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The effects of climate change event characteristics on experiences and response behaviors: a study of small woodland owners in the Upper Midwest, USA

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Introduction: Whether and under what conditions people are compelled to adapt to climate change is a question of significant policy and scholarly importance. However, little is known about the influence of the characteristics of the climate change events with which people have experience on people's decisions to modify their behavior to reduce risk.

Methods: We used structural equation models to quantitatively analyze survey data that we collected from small woodland owners in areas affected by three types of severe events known to be exacerbated by climate change: droughts, storms, and tree insect and disease outbreaks.

Results: We found that events with faster onset and termination speeds and greater visibility were associated with people's self-reported experiences of these events and decisions to undertake various practices out of concern about them, likely because events with these characteristics are easier to observe, although there are exceptions.

Discussion: These findings improve scientific understanding of the climate change conditions that compel people to perceive risk and act.

KEYWORDS

climate change, adaptation, forest, landowners, structural equation modeling, survey research

1. Introduction

As climate change drives more frequent and severe storms, droughts, heat waves, and wildfires worldwide, it is becoming increasingly clear that people must adjust their ways of living to reduce risk. What compels people to adapt to climate change is, therefore, a question with important implications for livelihood and wellbeing in the future. While many factors influence adaptation, knowing how people's direct experiences with climate change compel them to take the initiative to adapt is vital for determining what additional policy interventions are needed to promote protective action (Smit et al., 2000; Dessai et al., 2004). However, the influence of experience on climate change adaptation behavior is not fully understood (van Valkengoed and Steg, 2019; Howe, 2021; Ng, 2022). While previous research has found that prior experience with natural hazards can compel people to take action to protect themselves against future events and a large body of literature describes the mechanisms behind this relationship (Slovic et al., 1981; Dessai et al., 2004; Grothmann and Reusswig, 2006; Sharma and Patt, 2012; Lawrence et al., 2014; Lazo et al., 2015; Konisky et al., 2016; Toole et al., 2016; Zanocco et al., 2018; Castañeda et al., 2020; Ng, 2022), how these mechanisms operate across different climate change stressors (i.e., storms, drought, wildfire, heat, disease) is not well understood.

Experience of a natural hazard or climate change event derives from more than whether one was exposed to the hazard or stressor. Experience involves awareness of exposure and comprehension of the event, including its causes and near- and far-term consequences (Dessai et al., 2004; Gifford et al., 2011; Reser and Swim, 2011; Toole et al., 2016). In the case of climate change, some stressors may be easier to experience than others because they are more visible or happen more suddenly or at a faster rate, which makes them easier to observe and associate with the damage that they cause (Dessai et al., 2004; Weber, 2006; Konisky et al., 2016). Sudden onset events such as floods, for example, may be easier for a person to experience than gradually evolving hazards such as sea-level rise because of the dramatic effects they often have on one's immediate environment in a short period of time. As compared to sea-level rise, floods develop and terminate relatively quickly. Moreover, associating an event with the damage it causes arguably also facilitates action because people will better understand the risks from that type of event and what actions they can take to respond effectively. For instance, storm damage is easy to recognize in broken tree limbs, whereas drought damage may be much more subtle in the form of discoloration of vegetation over many weeks. Therefore, we propose that predicting climate change adaptation as a function of experience must account for attributes of the stressor and how those attributes shape whether and how the stressor is experienced.

Here, we explore how different types of climate change stressors with different speed and visibility characteristics influence experience and behavior in forest management. We use social survey data from small woodland owners (individuals and families who own forestland) (Harrison et al., 2002) to model the relationship between exposure to three different types of climate change events (storms, droughts, and tree insect and disease outbreaks), experience of impacts from the events, and use of forest management practices. The three events have different relative characteristics of speed and visibility: droughts are slow and have low visibility, tree pest (insects and diseases) outbreaks are also slow but more visible than droughts, and severe storms are fast and highly visible. We investigated two broad research questions:

1. Does the speed and visibility of an event help explain whether someone experiences it? In other words, are people more likely to experience more rapid and visible events than slower and less visible events?
2. Does experiencing events with different speeds and visibilities increase the chance of responding?

This study makes three main contributions to the literature. First, it contributes to a better understanding of the expected relationship between climate change experience and adaptation to different kinds of events by introducing the construct of observability, which combines an event's general speed and visibility. Second, it contributes to methods for studying this relationship by exploring use of a novel model to consider the effects of multiple types of events and behavioral responses in the same model. Third, it contributes to the scarce literature on the relationship between experience and climate change adaptation in forest management in the U.S., specifically among small woodland owners.

2. Study context: managed temperate forests

We conduct our study in the context of managed temperate forests and small woodland owners in the Upper Midwest, USA. Climate change is threatening temperate forests around the world (Millar and Stephenson, 2015; Seidl et al., 2017), including in the Upper Midwest (Janowiak et al., 2014; Swanston et al., 2018). These threats come from a range of events and conditions, singly and in combination, including wildfires, droughts, severe storms (high winds and precipitation type), insects, and pathogens (Seidl et al., 2017). For instance, droughts and storms can facilitate and exacerbate insect and disease outbreaks (Kolb et al., 2016; Seidl et al., 2017; Pureswaran et al., 2018; Sommerfeld et al., 2018), and warmer and wetter conditions are associated with wind and disease damage (Seidl et al., 2017) and at least some kinds of insect damage (Pureswaran et al., 2018). Forest management can help make forests more adapted to climate change by changing species composition by planting different/diverse tree species (Jactel et al., 2017), planting tree species better adapted to current and future conditions (Kolb et al., 2016), and thinning trees, which can reduce competition for water during droughts (Kolb et al., 2016).

Although many types of individual and family land managers have received attention in the published literature on climate change experience and response (Berrang-Ford et al., 2021; Fischer et al., 2022a) forest owners are a particularly useful group for studying climate change adaptation for two reasons. First, their forest provides them with a larger scale than the average person for observing changes over time as their forest is affected by climate change (Blennow and Persson, 2009; Fischer, 2019b). Second, with forests usually managed on the scale of decades, they have the opportunity to respond to those changes over time and to do so in ways that contribute to climate change adaptation (Fischer, 2019b). In addition, their actions have particular relevance to climate change, as forest management can change forests' ability to store carbon and be resilient to climate change (Millar and Stephenson, 2015; Seidl et al., 2017; Sánchez et al., 2021). Because small woodland owners hold nearly 40% of all US forest acres (Butler et al., 2021), it is important to understand how these owners manage their forests and how they change their forest management due to climate change-related events.

3. Conceptual background

Behavioral adaptation to climate change is "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities" (Mach et al., 2014, p. 118). Several theoretical frameworks explain climate change adaptation at the individual level (Risbey et al., 1999; Grothmann and Patt,

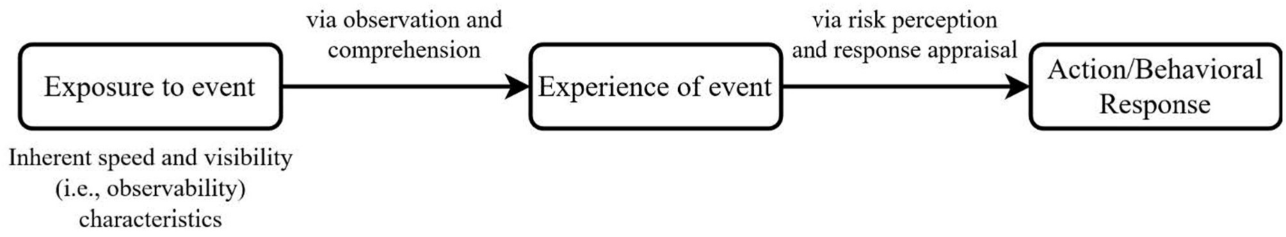

FIGURE 1
Conceptual diagram of theoretically expected relationship between event exposure, event experience, and behavioral response.

