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ORIGINAL RESEARCH

More Forest More Problems? Understanding Family Forest Owners' Concerns in the United States

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Abstract

Forests face an increasing number of threats, which are expected to increase in frequency and intensity in the future. Recent calls have pointed out the need for holistic approaches when developing forest management policies, which requires a broad understanding of how forest owners perceive the uncertainties and risks that may threaten their forests. In this paper, we study a set of sixteen concerns in the United States National Woodland Owner Survey (NWOS). Our set of concerns span an array of types and causes—natural and anthropogenic—that capture multiple aspects of forest ownership. We measure the level of concern that family forest owners associate with each concern variable, and explore how they vary with each other. We then measure "total concernedness" to study how individuals distribute their concerns across multiple ownership challenges, and relate total concern to socio-demographic and forest-ownership attributes. We find that private forest owners moderately distribute their concerns across all types, as opposed to high levels of concern for one issue and none for others, and that concerns are, in general, positively correlated with each other. Our analysis highlights a general need for policy and regulations that properly consider the full suite of owner preferences, including concerns.

Keywords Concerns · National Woodland Owner Survey (NWOS) · Family forest owners · Threats · Tobit regression

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Introduction

Forests have come under increasing threats from multiple sources of damage in recent decades, and the impacts of climate change are expected to further intensify forest damages at a global scale (FAO 2022). Recent calls in the literature have pointed out the need for holistic approaches that integrate multiple aspects of threats, incorporating natural disturbances as well as anthropogenic pressures, when determining ecosystem and forest management policies (Buma 2015; Gallina et al. 2016; Montagné-Huck and Brunette 2018; Turner 2010). However, doing so requires more complete knowledge of forest owner preferences including not only what owners value (Hansjurgens et al. 2017; Joshi and Arano 2009; Kuuluvainen et al. 1996; Shanafelt et al. 2022), but also how owners perceive the wide range of uncertainties and risks that may threaten the flow of those benefits now and in the future (Vehola et al. 2022). Private forest owner perceptions of anthropogenic and natural forest disturbances are important for policymakers to understand given the substantial benefits that forests provide to society as a whole (Taye et al. 2021). In this paper, we use the United States Forest Service's National Woodland Owner Survey (NWOS) to understand three primary research questions: what are family forest owners concerned about regarding their forests, how are their concerns related to each other, and how do family forest owners distribute their concernedness across all concern variables in the survey?

The United States has the fourth largest forest estate in the world, representing approximately 310 million hectares of forestland or 7.65% of the world's forests (FAO 2020). Of those, privately owned forests make up more than half of the forests in the United States (Service 2015). These lands provide a variety of forest ecosystem services including timber and firewood production, clean air and water, recreation and cultural services, biodiversity and habitat conservation, and carbon storage (Caputo and Butler 2017). However, the provisioning of these services is always in jeopardy due to the occurrence of natural or anthropogenic hazards. For example, between 2001 and 2020, the United States experienced an average of 443,524 fires per year burning just over a total of 40.6 million acres[1]. The frequency of novel species being introduced, establishing, and spreading is on the rise (Costello et al. 2007; Markowski-Lindsay et al. 2021; Seebens et al. 2017, 2018), as is the number and intensity of extreme weather events such as drought and storms due to climate change (Intergovernmental Panel on Climate Change 2013). Furthermore, hazards can often interact with each other across space or time (Buma 2015; Gallina et al. 2016), amplifying their potential damages. Bentz and Klepzig (2014), as an example, showed an increase in bark beetle damages due to climate change in the western United States.

Forest policy and regulations must consider forest owner perceptions of these hazards in order to be effective and efficient, as perceptions are linked to forest owner behavior (e.g., management) (Stødal et al. 2007). Not properly accounting for owner concerns can lead to monetary damages and costs to individuals and society, as well as disruptions in the flow of ecosystem services, biodiversity loss, etc. A standard assumption of utilitarianism and welfare economics applied to forestry is that the

[1] https://www.ncei.noaa.gov/access/monitoring/wildfires/.

