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A Process-Oriented Model of Decision-Making toward Landscape-Scale Prescribed Fire Implementation in the Southern Great Plains, USA

J. Kelly Hoffman[1] · Gerard T. Kyle[2] · Morgan L. Treadwell[3] · R. Patrick Bixler[4] · Urs P. Kreuter[5]

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Abstract

In this investigation, we developed a model of the psychological drivers of landowners' decisions to implement prescribed fire on their properties. The Southern Great Plains in the USA evolved with fire and prescribed fire is an important management tool aimed at maintaining and enhancing ecological and economic resilience in the region. The conceptualized model is reflective of a decision-making paradigm that considers decision making to be a process inclusive of a variety of factors and their inter-relationships to arrive at judgments on whether or not to utilize prescribed fire. The approach considered a spectrum of inputs, obstacles, and their associations to capture the complexity of decision making that is often lost when modeling single factors in dynamic social-ecological settings. Further, we considered the decision to use prescribed fire as a multifactor process that incorporates not only individual barriers to fire implementation but inter-barrier associations and other inputs (e.g., sociodemographic variables). Path analysis revealed five statistically significant relationships within the hypothesized model. For prescribed fire decision making, women tended to be more analytical whereas men were more inclined to rely on heuristics. Additionally, those who indicated owning their property for non-consumptive recreation-related reasons were also more inclined to rely upon heuristics. Texans reported more experience with prescribed fire as did respondents who indicated owning property for livestock product. Alternately, those owning their property for an investment and non-consumptive recreation opportunities reported less experience with prescribed fire. Last, ownership for crop and livestock production was positively associated with past wildfire experience. Findings have implications for three issue areas: (1) the provision of an evolved conceptualization through which prescribed fire implementation decisions can be examined, (2) enhancing the approach of prescribed fire outreach to a changing landowner population, and (3) improving the content and delivery of prescribed fire education efforts.

Keywords Decision making · Landowner attitudes · Prescribed fire · Rangeland management · Wildfire mitigation

Introduction

Natural and anthropogenic fire, along with defoliation by herbivores, has been an abiotic driver of grasslands ecosystems around the world (Pyne 2001). This is especially true of the Great Plains of North America since the region began to shift from a boreal forest to a grassland system following the last glacial epoch (Axelrod 1985; Pyne 2017). Specific to the study reported here, the Southern Great Plains (SGP) of Texas and Oklahoma is a region with a long pyric history (Axelrod 1985). However, beginning in the 19th century, Euro-American expansion into the SGP began to shift the region's historic fire regime through the suppression of fires that had been largely responsible for the evolution of the SGP's extensive

✉ Gerard T. Kyle
gkyle@tamu.edu

[1] Department of Ecosystem Science and Management, Texas A&M University, Austin, TX, USA

[2] Department of Rangeland, Wildlife & Fisheries Management, Texas A&M University, College Station, TX 77843, USA

[3] Department of Rangeland, Wildlife & Fisheries Management, Texas A&M AgriLife Extension Service, Texas A&M University, San Angelo, TX 76901, USA

[4] Lyndon B. Johnson School of Public Affairs, University of Texas, Austin, TX 78712, USA

[5] Department of Ecology & Conservation Biology, Texas A&M University, College Station, TX 778473, USA

grasslands (Fuhlendorf et al. 1996; Twidwell et al. 2016). The removal of fire has led to an increasing shift in the SGP's vegetative composition from herbaceous-dominated grassland to woody-dominated shrubland (Twidwell et al. 2013). Compared to other regions of the USA, the SGP has experienced five to seven times more woody plant encroachment (WPE) in the last 200 years (Barger et al. 2011).

WPE has impacted the ecosystem services delivered by the region's historic grasslands. The provisioning of forage and wildlife habitat, which are critical ecosystem services for the maintenance of grassland-based livelihoods in the SGP, has been severely depleted thereby significantly diminishing livestock carrying capacity (Wilcox et al. 2018; Weir et al. 2019). Additionally, grassland-dependent species have experienced habitat degradation as bunchgrasses were outcompeted by woody plants, which has resulted in a decrease in avian and other biodiversity throughout the SGP, including the greater and lesser prairie chicken and the northern bobwhite (Fuhlendorf et al. 2002; Engle et al. 2008; Hovick et al. 2015). Moreover, carbon storage capacity has become more variable as an increasing proportion of the region's biomass has converted from fire-protected herbaceous root biomass to fire-vulnerable aboveground woody plants biomass, large portions of which can be consumed by high-intensity wildfires, resulting in large post-wildfire carbon pulses (Twidwell et al. 2013). Wildfire threats to urban and rural areas have also increased as the amount of volatile woody plant biomass has increased (Blanchard and Ryan 2007; Twidwell et al. 2013). Collectively, the shift in vegetative composition has reduced the resilience of the SGP's historic grasslands and negatively affected the wellbeing of people whose livelihood is tied to productive grasslands in the SGP.