2005; Reser and Swim, 2011; Lindell and Perry, 2012; Howe, 2021). These theoretical frameworks share a basic set of elements and relationships: experience influences behavior through an individual's perception of the risk they face from the event (typically considered as the likelihood of the event happening and the impact expected if the event were to happen) and their perception of their ability to act (both through believing an action to be effective in reducing their risk and believing that they can undertake the action) (Ng, 2022). Most of these theoretical frameworks also include additional influences, such as social and structural contexts, and some include feedbacks from behavior to the environmental or social context in which experience takes place (e.g., Lindell and Perry, 2012).

An understudied aspect of behavioral adaptation to climate change is how people may respond to events with different characteristics. Any experience requires an event to have happened; exposure to an event creates the opportunity to experience it but does not ensure experience (i.e., if a person does not notice an event, they have not experienced it) (Byrne, 2016). Risbey et al. (1999) and Lindell and Perry (2012) both include an explicit observational stage in their theoretical frameworks that mediates the relationship between an event exposure and its influence on the individual's risk perception and response appraisal, which in turn mediates the relationship between event experience and taking action (Figure 1). The characteristics of an event, such as its speed and visibility, are important for understanding behavioral responses because they influence how exposure to an event translates to an individual's experience of that event (Reser and Swim, 2011; Lindell and Perry, 2012; Staupe-Delgado, 2019; Howe, 2021). Reser and Swim (2011) and Lindell and Perry (2012) both note that different types of events may provide different types of behavioral cues. However, they do not theorize further on the ways that event characteristics may influence behavioral responses.

Two key attributes of severe events are event speed and visibility (Figure 2). These temporal and physical characteristics make it easier for people to observe and experience an event. By speed, we refer to the rate of an event's onset and termination. A growing body of research on slow-onset disasters emphasizes how the speed of onset and, by extension, termination of an event is an important factor in whether people notice and respond (Staupe-Delgado, 2019; Tosun and Howlett, 2021; Chen and Cong, 2022; Staupe-Delgado and Rubin, 2022). By visibility, we refer to how tangibly the event manifests (e.g., tree insects can be seen with one's eyes, but drought can only be seen indirectly through vegetation responses and rainfall records. The less visible an event is, the more easily it can be ignored and the more uncertainty about what can and should be done about it (Rosa, 1998; Carolan, 2004).

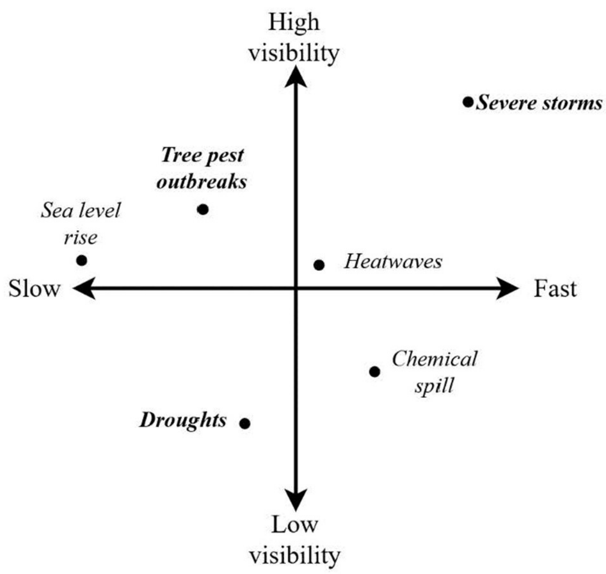

FIGURE 2
Conceptual diagram of event observability. Types of events have been loosely placed relatively to each other for purposes of illustration. The bold events are those considered in the present analysis.

We refer to event observability as the combined effect of the event's speed and visibility. The less observable an event is, the more difficult it is to recognize that it has happened and respond to it. Many events closely related to climate change, like average temperature increase and sea-level rise, happen slowly and incrementally over time (Fiske and Marino, 2020; Yamori and Goltz, 2021) and have low visibility (Carolan, 2004). These types of events are less likely to be observed and responded to than fast, visible events (Fiske and Marino, 2020; Staupe-Delgado and Rubin, 2022). For instance, Howe et al. (2014) found that drought was more difficult for people to perceive and recall than experiences with tornados or hurricanes. Even once someone has noticed that a low visibility event is happening, the chronic and gradual nature of the event can make it less observable such that responding does not seem urgent. For example, a sudden chemical spill may be more alarming than incremental contamination of a waterway by industrial pollution. The conditions associated with a low observability event can become part of the normal background context thus further reducing the likelihood of taking action before the event reaches critical levels (Fiske and Marino, 2020; Staupe-Delgado and Rubin, 2022).

In our study context, droughts are the least observable of the three events, followed by insect and disease outbreaks and severe storms. We consider droughts to be the least observable because, in addition to being slow, droughts have the lowest visibility since they are defined by a cumulative lack of rain over a period of time, and the impact that the reduced moisture has on trees is difficult to discern in the longer term (Howe et al., 2014; Deuffic et al., 2020). Thus, the relationship between drought exposure and drought experience will be small. Severe storms are the fastest and most observable of the three events, being both fast and visible, so we expect that there will be a large relationship between exposure and experience. However, they are also the most "normal," which may diminish the relationship. Insect and disease outbreaks are relatively visible but also relatively slow as levels of insects or diseases increase beyond normal background levels or novel ones arrive (Tobin et al., 2014). Thus, we expect the relationship between exposure and experience for insect and disease outbreaks will fall somewhere between those of droughts and storms. However, we are still determining which characteristic, speed or visibility, will be more important.

4. Data and methods

4.1. Study area

Our study area is the Laurentian Mixed Forest ecological province (Cleland et al., 2007) of the Upper Midwest, a mixed-forest ecosystem in the northern portions of Minnesota, Wisconsin, and Michigan. Climate change is expected to worsen heatwaves, droughts, storms, and insect and disease outbreaks over the next century in this area (Handler et al., 2014a,b; Janowiak et al., 2014; Duveneck and Scheller, 2016; Swanston et al., 2018). Small woodland owners control about 55% of the forestland in the north-central region of the US (an area that includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin), and typically have forests of <100 acres (Butler et al., 2021). Their reasons for owning their forested property range from the enjoyment of scenery to timber production (Butler et al., 2021).