maximization of net social benefits or welfare entails managing the forest in such a way that net benefits are maximized across all individuals (Conrad 1999; Conrad and Clark 1987; Perman et al. 2003). Understanding concerns reflects potential costs that threaten individuals, which at a large enough scale will factor directly into the calculation of net social benefits. Disturbances alone have the potential to threaten the ecological and economic livelihoods associated with forests, such as, for example, changes in timber price and inventory that followed Hurricane Hugo in 1989 (Kinnucan 2016; Prestemon and Holmes 2000). Additionally, individual forest owners are limited by budgets in terms of money, time, and energy. They will have to distribute their resources across all of the issues affecting their forests, some of which may be misperceived (e.g., an owner perceives a hazard as threatening when it is in fact not) and some may not be in line with social welfare. It is one of the jobs of forest policy to align owner perceptions of hazards with the actual realities of their properties, and to incentivize owner behavior to prioritize those issues most relevant to social welfare. Not investing in preventative or mitigating measures due to the misallocation of resources to irrelevant or inappropriate (from a social welfare perspective) hazards can lead to much greater damages than if those measures were in place. For example, pre-fire treatments such as prescribed burns or tree thinning can significantly reduce forest fire severity compared to areas where no preventative measures were put in place (Cochrane et al. 2012; Pollet and Omi 2002).

In this context, understanding forest owner behavior towards various threats is of the utmost importance to ensure or improve the flow of forest ecosystem goods and services. This implies that an individual's attitudes and preferences influence their behavior, a notion underlying behavioral science frameworks such as the theory of "reasoned action" or "planned behavior" (Ajzen 1991; Young and Reichenbach 1997), "value-belief-norm" theory (Stern 2000), or "goal framing" (Lindenberg and Steg 2007). Yet while researchers traditionally focus on natural hazards, such as wildfire or storms (Montagné-Huck and Brunette 2018), the true set of forest owner concerns is often much broader, including fears of government intervention, development of nearby land, or vandalism, in addition to the traditional natural hazards. In this paper, we consider a set of sixteen concerns or hazards in the United States National Woodland Owner Survey (Table 1).

As our key variables of interest, our paper deals with the concept of "concern", which is related to but different from "risk". Like squares and rectangles, a risk is a concern, but a concern is not necessarily a risk. The classic definition of risk is a quantitative and economic one, where risk is equal to the probability of an event multiplied by its damages (Knight 1921). The same is not true for a concern, which we define here as a subjective perception of uncertain or actual events relative to the inherently quantitative measure expressed in a risk. Concerns are broader and can be used for not only events but also states of a system (Fischer et al. 1991) and be applied across all scales of social aggregation. For example, a person can be concerned about society, politics, the environment, or an individual's health and well-being. While the concepts of risk and concern are linked, mapping quantifiable measures of risk to potentially non-quantified subjective measures of concern is hardly one-to-one, as the drivers of an individual's concern for any given topic is often influenced by factors other than the probability of an event and the damage it might cause, e.g., Paveglio

Table 1 Summary statistics of concerns, and explanatory variables for the Tobit regression

Concerns[§]	Mean	SD	Skewness
Damage from animals (ANIM)	2.66	1.53	0.30
Damage or noise from off-road vehicles (OHV)	2.80	1.83	0.20
Climate change (CLIM)	2.95	2.01	0.03
Clean air and water (CAW)	3.12	1.74	−0.15
Wind or ice storms (STORM)	3.17	1.62	−0.16
Development of nearby lands (DEV)	3.20	1.77	−0.20
Drought or lack of water (DRY)	3.32	1.72	−0.29
Invasive plants (INVA)	3.54	1.38	−0.47
Water pollution (POL)	3.55	1.69	−0.49
Wildfire (FIRE)	3.78	1.52	−0.70
Unwanted insects or disease (INS)	3.88	1.18	−0.82
Government regulation (GOVT)	3.96	1.43	−0.96
Misuse of wooded land, such as vandalism or dumping (DUMP)	4.00	1.35	−1.00
Trespassing or poaching (TRES)	4.19	1.06	−1.23
Keeping land intact for future generations (HEIR)	4.21	1.07	−1.38
High property taxes (TAX)	4.22	1.10	−1.34

Explanatory variable	Type	Mean	SD
Owner age	Continuous	65.27	11.53
Owner education	Categorical		
Less than 12th grade		0.03	0.16
High school/GED		0.18	0.38
Some college		0.19	0.40
Associate's degree		0.08	0.27
Bachelor's degree		0.27	0.45
Advanced degree		0.25	0.43
Percent income from woodland	Continuous	4.77	13.61
Primary residence	Binary	0.53	0.50
Number of registered owners of the property	Continuous	2.52	5.74
Multiple properties owned	Binary	0.43	0.50
Acreage of woodland	Continuous	1406.36	10,014.08
Proportion of woodland on property	Continuous	0.70	0.30
Number of years owned	Continuous	25.16	15.29
Acquisition of property[*]			
Purchased	Binary	0.75	0.43
Inherited	Binary	0.38	0.49
Gifted	Binary	0.03	0.18
Other	Binary	0.01	0.07
Enrollment in environmental program(s)[¥]	Binary	0.42	0.49