Prescribed fire is capable of mitigating and, in some cases, reversing the shift in the delivery of ecosystem services caused by WPE (Fuhlendorf et al. 1996; Taylor et al. 2012). Prescribed fire is the purposeful ignition of fire under specified meteorological and fuel conditions (wind speed, air temperature, and fuel load fuel moisture) in order to mimic the system's historical fire regimes and achieve management outcomes. The tool remains underutilized at a landscape-scale despite being statistically one of the safest land management practices used in the United States (Twidwell et al. 2015; Weir 2010; Toledo et al. 2012; Weir et al. 2019). As Twidwell et al. (2015, p9) state, the "data universally suggest that current risk aversion driving the preference for alternative land management techniques over prescribed fire is not supported." Given that land in the SGP is predominantly privately owned, the number of acres burned prescriptively is ultimately determined by the decision-making processes of individual landowners or managers.

Barriers to the Use of Prescribed Fire

The barriers considered to understanding the decision-making process relating to prescribed fire have generated an extensive body of literature; in this study, the terms 'barrier,' and 'obstacle,' are used synonymously. Landowner concerns about overly stringent state liability statutes regarding escaped prescribed fires has been cited as hampering fire implementation (Kreuter et al. 2008; Wonkka et al. 2015). Toledo et al. (2013) conclude social norms (e.g., lack of support from family and neighbors) influence an individual's attitudes toward using the tool. Twidwell et al. (2019) noted that an aversion to prescribed fire might be partially driven by relatively uninformed landowners conflating media reports of wildfire-related events with properly implemented prescribed fires and relevant information. A lack of local capacity, including labor, equipment, and safe fire expertise, also limits the widespread use of prescribed fire (Taylor 2005; Kreuter et al. 2008). Additionally, the often-unpredictable periods during which suitable conditions for applying effective prescribed fire safely also hinder its use (Quinn-Davidson and Varner 2012). These windows, which are often already brief due to dynamic climatic and fuel conditions, can be abbreviated further by county and state burn bans, which may persist under conditions that no longer warrant their implementation (Twidwell et al. 2013). While this list is by no means exhaustive, it highlights numerous barriers to the widespread prescribed fire implementation. These obstacles likely contribute to the finding that many private landowners perceive prescribed fire to be a high-risk land management tool that is difficult to implement safely (Weir et al. 2019).

Similar barriers are faced in other countries. Altangerel and Kull (2013) noted some Australian citizens' aversion to prescribed fire as a wildfire mitigation tool, even following catastrophic wildfire seasons, and concluded that the public's fear that prescribed fires present a high risk of "frequent escape" signifies a substantial barrier to the use of this wildfire mitigation tool (Altangerel and Kull 2013, 110). This is inconsistent with the finding that fewer than 1% of prescribed fires escaped their intended boundaries (Ryan et al. 2013). Misunderstood issues surrounding prescribed fire were also found to negatively impact its use for promoting wildlife biodiversity in South Africa's Kruger National Park (Bond and Archibald 2003). Harper et al. (2018) noted similar public opinion barriers to use of prescribed burning in the United Kingdom.

Additionally, Wonkka et al. (2015) and Yoder (2008) investigated the impact of state legal liability standards on prescribed fire usage and escape. Their research determined that, compared to states with simple negligence (stricter) standards, states with gross negligence (more lenient)

liability standards experienced significantly more prescribed fires in terms of both the number of ignitions and the area burned (Wonkka et al. 2015). Furthermore, although states with more lenient liability standards documented more escaped burns, fire suppression or damage costs and injury rates were not higher than in states with more stringent liability standards (Yoder 2008; Wonkka et al. 2015).

Understanding Landowner Decisions Processes

While the preceding levels of analytic specificity are invaluable for understating the effects of barriers to prescribed fire implementation and multiple obstacles are sometimes addressed in a single investigation (Quinn-Davidson and Varner 2012; Toledo et al. 2013), these models do not focus on a single, centralized decision to leverage understanding of the impact of multiple factors on the fire decision-making process. With most land in the SGP in private ownership, an impactful effort to implement prescribed fire at a landscape-scale requires better understanding of how landowners make the decision to implement prescribed fire. This decision does not occur in an environment with a single or even several independent barriers as the only considerations. In real-world land management contexts, perceived barriers, challenges and opportunities interact to create a dynamic decision-making environment in which the decision maker operates. The process the decision maker utilizes considers not only liability concerns, capacity shortages, burn bans and liability statues, but also the associations among these and other physical and psychological factors.

The Two System Theory (TST) of decision-making attempts to bridge the divide between the logical, analytical processes of *homo economicus* and more intuitive, emotional decision processes (Kahneman 2011). While most 20th century decision-making theories centered on fully informed, infinitely sensitive, and utility-maximizing rational decision makers (Slovic 2010), the TST proposed a dual-process model of decision-making. This theory views the decision-making process as one comprised of intuitive, instinctual responses to situations coupled with more analytic cognitive processes. The more responsive, intuitive processes are characterized as System 1, while the more logical, analytical processes comprise System 2.