4.2. Survey and sample

Our sample consists of small woodland owners in nine counties that have experienced greater than average damage from severe events related to climate change. The counties were selected based on their combined above-average area that had sustained forest damage from tree pests, storms, fire, and drought, and the number of heat wave days, winter ice days, and heavy precipitation days (based on z-scores). We obtained these data from the US Forest Service Insect and Disease Detection Survey (US Forest Service, 2018), the Monitoring Trends in Burn Severity database of wildfires (MTBS, 2018), and the US Climate Resilience Toolkit Climate Explorer (US Federal Government, 2015). We then selected the three counties in each state that had the highest levels of exposure to severe events and extensive areas of family-owned forestland for which we could get tax lot-level ownership information (Figure 3). To select the sample, we used GIS software to randomly cast points onto parcel maps of the nine counties to generate a list of properties. We then obtained the parcel owners' names and addresses according to public tax lot records from Digital Map Products. We removed from the list any owners who appeared to be corporate, public, or institutional.

In the winter and spring 2019, we mailed 4,472 surveys to the samples of owners in the nine counties randomly drawn from the list generated proportionately to the estimated number of family forest owners in the county. The survey administration followed the Tailored Design Method (Dillman et al., 2014), beginning with an announcement card, followed a week later by the survey, and a thank you/reminder card 2 weeks later. We sent a second survey to those who did not respond to the first survey. The survey consisted of 31 questions over eight pages. Previous qualitative focus groups in the Northwoods region guided the topics and framing of the survey (Fischer, 2019a; Fischer et al., 2022b). Of the surveys sent, 1,255 were valid responses (owned a parcel of at least 10 forested aces and answered 50% or more of the survey questions), while 467 were ineligible (land not forested, could not reach the owner), yielding an effective overall response rate of 31%.[1] Using case-wise deletion of missing values, we use 943 cases in our analysis.

4.3. Study variables

The exposure measures indicate the portion of a circular, 206-acre area centered on each property damaged by each type of event at least once in the past 19 years (see Appendix). The experience measures for insect and disease outbreaks, droughts, and severe storms reflect owner-observed forest damage of one or more kinds in the past 20 years that they attribute to the different types of events (Table 1). The exposure measures were constructed from aerial tree damage detection data collected by the US Forest Service (2018). The control variables include three measures of property use (as a primary residence, the importance of scenery, and the importance of wood products), two measures of how active a forest manager the owner is, the owner's education level and age, the number of information sources they used in the last 5 years, and their willingness to take risks in forest management (Table 1).

Our outcome measures are binary variables indicating whether the owners used each of eight forest management practices in the last 5 years out of concern about severe events. These practices include relatively low-effort practices such as having *monitored* one's forest for signs of damage and having *avoided* working in

1 This rate is equivalent to Response Rate 2 as defined by the American Association for Public Opinion Research (https://www.aapor.org/AAPOR_Main/media/publications/Standard-Definitions20169theditionfinal.pdf). The county-level response rates ranged from 14% (Missaukee County, MI) to 41% (Cook County, MN).

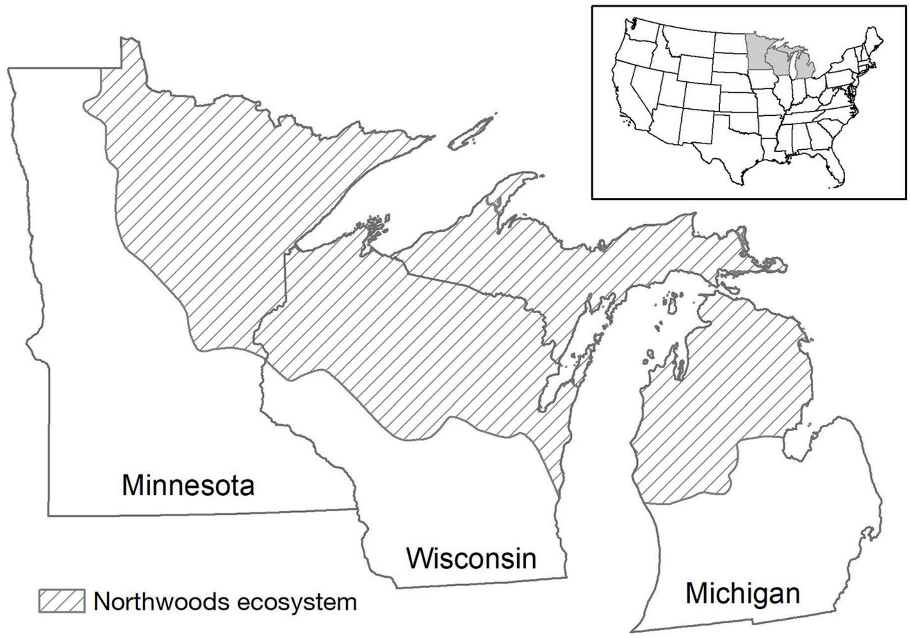

FIGURE 3
Study area.

one's forest in unfavorable conditions to avoid damaging soil and tree roots and spreading tree insects and diseases. The practices also include more labor and equipment intensive practices such as having *harvested damaged* trees, *harvesting vulnerable* trees, *thinning to protect* trees from future damage, and *thinning for* [forest] *health*, as well as having *planted for a diversity* of tree species, and *planted for the robustness* of tree species (Table 1). All the practices may be plausibly used with the three types of events we consider. While we do not have particular hypotheses relating to using specific practices over others, we consider them separately because different practices may be used to address different conditions (i.e., exposure and experience).

We designed our statistical model of the relationship between climate change event experience and forest management practice use to be consistent with the conceptual expectations from the literature and our research questions and to accommodate our specific measures (Figure 4). We thus use event exposure as a predictor of event experience, which in turn is a predictor of practice use. However, because our experience measure requires that owners observe damage to their forest and attribute the damage to a specific type of event, we include a direct effect between exposure and practice use that will capture the effects of any experience that falls outside of our specific experience measure. In effect, we test if the effect of event exposure on forest owner practice use is mediated by having experienced forest damage from the specific type of event.

We expect that for storms and outbreaks (the more observable events), experience mediates the effect of exposure on practice use. However, for drought, which is much less observable, we might find some direct effect of exposure on practice use, even if that exposure does not translate to self-reported drought experience. Because we are interested in the relationship between event exposure, event experience, and the use of forest management practices, we do not include other conceptually relevant, mediating socio-cognitive measures (such as risk appraisal and response appraisal); the total effect of experience on practice use is not affected by the absence of a conceptual mediator as long as that mediator is not included elsewhere in the model (MacKinnon et al., 2007) and creates an endogeneity problem.

We include multiple forest management practices in our model rather than a single binary variable indicating whether they had undertaken any management practices because not all practices are appropriate responses to all events and because practices are also used with different frequencies (e.g., people thin forests more frequently than harvest) making some easier to capture in survey data than others. Given these multiple outcomes, our model is in the form of a seemingly unrelated regression (SUR) model with parallel mediation. SUR models are a special type of non-recursive structural equation model composed of multiple equations that are related to each other only through correlations between their error terms (Paxton et al., 2011). Our particular model contains two sets of error correlations, one set between the eight practice variables and one set between the three mediating experience variables, since experiencing one type of event does not preclude experiencing the other types of events.

We used a step-wise model-building process to include a minimum set of control variables[2] related to owner and property

2 Control variables that were considered and ultimately not included in the final model due to lack of significance and failure to significantly improve the variance explained by the model were: length of property ownership, property size, gender (female compared to male respondents), and belief that climate change is happening.

TABLE 1 Study variables.