[§]Responses are ranked on a Likert scale from "no concern" (1), "of little concern" (2), "moderate concern" (3), "concern" (4), to "great concern" (5)

[*]The survey allows owners to have obtained parts of their property through purchase, inheritance, gift, or other means. Respondents were presented with a single question and asked to "check all that apply"

[¥]This variable is equal to 1 if the property is currently enrolled in a conservation easement or green certification scheme, or whether a cost-share program was used in the last five years to establish or manage the woodland (and 0 otherwise)

et al. (2018) and Olsen et al. (2017). Indeed, in terms of language, studies in the risk literature are careful to restrict the usage of the word "risk" to cases that fit within its mathematical definition. For example, wildfire scientists are careful to say "hazard", "potential", "uncertainty", or "disturbance" instead of "risk" unless they are able to include estimates of the value of potential damages (Dillon et al. 2015; Short et al. 2020). In terms of concerns, the wording in the literature is not unique. We can find instances of "awareness", "perception", "belief", "worry", or a "concern", but all the concepts refer to a similar psychological construct: an individual's subjective opinion of a potentially negative event or state that can affect her/him personally (Blennow et al. 2014). In this sense, we could think of a concern as a subjective perception of an underlying risk.

As opposed to risks, the literature on *concerns* is quite sparse. We know of few studies in the forestry literature that explicitly address forest owner concerns. A recent exception is a paper by Danley et al. (2021), who investigated the relationship between private forest owner concern for wildfire (from the NWOS) and location-specific measures of the United States Forest Service's wildfire hazard potential index. To illustrate the importance of non-traditional risk factors for subjective concerns, Danley et al. (2021) found that non-biophysical hazard factors, such as emotional attachment to one's forest property, tended to have as much or more influence on subjective concerns as moving from the lowest to the highest ends of the wildfire hazard spectrum. In contrast, the literature on perceived *risks* is quite large, particularly for natural hazards (Montagné-Huck and Brunette 2018). Blennow and Sallnäs (2002) were the first to conduct such a study in the context of forestry. They questioned Swedish private forest owners about their perceptions of fourteen hazards including damage to plant regeneration (due to browsing by large herbivores, pine weevil, vole, frost, and spruce bark beetles), damage to standing trees (wind, snow, high resin flow, root rot), increased harvesting costs, falling timber prices, increased forest estate prices, and increased interest rates. Since then, the literature has expanded to consider forest owner perceptions towards climate change and climate change adaptation (Blennow and Persson 2009; Thomas et al. 2022), bark beetles (Flint 2007), invasive plants (Fischer and Charnley 2012), wildfire (Jarrett et al. 2009; Novais and Canadas 2022), and environmental regulations (Eriksson 2014), among others. We do not mean to argue that the literature on risk is not applicable to concerns—indeed, the topics clearly overlap—but rather than our study fits into a context broader than more traditional analyses with strict mathematical definitions of risk.

Our main contribution in this paper is that we analyze a broad range of forest owner concerns usually considered separately and, in doing so, capture multiple aspects of forest owner concerns—natural and anthropogenic. Our set of concerns spans a broad array of types and causes, better representing the actual set of potential threats to forest owners. Specifically, we measure the level of concern family forest owners most commonly associated with each concern variable and ask how the levels of concern for each vary with each other. The latter is particularly useful, as the potential linkages between multiple threats are seldom studied, but increasingly interact (Seidl and Rammer 2017). Finally, we sum the level of concern across all concern variables to develop an index of family forest owner's level of total concern or overall "concernedness". By studying the distribution of overall concernedness,

we are able to understand how forest owners distribute their concerns across all topics in the NWOS. Furthermore, we relate an individual's total concern to her/his socio-demographic and forest-holding specific characteristics to get a sense of how variation in these factors may be associated with owners' level of overall concernedness, which is useful for designing and implementing forest policy.

We use the 2018 iteration of the United States National Woodland Owner Survey (NWOS)—a product of the USDA Forest Service, Forest Inventory and Analysis Program (FIA). The NWOS is a nationwide survey of private forest owners (NWOS). It encompasses a diverse set of questions, from previous and future land use practices, reasons for owning, and concerns for the present and future state of the woodland. In addition, it also includes owner demographics and characteristics of the ownership's forest holdings. Previous research has used the NWOS to characterize family forest owners (Majumdar et al. 2008); assess the sustainability of family forestland (Butler et al. 2022); estimate landowner familiarity and participation in carbon programs (Sass et al. 2022); calculate life expectancy and survivorship of family forest landowners (Caputo et al. 2023); analyze owner language in the free-response section of the survey (Andrejczyk et al. 2016); estimate the benefits provided by forestland and the beneficiaries who receive them (Caputo and Butler 2017); document trends in forest ownership over time (Huff et al. 2019; Sass et al. 2023); measure the relationships between forest property size, landowner characteristics, and stated management practices (Butler et al. 2021a); and evaluate stated owner preferences for reasons for owning woodland (Shanafelt et al. 2022), and others.