The TST agrees with earlier, more economics-focused models of decision-making in that conscious, analytic choices account for a large proportion of how individuals reach a decision. Where the TST diverges is in the relative contribution of these analytic processes in decision-making and the autonomous nature in which the earlier models assumed these processes operate. Slovic et al. (2004, 313) discuss these bifurcated 'analytic' and 'experiential' (i.e., instinctual) systems of thought and their interplay by stating that "[l]ong before there was probability theory, risk assessment and decision analysis, there were intuition, instinct and gut feeling…As life became more complex and humans gained more control over their environment, analytic tools were invented to 'boost' the rationality of our experiential thinking." As humanity evolved, the analytic tools of System 2 became more sophisticated and widely accepted, while the intuitive processes of System 1 came to be viewed as emotion impeding rationality. The TST proposes that the 'emotion impeding rationality' argument is erroneous and that the exact opposite is true: to accurately evaluate a situation humans must utilize their intuitive system in conjunction with the conclusions reached by their analytic system (Damasio 1994; Slovic et al. 2004).

In this investigation, the TST provides a theoretical tool that facilitates insight into how risks concerning prescribed fire are perceived and evaluated by individuals. With this tool, the impact of the intuitive system on the decision whether or not to use fire can be better understood. Possibly due to fire's general potential for calamitous outcome (Pyne 2001), prescribed fire seems to engender fears unsupported by evidence (Twidwell et al. 2015). For instance, concern over escaped prescribed fires and resultant fatalities or damage to neighboring properties has been identified as a significant concern for private landowners considering fire implementation (Twidwell et al. 2015), despite the fact that escaped prescribed fires are rare, and those causing significant property damage or fatalities are exceedingly uncommon (Weir et al. 2019). Interestingly, focus group participants in stage one of the overarching project that incorporates the research reported here often bifurcated their largest concerns with prescribed fire, initially citing a risk they found more likely to occur as being paramount (e.g., smoke hazards), then amending their response to list possible fatalities from escaped fire as the 'number one' concern. Loewenstein et al. (2001, 269) address these workings of the intuitive system by noting how people "experience powerful fears about outcomes that they recognize as highly unlikely," while, in contrast, "many experience little fear about hazards that are both more likely and probably more severe." It seems likely that the intuitive system influences individuals' choices to implement prescribed fire in a variety of ways.

Generally, the use of the TST framework for understanding decision-making might provide greater insight into natural resource management decisions made by private landowners. Specifically, the application of this toolbox of heuristics to individuals' prescribed fire implementation decisions might create a clearer picture of the barriers and opportunities to landscape-scale implementation of this management tool in the SGP and other private land areas.

While research on decision-making concerning prescribed fire implementation exists, knowledge gaps remain. Investigations into decision-making exist at the agency (Twidwell et al. 2015) and regional (Weir 2010) levels, but these are largely focused on analytic processes. A coherent conceptualization of individual decision-making is needed that focuses on the intuitive, emotional genesis of much of human choice. Beyond the use of the affective heuristic (Ascher et al. 2013; Wilcox et al. 2018), a deeper understanding of general, individual level, heuristical decision-making processes employed in the consideration of prescribed fire is also needed in order to more effectively promote the safe use of this land management tool.

Study Approach and Objectives

To fill this knowledge gap, we developed a process model to provide insight on factors driving landowners' decision to implement prescribed fire (Taylor 2005; Yoder 2008; Twidwell et al. 2013; Wonkka et al. 2015; Weir et al. 2019). The process model is a decision-making paradigm that conceptualizes the decision as a process considering a variety of factors and their inter-relationships to reach judgements (van Riper and Kyle 2014). An approach which views a broad spectrum of inputs, obstacles, and their associations might capture more of the complexity that is often lost when modeling single factors in dynamic social-ecological settings (Beratan 2007). Our study views the decision to use prescribed fire as a multifactor process that considers not only individual barriers to fire implementation but inter-barrier associations and other inputs (e.g., socio-demographic variables). We used the process model to address two specific objectives:

Objective 1: Develop a model conceptualizing the prescribed fire decision-making process based on past empirical evidence.

Objective 2: Empirically identify the most salient factors associated with the fire decision-making process.

Methods

Study Setting

This study focused on the southern extent of the Great Plains biome in central North America. This portion of the Great Plains, known as the Southern Great Plains, encompasses eastern Colorado and New Mexico, nearly all of Kansas and Oklahoma, and the entirety of northern and central Texas, extending as far south as the Gulf of Mexico. This investigation focused on the central portion of the SGP located in Texas and Oklahoma.

Sample

The study consisted of a multi-phase targeted mail survey of 1200 landowners in Texas and Oklahoma. Six rural counties in both states were surveyed for a total of twelve counties. Half of the counties in each state were selected based on having an active Prescribed Burn Association (PBA) or Fire Management Association (FMA). Open-access county tax appraisal roles were utilized to randomly select participating landowners. Because we were interested in studying the decision-making processes of identifiable landowners whose properties are sufficiently large for prescribed fire application, we excluded properties that were: (1) held in legal trusts, (2) listed as under the care of an attorney, or executor, (3) in the possession of a municipal, county, state, national, or tribal government entity, or 4) less than 20 ha (~50 ac).