Variable name	Variable description	Measurement scale
Exposure		
Drought exposure	Portion of property and immediate area that has had tree damage due to drought since 2000 (see Appendix)	0.0-1.0
Outbreak exposure	Portion of property and immediate area that has had tree damage due to insects and diseases since 2000 (see Appendix)	0.0-1.0
Storm exposure	Portion of property and immediate area that has had tree damage due to severe storms since 2000 (see Appendix)	0.0-1.0
Experience		
Drought experience	Owner experienced dead trees, sick trees, damaged trees, loss of tree species and/or other damage due to drought at least once in the past 20 years	0 = no, 1 = yes
Outbreak experience	Owner experienced dead trees, sick trees, damaged trees, loss of tree species and/or other damage due to insect and disease outbreaks at least once in the past 20 years	0 = no, 1 = yes
Storm experience	Owner experienced dead trees, sick trees, damaged trees, loss of tree species and/or other damage due to severe storms at least once in the past 20 years	0 = no, 1 = yes
Forest management practices		
Monitored	Owner “monitored [their] woods for signs of damage from insects and diseases, drought, and other events” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Avoided	Owner “avoided working in [their] woods in warm or wet conditions to prevent soil damage or spread of insects and diseases” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Harvested damaged	Owner “harvested trees that have already been damaged” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Harvested vulnerable	Owner “harvested trees that may be damaged in the future” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Thinned for health	Owner “thinned stands to increase health and productivity” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Thinned to protect	Owner “thinned trees to protect them from future events” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Planted for robustness	Owner “planted trees that might withstand insect and disease outbreaks, storms, droughts, and other events” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Planted for diversity	Owner “planted trees to diversify stands” in the past 5 years out of concern about severe events	0 = no, 1 = yes
Controls		
Primary residence	Owner reported that their primary residence is on the parcel	0 = no, 1 = yes
Product importance	Importance of wood products as a reason to own woodland	1 = not important to 4 = very important
Scenery importance	Importance of enjoying scenery as a reason to own woodland	1 = not important to 4 = very important
Regular manager	Owner reports that they “manage regularly (according to a plan)” (compared to those who report managing their woodland when they “happen to think about the property,” “if something obviously needs to be done,” or “periodically (not scheduled)”)	0 = no, 1 = yes
Non-manager	Owner reports that they “don’t manage the woods on [their] parcel” (compared to those who report managing their woodland when they “happen to think about the property,” “if something obviously needs to be done,” or “periodically (not scheduled)”)	0 = no, 1 = yes
Education	Owner has a bachelors, graduate or professional degree (compared to those with “some college” or less)	0 = no, 1 = yes
Age	Owners who are 75 or older (the oldest ∼25% of owners)	0 = no, 1 = yes
Information sources	The number of information sources owner interacted with over the past 5 years about the potential for damages from severe events to their woodland and management options. Includes extension, public agencies, non-profits, forestry consultants, family, and friends and neighbors.	0-6
Risk taker	Owners who indicated that they were somewhat or very willing to “take risks” when managing their woodland	0 = no, 1 = yes
Mackinac	Property is located in Mackinac County, MI (compared to St. Louis County, MN)	0 = no, 1 = yes
Missaukee	Property is located in Missaukee County, MI (compared to St. Louis County, MN)	0 = no, 1 = yes
Oceana	Property is located in Oceana County, MI (compared to St. Louis County, MN)	0 = no, 1 = yes
Cook	Property is located in Cook County, MM (compared to St. Louis County, MN)	0 = no, 1 = yes
Pine	Property is located in Pine County, MN (compared to St. Louis County, MN)	0 = no, 1 = yes
Burnett	Property is located in Burnett County, WI (compared to St. Louis County, MN)	0 = no, 1 = yes
Douglas	Property is located in Douglas County, WI (compared to St. Louis County, MN)	0 = no, 1 = yes
Iron	Property is located in Iron County, WI (compared to St. Louis County, MN)	0 = no, 1 = yes

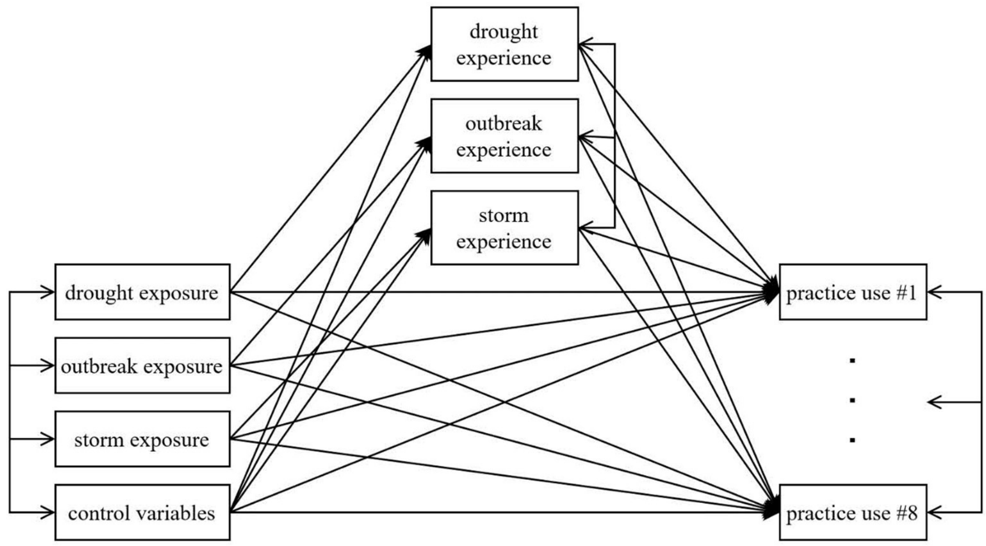

FIGURE 4
Simplified diagram of SUR model. Note the correlations between the error terms of the endogenous measures represented by the double-ended squared arrows.

characteristics that influence both experiencing severe events (some owners may be more observant than others) and the use of forest management practices (some owners are more active managers than others). We also included county dummy variables to control for uneven exposure to events and other unmeasured factors that may vary across counties (Table 1). Non-significant effects from control variables on experience and practice use measures were dropped from the final model, with no significant reduction in explained variance. We estimated our model with the lavaan (0.6–6) package in R. Due to the use of binary measures of experience and practice use, we used a diagonally weighted least squares (DWLS) estimator, specifically the weighted least squares means and variance adjusted (WLSMV) estimator, with a probit link (Li, 2016). The coefficients estimated by this method are probits. Due to the use of independent variables on different scales, we report the standardized effects of the probit coefficients. This is based on the latent response formulation of probit coefficients, which uses as the model outcome a latent continuous variable that is paired with the observed binary variable (Muthén et al., 2016). We remind readers that probability functions are not linear, so while the linear estimates presented for this analysis are related to the estimated likelihood of practice use in terms of effect direction, they do not correspond to the magnitude of the effect on probability. This means that the sizes of effects can be meaningfully compared within each practice model, but comparisons of effects across practice models should be made cautiously, recognizing that these comparisons are only of the linear effects.

