen as a discount on management activities the landowner planned to do anyway (Andrejczyk et al., 2016). We advance here that perhaps the cost-share may also be seen as an opportunity to adopt new practices that are approved by an authority. More specifically, a cost-share contract may be seen as a strategic partnership with a state agency or conservation group (Andrejczyk et al., 2016; Chizmar et al., 2021). Formalizing public-private partnerships in fire can not only allow the forest owner to be viewed by society as responsible land managers but also help minimize their responsibility if burning produces socially undesirable outcomes (e.g., burnt landscapes, smoke). In sum, the economic and social benefits of partnering with another group may be the reason why the cost-share option adds value to prescribed burning activities.

Landowner training opportunities were ranked somewhat lower compared to other program options, but when combined with other program attributes such as enhanced forest health benefits and reduced liability, this approach still incurred significant positive WTP value ($22.86 per acre; Table 7). Prescribed Burn Associations are one of the leading strategies to promote prescribed fire on private lands (Toledo et al., 2014; Weir et al., 2016). They work by teaching landowners how to safely conduct their own burn and find implementation support by connecting to a network of other trained landowners. Interest in these programs requires participants who (1) expect to be confident in their abilities after training (i.e., perceived behavioral control) and (2) are willing to work with other landowners to get the job done. Hesitancy towards landowner training in Pennsylvania may be a function of people's limited experiences with fire, so they may be unsure about what it really takes to conduct a burn safely. They may also be unsure about collaborating with other forest owners since cooperative forms of forest management are uncommon in Pennsylvania (DCNR-PA, 2022). On the trust scale, most respondents trusted landowners who have been trained to use fire, but trust was even higher for professionals who implement prescribed fire.

Respondents generally favored options that employed consultants and burn bosses (see models 1 and 3) and were willing to pay $16 to $19 more per acre for professionals to do the work for them. Under Pennsylvania standards, a qualified burn boss is required for state supported liability protection. When combined with forest heath and reduced liability benefits, the value of having a burn boss was estimated to be $68.45 per acre (Table 7). Comparing this value with the average cost of prescribed burning in the southern US (i.e., $31.92 per acre) there appears to be real potential for establishing a viable marketplace for prescribed fire services (Maggard and Barlow, 2019). However, this potential has not yet been realized since investment in infrastructure, insurance, and training for private prescribed burn professionals is still limited in Pennsylvania. Also, there are very few qualified burn bosses who can burn under the PA standards, given the experience required is among the most difficult to achieve in the US (J. Kreye Personal Communications).

One interesting finding was the preference by respondents for liability protection, but not for relaxing current standards, which could help them achieve liability protection under state law. The preference for liability protection is likely due to concerns about economic loss if a landowner was required to pay for damages from an escaped fire. Reducing the requirements to become a qualified burn boss under the current standards could increase the supply of a qualified consulting workforce and help forest owners achieve liability protection. However, many forest owners perhaps don't see the standards as a barrier to achieving liability protection. If forest owners choose to burn outside the standards, it may be important to offer other affordable insurance options or other accommodations that provide owners with some liability protection (Yoder et al., 2004). The value of this attribute ($15 - $21per acre) is likely representative of the premium forest owners would pay to attain liability protection. Keep in mind also that owners risk perceptions are low, and the empirical risk of escaped prescribed fires in Pennsylvania is minimal (Weir et al., 2019).

To help establish a prescribed fire economy in PA, it may be useful for investors and fire professionals to identify which categories of forest owners may be early adopters or willing to pay a premium for prescribed fire services. We found younger and wealthier landowners were willing to pay more on average, and therefore may be ideal clients to start working with. To help scale down implementation costs, prescribed fire implementors may seek out landowners with larger properties (e.g., Stuart et al., 2010). However, Table 8 shows that smaller properties owned by certain categories of landowners can be just as valuable as larger properties (i.e., compare program 4: $2396 with program 2: $2286). Conversely, landowners who are trained to use fire may be more likely to apply fire themselves. The value of this training is somewhat less compared to the value of hiring a burn boss (i.e., compare program 2: $22,86 per acre with program 3: $68.45 per acre; Table 7). However, the relatively lower cost of offering landowner trainings, compared to training new burn bosses, could still provide the state a positive return on investment in forest health (Bennett, 1976). It is often assumed that landowners who invest in timber production tend to avoid using prescribed fire due to concern that it could impact timber quality (De Ronde et al., 1990; Mann et al., 2020). There was no evidence that respondent's priority management objectives, including timber production, were perceived as being in conflict with the prescribed fire. Also, prescribed fire tends to have a lesser impact on timber values in eastern oak forests compared to other silvicultural techniques (e.g., mechanical operation) (Mann et al., 2020).

The potential value of building a prescribed fire economy in Pennsylvania over the next 5 to 10 years is expected to range from $2.8 million to over $60 million annually (Table 9). As described, the level of economic impact will be strongly dependent on the types of policies and programs offered to forest owners and which owners are targeted. While the expected value of prescribed fire to forest owners is reported here, the social value of maintaining healthy forest ecosystems on private lands will likely be larger, further justifying public investment in private lands burning. A key limitation in this study was the under-sampling of women forest owners. The weighting procedure attempted to correct for the under-sampling of women, but we cannot definitively claim women's perspectives of fire were appropriately captured in this study. Non-response bias in this area suggests the importance of examining the potential for gender differences in perspectives on fire management in Pennsylvania (Lim et al., 2009).