Two property size strata were used, the first being 21–64 ha and the second 65 ha and larger. This threshold was based on the fact that 65 ha represents one-quarter of a surveyor's section and provides a property size that was historically considered to be agriculturally feasible. Owners of larger properties typically have a different relationship with prescribed fire than owners of smaller properties, thus justifying such stratification (Kreuter et al. 2008). Fifty landowners were randomly selected from each stratum in each of the 12 counties for a total sample size of 1200 landowners.

The survey consisted of five mailings (Dillman 2007). The first mailing was an introductory letter describing the study and whom respondents could contact to answer questions. The second mailing consisted of a cover letter, the survey questionnaire and a postpaid return envelope. This was followed by a thank you/reminder postcard. The fourth mailing sent to non-respondents only and consisted of a cover letter, replacement questionnaire, and a postpaid return envelope. A fifth and final mailing consisting of another reminder/thank you postcard was send to remaining non-respondents, urging them to respond. Survey responses were accepted for up to two months following the final mailing. Additionally, a one-page questionnaire was sent to all non-respondents after the survey period to determine why they did not participate in the study and to obtain a limited amount of data for key survey questions to conduct a nonresponse bias analysis.

Survey Instrument

Based on a review of the literature, the barriers and inputs deemed most impactful to prescribed fire decision-making were identified. This review revealed six areas of inquiry: (1) prescribed fire decision-making processes, (2) prescribed fire experience, (3) wildfire experience, (4) possible outcomes of

Table 1 Prescribed fire decision-making measures

Variable name	Constituent variable(s)	Description	Measure
Prescribed fire decision-making process	11 semantic differential pairs	Degree to which decision-making is analytic or heuristic	11 = entirely analytic … 66 = entirely heuristic[a]
Possible perceived outcomes of prescribed fire use	Fire damage to adjacent property Smoke hazards	Perceived likelihood of outcome occurring	1 = highly *un*likely … 6 = highly likely
Prescribed fire experience	Burn frequency	Total fires 2008–2017	–
	Total area burned	Total burned area 2008–2017	–
	Area per burn	Average area/burn 2008–2017	–
Wildfire experience	Firsthand experience	Y/N	–
	Negative impact from experience(s)	Degree of impact	1 = not affected …
4 = severely affected			
Property ownership motivations	Crop production	Y/N	Multiple ownership motivations per respondent allowed
	Livestock production	Y/N	
	Wildlife enterprises	Y/N	
	Investment purposes	Y/N	
	Non-consumptive or recreational uses	Y/N	

[a]Respondents were requested to indicate how each pair "describes your decision-making process when deciding whether or not to use prescribed fire". Items were scored on a six-point scale

prescribed fire, and (5) property ownership motivations (Table 1). The study also controlled for the effect of socio-demographic variables (Table 2). Our criterion variable, prescribed fire decision-making process, was measured with 11 items using a semantic differential response format (Osgood et al. 1957). The items were used to create an index illustrative of respondents' decision-making processes relative to the use of prescribed fire. Respondents were requested to indicate (along a 6-point scale) the extent to which each pair of adjectives characterized their "decision-making process when deciding whether or not to used prescribed fire." The adjective pairs were: fast/slow, methodical/casual, analytic/intuitive, reasoned/felt, precise/approximate, solitary/collaborative, difficult/easy, risk-averse/risk-seeking, optimizing/approximating, calming/worrying, and informed/uninformed. The computed index subsequently placed respondents along a continuum anchored by analytic decision-making styles and heuristic decision-making styles. Respondents' scores ranged from 11 (entirely analytic) through 66 (entirely heuristic).

Wildfire experience was measured using eight items (e.g., loss of forage, loss of trees, personal injury, injury to other people you know, death of a person you knew) with a response scale 1 = not affected through 4 = severely affected. Items were summed to create a composite index used in subsequent analyses.

Statistical procedures to estimate missing data were conducted using Stata/SE 15.1 (Multiple Imputation in Stata 2019).

Data Analyses

Missing decision-making process data (24% missing at random) were estimated using multiple imputation with chained equations (MICE), a robust iterative process that creates a specified number of imputed data sets, each identical except for missing values (White et al. 2010; Multiple Imputation in STATA 2019). All present values for all survey questions were used to estimate all missing values, thus preserving the uncertainty of the missing data while also providing a more accurate estimation than other missing data estimation techniques. Twenty imputations were created utilizing the seed number '2031,' and the imputed values were then averaged across all imputed sets to create a single, complete dataset.

The hypothesized model (Fig. 1) was tested using covariance structure analysis (Anderson and Gerbing 1988) in LISREL 10.10 (2020). Due to the mixture of categorical, ordinal, and continuous measures, the analyses were based on biserial and asymptotic covariance matrices using the weighted least squares estimator (Byrne 1998). Multiple fit indices were utilized to assess the proposed model's adequacy (Bentler 1990; Steiger 2007). These included the root mean square error of approximation (RMSEA) ≤0.08 (Hu and Bentler 1999), and the comparative fit index (CFI) and non-normed fit index (NNFI) ≥0.95 (Hu and Bentler 1999; Kline 2016). Collectively, these fit indices help us to determine the plausibility of the hypothesized relationships being tested in our model.