5. Results

5.1. Descriptives

In our analysis sample, *outbreak exposure* was by far the most common type of exposure with 60% of the average property vicinity having been impacted by outbreaks, in contrast to 7% for droughts and 3% for storms (Table 2). *Storm experience* was the most common experience type, with 68% of respondents reporting that they had experienced storm damage to their woodland, while 48% reported experiencing outbreaks, and 13% droughts (Table 2). For comparison, only 6% of property vicinities had been exposed to severe storms at all, while for outbreaks 67% had been exposed, and for drought 9% had been exposed. Among the forest management practices, *monitored*, *avoided*, and *harvested damaged* were the most frequently reported practices (used by 50–70% of the respondents) (Table 2). *Harvested vulnerable*, *thinned for health*, *thinned to protect*, and *planted for diversity* were used less often (by 37–47% of our sample), while *planted for robustness* was the least frequently reported practice, used by just 20% of the sample (Table 2).

Our control variables provide a general sense of the characteristics of our sample. Nearly 30% lived on the property in question, and on average they rated scenery as being a more important reason for owning their property than producing wood products. Fifteen percent characterized themselves as regular forest managers, while 13% reported that they do not manage their forest (leaving 72% as "sporadic" managers) (Table 3). Forty-seven percent have at least a college degree, and 15% are 75 years old or older. The average owner consulted with two information sources about their forest management, and about a third characterized themselves as a risk taker when it came to their forest management.

5.2. Model results

Our final mediated SUR model of the use of forest management practices has very good model fit (Figure 5). The robust Chi-square is not significant, the Comparative Fit Index (CFI) and

TABLE 2 Study descriptive statistics ($n = 943$)*.

	Mean	Std Dev
Exposure		
Drought exposure	0.07	0.25
Outbreak exposure	0.60	0.47
Storm exposure	0.03	0.16
Experience		
Drought experience	0.13	0.34
Outbreak experience	0.48	0.50
Storm experience	0.68	0.47
Forest management practices		
Monitored	0.50	0.50
Avoided	0.64	0.48
Harvested damaged	0.69	0.46
Harvested vulnerable	0.41	0.49
Thinned for health	0.47	0.50
Thinned to protect	0.40	0.49
Planted for robustness	0.20	0.40
Planted for diversity	0.37	0.48
Controls		
Primary residence	0.29	0.45
Product importance	2.34	0.97
Scenery importance	3.48	0.73
Regular manager	0.15	0.36
Non-manager	0.13	0.34
Education	0.47	0.50
Age	0.15	0.36
Information sources	1.99	1.39
Risk taker	0.34	0.48
Mackinac	0.17	0.37
Missaukee	0.04	0.20
Oceana	0.09	0.28
Cook	0.03	0.16
Pine	0.08	0.27
Burnett	0.08	0.28
Douglas	0.17	0.38
Iron	0.10	0.29

*Minimum and maximum values are the same as the measurement scales provided in Table 1.

TABLE 3 Results of experience portion of model.

	Experience		
	Drought	Outbreak	Storm
Exposure			
Drought exposure	−0.10 (0.43)		
Outbreak exposure		**0.19 (0.16)****	
Storm exposure			0.05 (0.36)
Controls			
Primary residence	**0.15 (0.12)****	**0.10 (0.10)***	
Product importance		**0.13 (0.05)****	
Scenery importance	**0.14 (0.08)***	**0.12 (0.07)****	**0.18 (0.07)*****
Regular manager			
Non-manager			
Education			
Age	**−0.13 (0.18)***	**−0.07 (0.13)**†	
Information sources	**0.15 (0.04)***	**0.13 (0.03)****	**0.21 (0.04)*****
Risk taker		**0.10 (0.10)***	
Mackinac		**0.26 (0.15)*****	**−0.18 (0.15)*****
Missaukee		**0.17 (0.27)*****	−0.02 (0.29)
Oceana		**0.22 (0.22)*****	−0.01 (0.23)
Cook		−0.04 (0.27)	0.01 (0.31)
Pine		−0.02 (0.23)	**−0.11 (0.23)***
Burnett		0.03 (0.25)	0.02 (0.25)
Douglas		0.02 (0.13)	**−0.08 (0.14)**†
Iron		**−0.17 (0.29)***	**−0.14 (0.29)**†

†$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Standardized coefficients (and standard errors) ($n = 943$). Significant variables are in bold.

Tucker-Lewis Index (TLI) are both >0.95 and the RMSEA is <0.06 (West et al., 2012). All error correlations between the experience measures and between the practice use measures are significant with $p < 0.1$, which supports our use of a SUR model (results not shown).

5.2.1. Predictors of experience

Consistent with our expectation that exposure to slow and low visibility events is less likely to result in recognized damage from that type of event, *drought experience* is not significantly predicted by *drought exposure*, though it is significantly predicted by *primary residence*, *scenery importance*, *age*, and *info sources* (Table 3). *Outbreak exposure* is a significant predictor of *outbreak experience* (0.19) (Figure 5), which is consistent with our expectation given its greater visibility than drought, as is *primary residence*, *product importance*, *scenery importance*, *age*, *info sources*, and *risk taker*, along with the *county* where the property is located (Table 3). In contrast to our expectations, *storm experience* is not significantly predicted by *storm exposure*, though it is significantly predicted by *scenery importance*, *info sources*, and *county* (Table 3). The influence of *scenery importance*, while not of theoretical interest, is notable. We speculate that people who place greater importance on the scenery of their forest property may pay greater attention to its appearance and therefore any changes caused by storms, insects and diseases, and droughts than owners who do not rate scenery as being so important.

TABLE 4 Total effects of exposure, experience and controls on practice use.