5. Conclusions

The findings in this study reveal that prescribed fire has the potential to provide significant ecological, cultural, and economic benefits to private forest owners in Pennsylvania. Most respondents had favorable perspectives of prescribed fire and fire implementors, but limited knowledge and experience in this area point to the importance of prescribed fire education and training programs. In general, forest owners want to use fire to protect forest health and they prefer opportunities that help reduce personal liability. Specific cultural benefits associated with prescribed fire outcomes may include an enhanced sense of place, expression of stewardship values, expression of family values through enhanced recreational experiences, and a sense of community through partnerships (i.e., cost -share) with the state agencies and conservation organizations. The state also has a vested interest in promoting education about prescribed fire, to ensure that it is applied safely and effectively. Advocates of oak restoration on private lands may benefit from educating forest owners about the benefits of fire and oak restoration for wildlife. Other successful strategies for getting fire on the ground may be to involve forest owners who have been enrolled in landowner assistance programs in the past, help arrange partnerships between landowners and state agencies, or NGOs, and provide cost-share incentives. The estimated value of the proposed programs appears substantive enough to encourage private consultants to invest in prescribed fire training in order to serve a larger clientele. However, public investment in the training and development of qualified burn bosses and consultants may also be necessary. As fire is reintroduced to the landscape, landowner and public perceptions will need to be carefully managed through strategic outreach. As fire use increases on private lands forest owners will benefit by achieving their stewardship objectives and associated resilience within natural ecosystems will help maintain the provision of important ecosystem services for the broader society.

CRediT authorship contribution statement

Arun Regmi: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Melissa M. Kreye:** Conceptualization, Methodology, Investigation, Supervision, Project administration, Funding acquisition, Writing – review & editing. **Jesse K. Kreye:** Conceptualization, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

A.1. The random utility theory

The random utility theory assumes that the true but unobservable utility of a good or service is made up of both deterministic and random components (Eq. (1)).

$$U_{ij} = \mathrm{V}(\mathrm{Z}_{ij}, \mathrm{S}_i) + \varepsilon_{ij} \tag{6}$$

where U_{ij} is the utility that an individual landowner i obtains from alternative j, which consist of the deterministic term $V(\mathrm{Z}_{ij}, \mathrm{S}_i)$ as a function of the vector of attributes Z associated with alternative j and socioeconomic characteristics S of the individual landowner i, and the unobserved random error term ε_{ij} (Rolfe et al., 2000). Based on the theory, the probability that individual i chooses alternative j over alternative k is the function of the probability that the utility of choosing i is higher than the utility of choosing k (Eq. 2).

$$P_{ij} = \mathrm{Prob}\ (V_{ij} > U_{ik}) = \mathrm{Prob}(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik})\ j \neq k \tag{7}$$

where V_{ij} is often assumed to be an additive linear combination such that $V_{ij} = \beta_i X_{ij}$ where β_i is the coefficient of parameters and X_{ij} is a vector of observable attributes. The indirect utility is measured when the respondent makes a choice (vote yes/no) to all the alternatives on offer consisting of different attribute combinations.

A.2. Weighting procedure

We used a normalized survey weight in the model to make the sample observations representative of the whole population. The survey weight was generated based on census data of the age variable obtained from Metcalf et al. (2012).

STATA code:

$$recode\ age\ (1 = 1)\ (2 = 2)\ (3 = 3)\ (4 = 4)\ (5 = 5)\ (6/max = 6), gen(age\_gp)$$

$$\mathrm{recode\ age}\ (1 = 7380)\ (2 = 18,451)\ (3 = 121,778)\ (4 = 214,034)\ (5 = 169,751)\ (6/max = 206,653), \mathrm{gen(agepop)}$$

###A raking method was then used to produce sample weight.

survwgt rake old_wt, by (age_gp) totvars(agepop) gen(age_wt).

##This weight matched sample statistic with the population and analyzed weight based on population total rather than a sampling total. Thus, using this weight for the modeling purpose would heavily affect standard error and test statistics. To avoid this error, a normalized weight was used which brings the population total into the sample total and provides a standard error estimate based on sample statistics.

Normalized weight:

$$\mathrm{gen\ age\_}norm = \mathrm{population\ weight\ (aa\_wt)/mean\ of\ population\ weight}$$

Appendix B

B.1. Landowner management objective and activities

Table B1
Forest Management objectives ($n = 224$).

Rank	Objectives	Mean	Std. Dev.	Freq.	Percent (%)
1	Enhance wildlife populations	0.83	0.38	183	83
2	Recreational hunting	0.74	0.44	164	74
3	Recreation in general (e.g., hiking, bird watching)	0.72	0.45	160	72
4	Timber production	0.71	0.46	156	71
5	Aesthetics, sense of place	0.67	0.47	149	67
6	Personal privacy, seclusion	0.58	0.49	129	58
7	Preserve or enhance natural heritage	0.57	0.50	126	57
8	Carbon sequestration	0.29	0.45	63	29
9	Environmental education/outreach	0.24	0.43	54	24
10	Cultivate and collect non-timber forest products (e.g., maple syrup, mushrooms)	0.21	0.41	46	21

Table B2
Forest management activities (n = 224).

Rank	Activities	Mean	Std. Dev.	Freq.	Percent (%)
1	Thinning/stand improvement	0.83	0.37	184	84
2	Control invasive plant species	0.81	0.39	179	81
3	Harvesting/timber sales	0.70	0.46	154	70
4	Habitat management	0.66	0.48	145	66
5	Recreation management (e.g., trails)	0.65	0.48	143	65
6	Planting native species	0.58	0.49	129	59
7	Erosion/sediment control	0.45	0.50	99	45
8	Food plots (e.g., for game species)	0.40	0.49	89	40
9	Control tree regeneration	0.39	0.49	87	40

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2022.102902.

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