Table 2 Sociodemographic characteristics of survey respondents

Sociodemographic variable	Description	Statistic
Age	years	M = 66.8; SD = 12.5
Personal property ownership	years	M = 24.8; SD = 16.7
Familial property ownership	years	M = 57.4; SD = 40.3
Gender	Female	19.2%
	Male	80.8%
Current PBA/FMA member	Yes	5.9%
	No	94.1%
Past PBA/FMA member	Yes	4.1%
	No	95.9%
State of residence	Texas	57.3%
	Oklahoma	42.7%
Education	High school	15.2%
	Postsecondary/ bachelor's deg.	48.6%
	Graduate/ professional degree	36.2%
Property size	20–64 ha (50–159 ac)	11.4%
	65–202 ha (160–500 ac)	27.3%
	203–405 ha (501–1000 ac)	16.2%
	405–2023 ha (1001–5000 ac)	27.9%
	2024+ ha (5001+ ac)	17.2%
Percentage of annual income from property	0–25%	60.1%
	26–50%	16.7%
	51–75%	11.6%
	76–100%	11.6%

M Mean, *SD* Standard Deviation

Results

Survey Response Rates and Bias

Of the 1200 contact addresses selected for the study, 21 mailings were returned as undeliverable. This reduced the sample size to 1179, of which 354 usable responses were received, representing an effective response rate of 30% (34% Texas; 26% Oklahoma). The nonresponse bias survey resulted in a response rate of 13% from the 825 initial non-respondents. Statistically significant response differences between the survey respondents and non-respondents were found for four of the eight response variables included in the nonresponse bias questionnaire (Table 3). These differences included longevity of land ownership, opinion about prescribed fire, and opinions about fire's efficacy as a fuel load reduction and woody plant control tool. Due to these statistically significant differences, the results of the study are not extrapolated to the overall SGP landowner population in the study counties.

Survey Respondent Characteristics

Respondents tended to be older (66.8 years) men (80.8%) with relatively long land tenures; 24.8 years of personal property ownership and 57.7 years of family ownership. Most were well educated with 84.8 percent indicating having a postsecondary degree. A slight majority of respondents resided in Texas (57.3%). The majority of respondents were not presently (94.1%) or had previously (95.9%) been PBA or FMA members. The distribution in property size across the five response categories was relatively flat with 11.4 percent indicating owning properties in the 20–64 ha range through 17.2 percent in the 2024+ range. Most respondents (60.1%) reported earning little to no income as a percentage of their annual household income (0–25%).

Covariance Structure Analysis

The results of the covariance structure analysis (i.e., path analysis) used to test the hypothesized model are presented in Fig. 2. The RMSEA, CFI, and NNFI goodness of fit indices used to ensure adequate fit of the model were all determined to be adequate (Table 4). Statistically significant associations are reported in Table 4. The nature of the relationships, reflected in gamma (γ), depict linear associations between a dependent variable and it predictor(s). The extent to which the predictors capture variability in the dependent variable is reflected in the R^2 value.

Statistically significant direct effects were found between multiple factors (bolded in Fig. 2; displayed in Table 4). The sociodemographic variables in BB_1 that were significantly related to prescribed fire experience was the state in which the respondent lives, with Texas respondents having more experience than Oklahoma respondents ($\gamma = 0.192$, $p < 0.001$). Consistent with BB_3 and BB_4, property ownership motivations are directly linked to both prescribed fire and wildfire experience, respectively. Specifically, ownership for livestock production was shown to be positively related with prescribed fire experience ($\gamma = 0.119$, $p < 0.001$), whereas ownership for investment and non-consumptive/recreational purposes were negatively related with such experience ($\gamma = -0.074$, $p < 0.001$; $\gamma = -0.72$, $p < 0.001$, respectively). These variables accounted for 7.4 percent of the variance in prescribed fire experience.

Ownership for crop ($\gamma = 0.144$, $p < 0.001$) and livestock production ($\gamma = 0.212$, $p < 0.001$) were found to be positively associated with wildfire experience (BB_4), suggesting that respondents with these two predominant ownership motivations may have experienced or at least perceived greater losses from wildfire than the respondents with other