	Monitored	Avoided	Harvested damaged	Harvested vulnerable
Exposure				
Drought exposure	0.07 (0.33)	0.04 (0.31)	0.06 (0.39)	0.05 (0.29)
Outbreak exposure	**0.17 (0.18)***	0.06 (0.16)	0.10 (0.16)	**0.14 (0.16)***
Storm exposure	0.05 (0.30)	−0.03 (0.29)	0.05 (0.40)	0.02 (0.29)
Experience				
Drought experience	**0.15 (0.09)***	0.10 (0.08)	0.06 (0.09)	−0.08 (0.08)
Outbreak experience	**0.29 (0.06)*****	**0.14 (0.06)***	**0.15 (0.06)***	**0.20 (0.06)****
Storm experience	−0.01 (0.09)	0.03 (0.08)	**0.21 (0.08)****	0.07 (0.08)
Controls				
Primary residence	**0.05 (0.05)****	**0.03 (0.04)†**	**0.18 (0.11)*****	**0.12 (0.10)****
Product importance	**0.14 (0.05)****	**0.15 (0.05)*****	**0.14 (0.05)****	**0.20 (0.05)*****
Scenery importance	**0.05 (0.03)****	**0.04 (0.02)****	**0.13 (0.06)****	**0.03 (0.02)†**
Regular manager	0.07 (0.15)	**0.11 (0.13)****	−0.04 (0.14)	0.05 (0.12)
Non-manager	**−0.28 (0.15)*****	**−0.15 (0.14)****	**−0.18 (0.13)*****	**−0.13 (0.16)****
Education		**−0.11 (0.09)****		**−0.08 (0.09)***
Age	**−0.04 (0.06)***	**−0.02 (0.04)†**	−0.02 (0.04)	0.00 (0.04)
Information sources	**0.24 (0.03)*****	**0.17 (0.03)*****	**0.21 (0.03)*****	**0.15 (0.03)*****
Risk taker	**0.03 (0.03)***	**0.02 (0.02)†**	**0.02 (0.02)†**	**0.02 (0.02)†**
Mackinac	**0.15 (0.16)****	**−0.10 (0.14)***	0.07 (0.15)	0.04 (0.08)
Missaukee	**0.15 (0.29)****	0.01 (0.25)	**0.12 (0.31)***	**0.03 (0.09)***
Oceana	**0.16 (0.26)***	−0.07 (0.22)	0.08 (0.23)	**0.04 (0.08)***
Cook	0.05 (0.32)	0.05 (0.32)	0.05 (0.32)	−0.01 (0.06)
Pine	0.08 (0.24)	0.05 (0.22)	0.01 (0.23)	−0.01 (0.06)
Burnett	**0.15 (0.25)****	0.07 (0.23)	**0.11 (0.25)†**	0.01 (0.05)
Douglas	**0.10 (0.15)***	0.07 (0.13)	−0.02 (0.14)	0.00 (0.04)
Iron	−0.06 (0.29)	−0.03 (0.27)	0.02 (0.33)	**−0.04 (0.08)***
	Thinned forhealth	**Thinned to protect**	**Planted for robustness**	**Planted for diversity**
Exposure				
Drought exposure	0.02 (0.31)	−0.02 (0.35)	0.15 (0.56)	0.02 (0.31)
Outbreak exposure	−0.05 (0.16)	**−0.14 (0.16)***	−0.04 (0.18)	0.04 (0.16)
Storm exposure	−0.03 (0.30)	0.02 (0.31)	**0.11 (0.30)****	**0.07 (0.28)†**
Experience				
Drought experience	**0.17 (0.09)***	0.13 (0.08)	0.01 (0.09)	0.06 (0.08)
Outbreak experience	0.01 (0.07)	0.04 (0.06)	0.08 (0.07)	0.03 (0.06)
Storm experience	−0.10 (0.09)	0.04 (0.08)	0.03 (0.09)	0.08 (0.08)
Controls				
Primary residence	**0.03 (0.04)†**	**0.02 (0.03)†**	0.01 (0.03)	**0.10 (0.10)***
Product importance	**0.21 (0.05)*****	**0.13 (0.05)****	0.01 (0.01)	0.00 (0.01)
Scenery importance	**0.09 (0.07)***	**0.03 (0.02)***	**0.15 (0.08)****	**0.15 (0.07)****
Regular manager	**0.15 (0.13)*****	**0.07 (0.13)†**	**0.16 (0.13)*****	**0.09 (0.13)***
Non-manager	**−0.24 (0.17)*****	**−0.21 (0.17)*****	**−0.12 (0.21)†**	**−0.20 (0.17)*****

(Continued)

TABLE 4 (Continued)

	Thinned forhealth	Thinned to protect	Planted for robustness	Planted for diversity
Education		**−0.09 (0.09)***		
Age	−0.02 (0.05)	**0.08 (0.13)***	**0.12 (0.14)****	−0.01 (0.04)
Information sources	**0.17 (0.03)*****	**0.23 (0.04)*****	**0.20 (0.04)*****	**0.13 (0.03)****
Risk taker	0.01 (0.07)	0.00 (0.02)	0.01 (0.02)	**0.11 (0.09)****
Mackinac	**0.09 (0.15)†**	0.06 (0.15)	**−0.12 (0.17)***	**−0.13 (0.15)***
Missaukee	0.03 (0.27)	0.03 (0.28)	0.04 (0.29)	0.01 (0.27)
Oceana	**0.11 (0.24)***	−0.01 (0.23)	−0.08 (0.24)	−0.02 (0.22)
Cook	0.02 (0.31)	0.04 (0.30)	0.02 (0.33)	−0.05 (0.30)
Pine	0.01 (0.22)	**−0.11 (0.23)***	−0.05 (0.26)	−0.02 (0.23)
Burnett	0.01 (0.25)	**−0.10 (0.25)†**	**−0.11 (0.26)†**	−0.07 (0.23)
Douglas	0.02 (0.14)	−0.04 (0.14)	−0.08 (0.16)	**−0.10 (0.14)***
Iron	0.06 (0.27)	0.03 (0.31)	−0.22 (0.54)	−0.08 (0.28)

$^{\dagger}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Standardized probit coefficients (and standard errors) $n = 943$. The bold values indicate the significant variables.

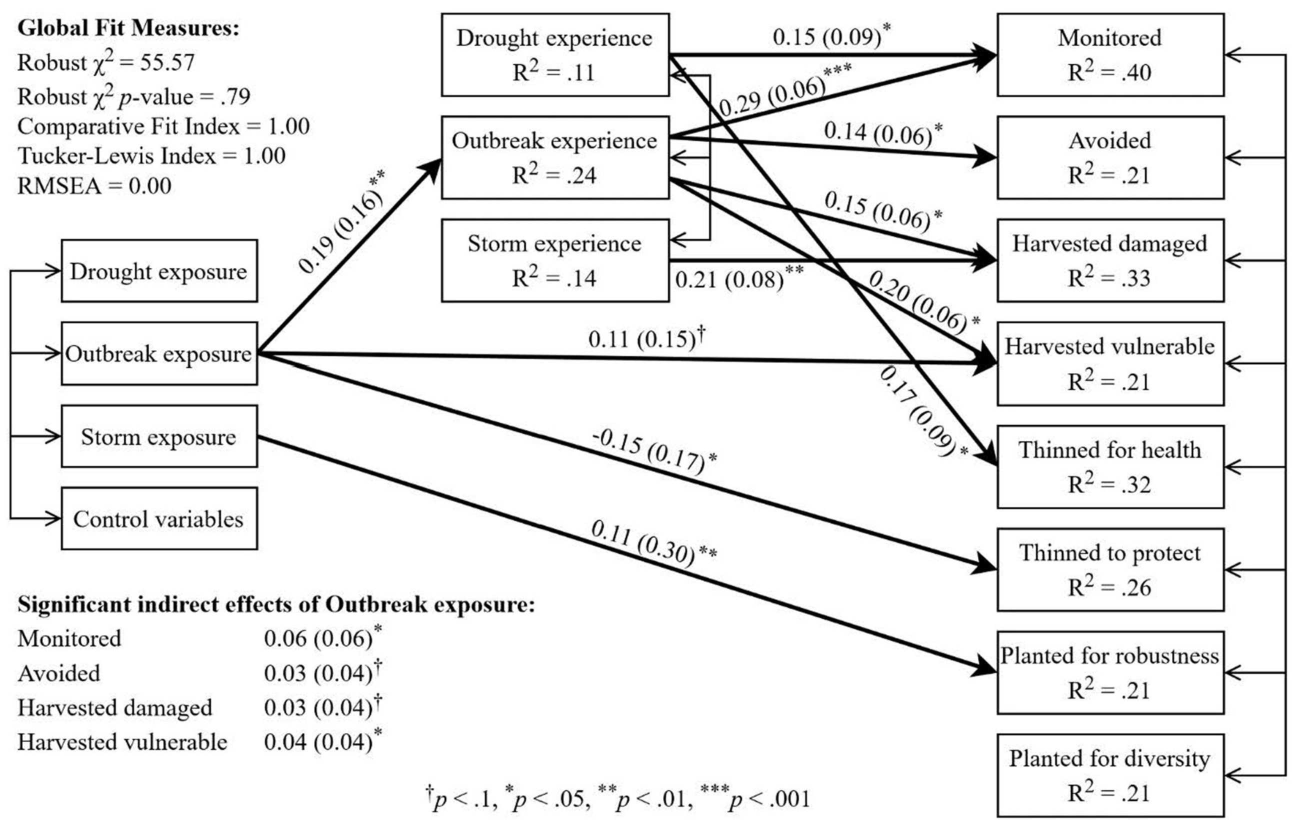

FIGURE 5
Showing only significant direct and indirect effects of exposure and experience measures on practice use; significant effects of control measures not shown—see Tables 3, 4.