The rest of this paper is organized as follows. In the next section we discuss the data of the National Woodland Owner Survey and our statistical approaches to analyzing the data. The third section presents our primary research findings. The final section discusses the main takeaways of our work and their implications for forest policy and management.

Methods

Data

The United States National Woodland Owner Survey (NWOS) is a nationwide survey of private forest and woodland ownerships of one or more acres (0.4 or more hectares) (Butler et al. 2016; Service 2015). It includes questions regarding land use practices, reasons for owning, and concerns for the present and future state of forest properties, as well as demographic, ecological, and socio-economic information specific to each forest owner and their properties. For detailed discussions of the design and implementation of the survey, see Butler and Caputo (2020) and Westfall et al. (2022).

We conducted our study using the 2018 iteration of the NWOS. For a more in-depth presentation of the 2017–2018 iteration of the survey and its associated summary statistics, see Butler et al. (2021b). The USDA Forest Services does provide a methodology to weight survey responses to obtain population-level inferences (Butler and Caputo 2020; Butler et al. 2021b). However, as we prefer to work with the

nationwide survey sample as opposed to population estimates (and as any subsequent statistical analysis would need to explicitly account for the weights), we only use the unweighted response values in our analysis. The published 2018 survey had a sample size of 9,518 (family forest landowners with 1+ acres, not including interior Alaska) and a cooperation rate of 39.7%. Missing responses (i.e., item non-responses) were addressed through an imputation approach (Butler et al. 2021b).

Specifically, we focus on the sixteen concerns in the data set (Table 1). These include clean air and water (CAW), climate change (CLIM), damage from animals (ANIM), development of nearby lands (DEV), drought or lack of water (DRY), damage or noise from off-road vehicles (OHV), government regulation (GOVT), high property taxes (TAX), invasive plants (INVA), keeping land intact for future generations (HEIR), misuse of wooded land, such as vandalism or dumping (DUMP), trespassing or poaching (TRES), unwanted insects or disease (INS), water pollution (POL), wildfire (FIRE), and wind or ice storms (STORM). For each concern variable, forest owners were asked to indicate their level of concern on a five-point Likert scale from "no concern" (1), "of little concern" (2), "moderate concern" (3), "concern" (4), to "great concern" (5). Our population of interest is family forest ownerships (FFO) with ten or more acres (4.04 hectares) of forestland. Family forest ownerships are a subset of private ownerships, consisting of individuals, families, and family trusts. It has been found that this 10+ acres threshold is good for separating individuals who own substantial, meaningful quantities of forestland from those who own a few acres here and there, while still providing variation in terms of objectives, intentions, and behaviors (Butler et al. 2021b).

Statistical analysis

We conduct our analysis in four steps. First, we study the distribution of each concern variable individually, calculating each variable's mean, median, standard deviation, and skewness across all family forest owners in the survey. Second, we measure correlations between each concern by taking a Spearman correlation coefficient between all pairwise combinations of concern variables. Third, we sum each forest owners' level of concern across all concern variables to calculate an owner's level of total concern or overall "concernedness". We find that this formulation captures well how individuals distribute their concerns across all variables in the data while providing at least a solid first approximation of overall concernedness of forest owners. We will return to alternative formulations of total concern—such as taking the average of each individuals' ratings across all individual variables, summing concerns but dropping highly correlated ones, or grouping concerns using a formal clustering analysis—in the Results and Discussion. We then calculate the mean, median, standard deviation, and skewness and plot its distribution to understand how family forest owners allocate their concern across all variables. In general, the first three statistical moments of an unknown random variable (i.e., the mean, variance, and skewness) are sufficient to paint a comprehensive picture of the shape and structure of its underlying statistical distribution.

Due to the censoring of the Likert scale, total concern is clearly truncated at minimum and maximum values. Therefore, in order to better characterize family forest owners, we conducted a censored normal regression model or Tobit regression relating

the level of total concernedness (independent variable) to owner- and forest-specific characteristics (dependent or explanatory variables) (Cameron and Trivedi 2005; Tobin 1958). Specifically, the model takes the form,

$$y^* = X'\beta + \varepsilon$$

where the latent variable y^* is observed when the independent variable y falls within the lower and upper bounds of the truncation. The variables X' and β represent the standard matrix and vector of the dependent variables and regression coefficients respectively. The error term, ε, is assumed to be homoscedastic and normally distributed with a mean of zero and variance σ^2. For details on how truncation and censoring affects the conditional mean and probability and cumulative density functions of the normal distribution in maximum likelihood estimation, we would direct the reader to Cameron and Trivedi (2005).