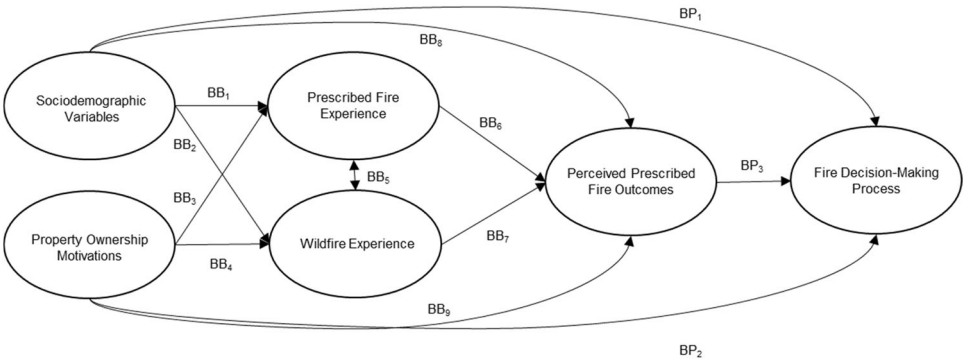

Fig. 1 Process model of the relationships among inter-barrier and barrier-process relationships to the prescribed fire decision-making process. Note: BB_1–BB_9 refer to inter-barrier relationships and BP_1–BP_3 refer to barrier-process relationships as described below. Based on past work, the following relationships were hypothesized: *BB_1*: Prescribed fire experience is influenced by sociodemographic variables (Toledo et al. 2014; Weir et al. 2019). *BB_2*: Wildfire experience is influenced by sociodemographic variables (Toledo et al. 2014; Weir et al. 2019). *BB_3*: Prescribed fire experience is associated with land ownership motivations (Yoder and Blatner 2004; Elmore et al. 2010; Kreuter et al. 2019). *BB_4*: Wildfire experience is associated with land ownership motivations (Yoder and Blatner 2004; Elmore et al. 2010). *BB_5*: Prescribed fire experience and wildfire experience are interconnected (Yoder and Blatner 2004; Knotek et al. 2008). *BB_6*: Possible perceived fire outcomes are related to prescribed fire experience (Knotek et al. 2008; Elmore et al. 2010). *BB_7*: Possible perceived fire outcomes are related to wildfire experience (Twidwell et al. 2015). *BB_8*: Possible perceived fire outcomes are related to sociodemographic variables (Blades et al. 2014; Toledo et al. 2014; Kreuter et al. 2019; Weir et al. 2019). *BB_9*: Possible perceived fire outcomes are related to land ownership motivations (Yoder and Blatner 2004). *BP_1*: The fire decision-making process will have a significant barrier-process relationship with sociodemographic variables (Toledo et al. 2014; Kreuter et al. 2019). *BP_2*: The fire decision-making process will have a significant barrier-process relationship with land ownership motivations (Yoder and Blatner 2004; Elmore et al. 2010). *BP_3*: The fire decision-making process will have a significant barrier-process relationship with possible perceived prescribed fire outcomes (Hoffman et al. 2021)

landownership motivations. These variables accounted for 5.6 percent of the variation in wildfire experience.

Two factors that that were directly linked to the prescribed fire decision-making processes were: gender (BP_1: $\gamma = 0.231$, $p < 0.001$) where male respondents were more likely to make decisions about prescribed fire than women; and property ownership for non-consumptive/recreational purposes which was negatively associated with prescribed fire decision-making process (BP_2: $\gamma = -0.210$, $p < 0.001$). This finding suggested that respondents who own land primarily for non-consumptive or recreational purposes are less likely to apply prescribed fire than respondents with other landownership motivations. Collectively, these predictors of fire-decision making accounted for 9.7 percent of the variation.

The relationships between prescribed fire experience, wildfire experience, and perceived fire outcomes (BB_5, BB_6, and BB_7, respectively) were not statistically significant.

Discussion

Barrier and Process Relationships

The path analysis revealed five statistically significant relationships within the hypothesized process model for the decision to use prescribed fire. Gender's effect on the prescribed fire decision-making process was such that men were more inclined to employ heuristics in their decision making compared to women who were more analytical. For property ownership motivations, for those motivated by non-consumptive recreational uses, their prescribed fire decision-making process were also more analytical Sociodemographics (state of residence) and property ownership motivation variables (livestock production, investment, and non-consumptive/recreational purposes) were also found to have significant associations with prescribed fire experience. Texas residents reported more experience as did respondents who reported undertaking livestock production. Alternately, respondent indicating property ownership motivates related to investment and non-consumptive recreational uses reported less prescribed fire experience. Finally, property ownership motivations (livestock and crop production) were found to have a direct and positive effect on wildfire experience.

Implications

These findings have implications for three issue areas: (1) the provision of an evolved conceptualization through which prescribed fire implementation decisions can be examined, (2) enhancing the approach of prescribed fire outreach to a changing landowner population, and (3) improving the content and delivery of prescribed fire education efforts.

First among these is the reinforcement of the concept that real-world decision-making is substantially more complex than the consideration of individual factors. While this reality has long been acknowledged in other natural resource decision-making contexts (Groeneveld et al. 2017), this perspective has been lacking in prescribed fire research. The

Table 3 Statistically significant differences between survey respondents and non-respondents

Survey question	*Statistic*	*p* value	Difference between survey respondents and non-respondents
Age (years)	$t = -1.082$	0.280	No statistical difference
Are you a member of a PBA? (yes/no)	$\chi^2 = 1.562$	0.211	No statistical difference
What proportion of your time do you spend on your property? (%)	$t = -1.143$	0.253	No statistical difference
Have you experienced wildfire firsthand? (yes/no)	$\chi^2 = 0.350$	0.554	No statistical difference
How many years have you personally owned your property? (years)	$t = -3.427$	0.001	Longer non-respondent ownership (+7 years)
What is your opinion of prescribed fire as a management tool?[a]	$t = 4.698$	<0.001	Respondents have a generally more positive opinion of prescribed fire
How useful do you think prescribed fire is for fuel load reduction?[b]	$t = 2.943$	0.003	Greater perceived efficacy among survey respondents for fuel load reduction
How useful do you think prescribed fire is for woody plant control?[c]	$t = 2.994$	0.003	Greater perceived efficacy among survey respondents for woody plant control

t is the test statistic used to examine mean differences between two groups. χ^2 (chi-square) test statistic is used to compare observed cell counts against what would be expected