5.2.2. Predictors of use of forest management practice

We find that experience of all three types of events is a significant predictor of one or more of the forest management practices, while *outbreak exposure* and *storm exposure* have significant direct effects on the use of three of the practices (Figure 5; Table 4). *Drought experience* has a significant positive effect on both *monitored* (0.15) and *thinned for health* (0.17). *Outbreak experience* has positive effects on *monitored* (0.29), *avoided* (0.14), *harvested damaged* (0.15) and *harvested vulnerable* (0.20) (Table 4). *Storm experience* has a significant effect on *harvested damaged* (0.21) (Table 4).

We also find significant direct effects between *outbreak exposure* and *storm exposure* and the use of three of the practices, which indicates that other types of experience than what we specifically measure in this study are important to the use of these practices. The direct effect of *outbreak exposure* on *thinned to protect* is negative and statistically significant (−0.15), with no significant relationship between *thinned to protect* and either of the three *experience* measures. The direct effect of *outbreak exposure* on *harvested vulnerable* is positive and statistically significant (0.11), though in this case *outbreak experience* also has a significant effect on *harvested vulnerable* as mentioned above. *Storm exposure* has a significant direct effect on *planted for robustness* (0.11). *Drought exposure* has no significant direct effects on the use of any of the practices.

The total effects of the exposure measures on practice use are the sum of the direct and indirect effects (via experience) between exposure and practice use. They indicate the effect of exposure on practice use via the specific form of experience we measure (the indirect effect) and forms of experience that we do not measure (captured in the direct effects). *Outbreak exposure* has a positive significant total effect on *monitored* (0.17) and *harvested vulnerable* (0.14), and a negative significant effect on *thinned to protect* (−0.14) (Table 4). *Storm exposure* has a significant total effect on *planted for robustness* (0.11) and *planted for diversity* (0.07) (Table 4), even though the direct effect between *storm exposure* and *planted for diversity* is not statistically significant. *Drought exposure* has no significant total effects on using any of the practices.

Among the total effects of the control variables (Table 4), *primary residence* is a significant, positive predictor of all the practices except for *planted for robust*, while *product importance* is a significant, positive predictor of all the practices except for *planted for robustness* and *planted for diversity*. *Scenery importance* is a significant, positive predictor of all the practices. *Regular managers*, as compared with sporadic managers, were more likely to have *avoided*, *thinned for health*, *thinned to protect*, *planted for robustness* and *planted for diversity*, while *non-managers* were less likely to have used all/any the practices compared to sporadic managers. *Education* had a negative relationship with the use of *avoided*, *harvested vulnerable* and *thinned to protect*. *Age* had a negative effect on *monitored*, *avoided*, *thinned to protect* and *planted for robustness*. The use of more *information sources* is a significant, positive predictor of all the practices. Owners who reported being a *risk taker* in forest management were more likely to have *monitored*, *avoided*, *harvested damaged*, *harvested vulnerable*, and *planted for diversity*. There were some significant differences in practice use among counties. Direct effects of county were included for all practices except *harvested vulnerable*, for which no significant differences were found so county was excluded from the final model.

6. Discussion

We examined how exposure to and experience of three types of events with different speed and visibility characteristics were related to the use of eight forest management practices by small woodland owners. We expected that slower and less visible (i.e., less observable) events would be less likely to be experienced than faster and more visible events. We found some evidence that slower and less visible events were less experienced. However, the relationship between event experience and exposure to fast and visible events was potentially complicated by the "normalness" of severe storms. We also found that having some form of event experience is related to the chance of practice use. However, experiencing damage attributed to specific types of events was not important in all cases. Furthermore, we found that the effect of event "experience" is not always positive, as demonstrated by the negative relationship we found between *outbreak exposure* and *thinned to protect*.

The relationships between exposure and experience of droughts and outbreaks are consistent with our expectations. Droughts, with their slow speed and low visibility, are not significantly associated with experiencing drought damage that is recognized as such, while for outbreaks, with their slow speed but high visibility, we find a significant relationship between exposure and experience. The lack of significant relationships between exposure and experience for storms, the fast and visible event type, does not meet our expectations, which may be at least partly due to the nature of our exposure and experience measures, as we will discuss below; the relative "normalness" of severe storms in the study area; and individual variation in what is considered "severe." Fast events that happen repeatedly can become perceived as "normal," decreasing the likelihood of taking adaptive or risk-reducing actions (Guiteras et al., 2015; Moore et al., 2019). For example, Moore et al. (2019) find that as local temperature anomalies happen more frequently, they are less remarked on, making it less likely that these temperature anomalies will spur action or behavior change.

Particularly for storms, the lack of significant relationship between our exposure and experience measures may be due to the large differences in how frequently they are measured by each source, with 68% of owners having reported experiencing storm damage, while only 6% of properties were reported as having been exposed to storm damage. This small portion of exposed properties weakens the precision of the statistical relationship. We expect that the discrepancy between the rates of storm exposure and experience is the result of the differences in perspective between property owners on the ground and aerial surveyors, particularly in the types of damage that can be observed. For example, broken limbs from a storm might be apparent to an owner on the ground but would not be so readily observed from the air. In contrast, the severity and extent of leaf discoloration and loss from an insect or disease outbreak would be more easily observed from the air than from the ground, which is also reflected in our data, with 48% of owners reporting outbreak damage and 67% being exposed.

These findings about the relationship between the observability of events and people's experiences of them contribute to several theories of risk perception as it relates to climate change adaptation. One theory emphasizes the affective dimensions of adaptation, i.e., that people form perceptions of risk less based on logic and analysis of information, and more through association and emotional response (Loewenstein et al., 2001; Leiserowitz, 2006). Our findings suggest that event speed and visibility may be particularly important to affect. Another theory calls attention to the normalization of climate risk, whereby psychological and social coping strategies attenuate people's perceptions of risk the longer or more frequently they are exposed (Luís et al., 2016; Moore et al., 2019). Our findings suggest that speed and visibility may be important to whether a climate change-related event is likely to become normalized. Speed and visibility may, therefore, be useful in the design of future empirical studies of affective dimensions of experience and the development of psychometric models and conceptual models for further investigating environmental cues that may trigger risk perception or normalization via affect.