[a]Measured along a scale where 1 = Very negative through 7 = Very positive

[b]Measured along a scale where 1 = Not at all useful and 5 = Always useful

[c]Measured along a scale where 1 = Not at all useful and 5 = Always useful

more holistic conceptualization of the prescribed fire decision-making process presented here demonstrates inter-factor and factor-decision process associations. Landowners contemplating fire implementation, especially for the first time, are influenced by multiple factors as well as their interactions. For instance, they are likely simultaneously influenced by their motivations for owning their property, prior direct and indirect experience of wildfire including sensationalized media reports, and their experiences with prescribed fire. These experiences inform the possible perceived outcomes of fire use and the ultimate fire implementation decision.

However, it would be difficult for any model to capture entirely the intricate nature of this process for two reasons. As Beratan (2007, 1) notes, the "extreme complexity of real-world systems that include human actors within a cultural context" is often lost when modeling social-ecological systems. By definition, models are simplifications of real-world phenomena and perfect decision modeling is impossible to achieve as decision-making is highly individualized (Gigerenzer and Brighton 2009) and dependent on self-reporting. For example, the association between ownership motivation and prescribed fire experience may evolve over time as an individual accumulates new experiences and ownership motivation shifts. As this relationship evolves, so too may the relationships between these and other factors. A strength of the process model is that evolving and newly identified factors may be added to the conceptualization, enabling the model to improve over time.

Second, these findings have implications for more effectively connecting prescribed fire outreach specialists in the SGP with an evolving landowner population. As property ownership and management in the SGP transfers to younger and more ethnically diverse population in coming decades (Texas Demographic Center 2019), future landowners may face similar prescribed fire implementation barriers as current landowners but they may also be influenced by other culturally or demographically novel factors in their decision-making processes (Sorice et al. 2014). Therefore, compared to single barrier or multifactor models, a using dynamic process models to understand decision-making could better equip outreach efforts aimed at enhancing prescribed fire implementation to connect better with these new types of landowners. This is an especially salient point as the current average property size is decreasing in Texas (Smith et al. 2019) and other states with fire-dependent ecosystems, further hindering landscape-scale prescribed fire efforts. Sorice et al. (2012) noted that property owners of smaller parcels (~20 ha/~50 ac) are often motivated by recreational or esthetic property values and that these motivations may be associated with perceptions that invasive woody plants are beneficial to native wildlife, even though detrimental wildlife habitat impacts of WPE have been wildly documented (Fuhlendorf et al. 2002;

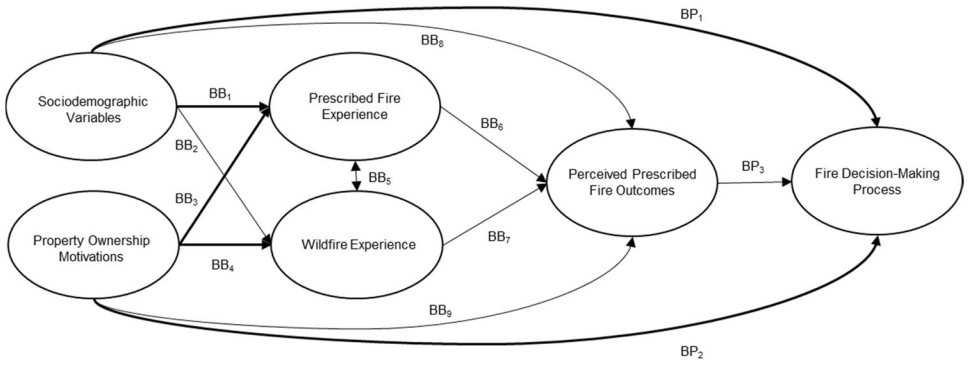

Fig. 2 Covariance structure analysis of the factors influencing the prescribed fire decision-making process. Statistically significant pathways denoted with bold arrows

Table 4 Final model parameters for the prescribed fire decision-making model

Dependent	Predictor	Constituent variable	Unstandardized beta	Standard error	γ	T value	R^2
Prescribed fire experience	Socio-demographic variables (BB_1)	State of residence	0.186	0.027	0.192	6.824***	0.074
	Property ownership motivations (BB_3)	Livestock production	0.120	0.026	0.119	4.552***	
		Investment	−0.074	0.027	−0.074	−2.792***	
		Non-consumptive/ recreational uses	−0.072	0.027	−0.072	−2.684***	
Wildfire experience	Property ownership motivations (BB_4)	Crop production	0.144	0.040	0.144	3.625***	0.056
		Livestock production	0.212	0.039	0.212	5.423***	
Fire decision-making processes	Socio-demographic variables (BP_1)	Gender	0.233	0.037	0.231	6.241***	0.097
	Property ownership motivations (BP_2)	Non-consumptive/ recreational uses	−0.211	0.052	−0.210	−4.073***	

***$p < 0.001$, $\chi^2 = 239.227$, $df = 70$, RMSEA = 0.0826, CFI = 1.000, NNFI = 1.000

Chapman et al. 2004; Fuhlendorf et al. 2012). Such erroneous perceptions can lead to uninformed opposition to prescribed fire implementation.

Third, these findings could enhance the content and delivery of fire teaching efforts. Much prescribed fire education focuses on familiarizing potential practitioners with technical details and methods, covering content areas such as fire management vocabulary, possible fire outcomes, and case studies (Loomis et al. 2001). While such information is undoubtedly essential for safe prescribed fire implementation, teaching efforts are likely to be more impactful if they also incorporate consideration of other factors that affect land management decision-making including property ownership motivations, which this study has shown directly impact the prescribed fire decision-making process. While the barrier approach has allowed researchers to identify numerous inhibitors for prescribed fire implementation (Kreuter et al. 2008; Quinn-Davidson and Varner 2012; Wonkka et al. 2015; Twidwell et al. 2019), a process model, such as the one presented here, provides a more comprehensive approach that allows educators to better address decision-making by individual landowners and managers. Ultimately, the process model approach could help better tailor fire education to the individual decision maker.

Study Limitations and Future Research

Compared to the survey respondents, non-respondents had owned their property for a longer period of time, had a generally more negative opinion of prescribed fire as a rangeland management tool, and perceived prescribed fire to be less effective both in terms of wildfire fuel load reduction and woody plant control. Often the landowners who have owned their land for a longer period of time might be older and less willing the change long held views that fire as a destructive force. These differences limit the extrapolative power of the research results to the overall SGP private landowner population. Future investigations into decision-making concerning prescribed fire would benefit from incorporating a more representative group of landowners by including a larger portion of more recent landowners who represent the increasing trend in ethnic and ownership motivation diversity of landowners.

An effort to implement prescribed fire at a landscape-scale in the SGP would benefit from a continually improving decision process models that are regularly refined with previously excluded and newly identified barriers to the use of prescribed fire, as well as improved conceptualizations of previously modeled obstacles. For instance, individual perceptions of legal liability were not included in this study for simplicity as some previous studies found they had no significant relationship with willingness to use prescribed fire (Kreuter et al. 2019; Hoffman et al. 2021), but these findings are inconsistent with other studies that found legal statues pertaining to prescribed fire do affect prescribed fire implementation (e.g., Wonkka et al. 2015).

Beyond including individual liability perspectives into the decision-making processes model, the addition of a 'land involvement' factor could also provide more insight into fire implementation decisions. Sorice et al. (2018, 160) cite the need to better understand "the degree to which [landowners] devote themselves to operating or managing their land" (i.e., a 'land involvement' factor) in order to appreciate their brush management preferences, including the use of prescribed fire. The process model described here would also be improved through the inclusion of factors such as the impact of past PBA membership effects on prescribed fire opinions and individual interpretations of escaped prescribed fire court judgements and relevant legal proceedings (Yoder 2008; Toledo et al. 2014).

Another improvement might include a way to gauge the 'permeability' of certain barriers (Toledo et al. 2012). For instance, burn ban represent relatively stable impermeable barrier while, an individual's experience with wildfire could change dramatically in a relatively short period changing the impact of their wildfire experience on prescribed fire decisions (Hoffman et al. 2021). Identifying obstacles that are prone to permeability shifts and how those shifts impact fire implementation decisions would be a beneficial model addition.

Conclusion

This investigation conceptualized a process-focused prescribed fire decision-making model that views multiple barriers to fire use as process inputs with barrier-barrier (BB) and barrier-process (BP) relationships. Path analysis determined multiple significant BB relationships, including between prescribed fire experience and a respondent's state of residence' as well as between wildfire experience and land ownership for livestock or crop production. Significant BP relationships included those between the fire decision-making process and 1) sociodemographic variables, specifically gender, and 2) property ownership for non-consumptive/recreational purposes.

The findings of this study have several implications for landscape-scale prescribed fire use in the SGP. In general, they provide a more realistic first approximation of a process model of human decisions regarding the use of prescribed fire and complement information derived from previous studies that used the barrier approach, thereby providing new insights into land management decision-making. This model is theoretically useful in progressing understanding of interrelationships among barriers to fire use.

Such a model could provide prescribed fire educators and outreach specialists a new way to connect with and educate new landowners about this powerful rangeland management tool. Understanding how individuals decide whether or not to burn their land requires knowledge about how they consider and interact with multiple factors and the decision process itself. While fire implementation capacity, expertise, and liability constraints should continue to be investigated at the biome-scale, these barriers also require consideration at the individual decision-making process level. In predominantly private land areas, landscape-scale prescribed fire can only be achieved by enhancing prescribed fire use by individual landowners.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

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