We find that experiencing climate change-related events is associated with using forest management practices among owners in our sample. However, our findings also highlight the importance of how experience is measured and the possible varieties of experience types. In our model, the three experience measures were only significant predictors of five of the eight practices that we considered, while outbreak and storm exposure had significant direct effects on three of the practices. These significant direct effects of exposure on practice use, only one of which overlaps with significant effects from experience (*harvested vulnerable* and outbreaks), indicate that other kinds of experience matter beyond our specific measure of experience. We can only speculate on what these other types of experience may be. However, some possibilities are that owners observed damage to their forest but were unable to attribute it to a particular type of event, that owners did not observe the damage to their forest but were aware of the event in their area and responded preemptively or forgot some of the damaging events they have experienced but remember the actions they have taken.

One particularly interesting finding is that of the negative relationship between *outbreak exposure* and *thinned to protect*. This effect is in the opposite direction than we expected and may reflect a perception that *thinning to protect* trees once an outbreak has occurred is ineffective, or that tree removal for protection due to outbreaks may be viewed as *harvesting vulnerable* trees instead, which has a positive association with *outbreak exposure*. Negative effects between experience and action are not well theorized, but previous research has found that the type of experience can influence behavior both positively and negatively. For instance, an indirect experience can serve as a "wake-up call" to the potential for negative impacts from an event that can spur action, and a direct experience can create a "let-down" that makes adaptation actions seem unnecessary (at least in the near-term) (Arvai et al., 2006; McGee et al., 2009; Dillon et al., 2014; Demuth et al., 2016).

Our findings are also consistent with those of previous studies that have found that small woodland owners observe disturbances to their forests or changing conditions in their area (Bissonnette et al., 2017; Vulturius et al., 2018; Fischer et al., 2022b), and research that indicates that at least some small woodland owners are changing their forest management practices in response (Eriksson, 2014; Bissonnette et al., 2017; Fischer, 2019a,b).

Our study also extends other research on the relationship between experiences of climate change-driven events and adaptation behavior among small woodland owners. In one of the few other studies of woodland owners, Thomas et al. (2022) found that more winter rain and less frost have negative effects on the likelihood of respondents using any forest adaptation strategies, athough when they consider the strategies as separate outcomes, only less frost is a significant and negative predictor of early harvest decisions. We find a greater number of associations between climate change-driven events and adaptation behaviors. Some studies have collected data on small woodland owners' experiences with various events and their use of different management practices, but have focused their analysis on differences between owner characteristics, between regions, and over time (e.g., Blennow, 2012). We focus on the relationship between event characteristics and behavior. Several studies have considered multiple severe events and adaptation activities (Blennow, 2012; Thomas et al., 2022), but we are unaware of any studies that have considered using multiple forest management practices in the same model simultaneously.

Other studies have investigated the relationship between experiences of climate change-driven events and adaptation behavior among small woodland owners by directly asking if forest owners have changed their practices because of climate change (Blennow and Sallnäs, 2002; Blennow et al., 2012; Sousa-Silva et al., 2016, 2018).[3] We avoid a potential bias in our sample created by the politicized nature of climate change, i.e., that people's political orientation may compel them to deny climate change even as they experience climate change-driven events and take actions to make their forests more resilient to the impacts of those events.

A unique feature of our study is our use of a model that accounts for exposure to and experience of multiple events, as well as the use of multiple practices. However, some limits to our study are that we use exposure and experience measures taken from such different vantage points (e.g., ground-level observations by landowners and overhead observations by researchers) that we potentially have measurement artifacts in our analysis. However, the exposure data we use is the only existing data that we are aware of that provides an external measure of forest damage relevant to our survey questions.

Future climate change adaptation behavior should carefully consider the expected relationship between severe event experiences and specific responses. Improper or insufficient combinations of events and practices could easily result in findings of non-significant effects and false conclusions about the relationship between "climate change and practice use" or over-ascribe the effects of one event on the use of a practice when the main effect is from an omitted, related event. For instance, our results differ when we only included a single event in the model at a time. We also encourage future researchers to consider the value of examining different measures of event "experience" to try to tease out more of the potential we found for important effects from experiences outside of observed damage that is ascribed to a specific event that may have important influences on behavior.

3 This relates to our question on the effects of severe event experience on climate change adaptation. Still, our approach does not require that the respondent attribute the event to climate change. Reser and Bradley (2020) may disagree with our use of severe events that may be related to climate change as a proxy for climate change experience in our consideration of climate change adaptation, but Hornsey et al. (2016) warned of, and (Denny et al., 2022) supports, a reciprocal relationship between experiences of climate change-related events and climate change belief, which complicates/confounds the relationship in question. Thus we feel that it is better to study experiences with severe events without a stated attribution to climate change.

7. Conclusion

We sought to better understand how climate change-related events with different levels of speed and visibility are associated with reported experiences of those events and with forest management responses that constitute climate change adaptation. Conceptually, our study contributes to the development of a more rigorous treatment of experience as a construct that acknowledges that people may be exposed to a climate change-related event without recognizing they have been exposed. In other words, people may be exposed to an event without "experiencing" it. We also offer a new construct—observability—that influences experience. An event's observability is a function of its speed of onset or termination and visibility; that is, how easy it is to see the process or effects. Methodologically, we used a novel approach to consider the effects of multiple events and practices in the same model. We found that events with greater speeds and visibilities were associated with people's self-reported experiences of these events and decisions to undertake various practices out of concern about them, although there are exceptions. For example, we found that exposure to severe events does not always result in damage that is observed by forest owners and that different kinds of experiences provide different kinds of cues, which for the most part, are associated with the use of different forest management practices. This study contributes to better understanding of the expected relationship between experience with different climate change events and adaptation. This study also contributes to the scarce literature on the relationship between experience and climate change adaptation in forest management in the U.S., specifically among small woodland owners, and the broader literature on prior experience and behavioral responses to risks and hazards.

Data availability statement

The datasets presented in this article are not readily available because confidential information. Requests to access the datasets should be directed to apfisch@umich.edu.

Ethics statement

The studies involving human participants were reviewed and approved by the University of Michigan Institutional Review Board. The participants provided their written informed consent to participate in this study.

Author contributions

APF led the study conception, design, and data collection. RCHD led the analysis. The first draft of the manuscript was led by RCHD with substantial contributions from APF. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Appendix

Event exposure measures

To construct our exposure measure, we used 2000–2018 data from the USDA Insect and Disease Survey (IDS), which is spatially explicit and forest specific. This is aerial detection data of tree mortality and defoliation from insects, diseases, and weather-related causes. The exposure measures are specific to each respondent's location (based on the GIS parcel maps) and are a measure of the portion of a circular, 206-acre (0.32 square mile) area, centered on the property, that had damage from each of the three event types. This "buffer" area is deliberately larger than the parcel asked about on the survey for more than 90% of cases and was chosen to cover the property surveyed and the immediate area around it. We did this for two reasons, the first is that the IDS data includes some locational error, and the second is that individuals' observing damage near their land may be sufficient to spur action, so we wanted an area that would count as "on-or-near" their property. For insect and disease damage we used the "high" level of impact (>50% defoliation) to construct the outbreak measure because the "high" damage areas were used. After all, nearly all parts of the study area had experienced "low" damage. For storms and droughts, we used 30% or more defoliation. The IDS data has some limitations—notably the potential for error in exact damage location and cause of damage—but also has several unique strengths. The main strengths of this data are that it measures forest-specific damage, not just occurrence, what is expected to be most relevant for influencing behavior, and it is quite possibly the only data on tree insect and disease occurrence available for a large area.