Our set of explanatory variables is fairly standard in the forest survey literature (Amacher et al. 2003; Beach et al. 2005; Garcia et al. 2014; Joshi and Arano 2009; Silver et al. 2015). These include forest owner age, education level, the number of individuals registered as owners of the property, and binaries for whether multiple parcels are owned and if the forest property associated with the survey response is the owner's primary place of residence. Additionally, we include the total acreage belonging to the ownership (i.e., size of forest holdings), proportion of forested land on the property, proportion of owner income that comes from the forestland, the number of years owned, and a set of binaries for how the property was obtained.[2] Finally, we include a binary variable that captures some of the behavioral traits of forest owners, which is equal to one if the property is currently enrolled in a conservation easement or green certification scheme, or whether a cost-share program was used in the last five years to establish or manage the woodland (and zero otherwise)[3]. Summary statistics for explanatory variables can be found in Table 1.

Note that we do not include a location-specific spatial variable in our analysis of total concern. We are not claiming that there is no spatial variation between states, but rather that it is moderate enough to warrant not considering it in the analysis. Indeed, while there is variation between states, concerns exhibit similar general trends as the national level, and we do not observe clear patterns between different regional aggregations (census regions, Special Federal Aviation Regulation or SFAR regions, or wildlife hazard potential or WHP zones) (Supplemental Material A). A proper in-depth treatment of the spatial aspect of total concern—including the statistical determination of the appropriate level of spatial aggregation (if any) and the most relevant baseline region(s) for comparison—is left for future work. For details, we present

[2] Forest owners can obtain all or parts of their properties through various means, including through purchase, inheritance, gift, or other means. The survey accounts for this by presenting respondents with a single question and asking them to "check all that apply".

[3] Individually, there are not enough observations of each variable for them to be included separately in the statistical analysis (e.g., there are many zeros in the data). However, as we would expect them to complement each other and capture similar aspects of forest owner behavior, we aggregate them into a single binary variable.

tables of summary statistics by state, as well as maps and histograms of the distributions of concerns by state, in Supplemental Material A.

We limit our analysis to family forest owners with greater than or equal to ten acres or 4.04 hectares of forestland (a total of 8642 observations), and to those individuals who answered all of the concern questions. In other words, if an individual stated that one or more concerns were "not applicable", then those responses were dropped from the analysis. This gives us a final sample size of 7767 observations in our data.

In order to improve the convergence of the Tobit regression, we standardize (scale) all continuous explanatory variables by subtracting the value of each observation by its mean and dividing by its standard deviation. The Tobit regression is censored at the minimum and maximum response values of 16 (no concern for anything) and 80 (maximum for concern for all variables). The censored maximum likelihood function for the Tobit regression was estimated in R 3.6.2 using maximum likelihood with the '*AER'* package (Kleiber and Zeileis 2008). Marginal effects were estimated using the *'margins'* package. When reporting the results of our statistical analysis, we take the 10% level as our threshold for statistical significance (though we also report the associated standard errors, z-scores, and p-values for our model estimates).

Code for our analysis is available in Supplemental Material B. An example of the survey can be found in the appendix of Butler et al. (2021b).

Results

Summary Statistics of Individual Concerns

Summary statistics for each individual concern are given in Table 1. In general, family forest owners express moderate levels of concern for all variables according to their mean values. High property taxes, keeping the land intact for future generations, and trespassing or poaching were the three highest ranking risks and concerns; damage from animals, damage or noise from off-road vehicles, and climate change were the three lowest ranking. With the exceptions of damage from animals and damage or noise from off-road vehicles (right-skewed) and climate change (centered), all risk and concerns exhibited left-skewness in the distribution of their responses (e.g., tails on the left-hand side of their distributions). In other words, relatively few respondents expressed little or no concern for most of the variables. Median values, presented in Supplemental Material A, are overall consistent with the means. Histograms for the distributions of forest owner concerns, as well as maps and full tables of summary statistics by state, can be found in Supplemental Material A. While there is some heterogeneity in the means and medians by state, states follow the same general trends as the national scale, with no clear patterns across regional aggregations (Supplemental Material A).

Pairwise Correlations Between Concerns

Spearman correlation coefficients between concern variables are presented in Fig. 1a. All correlation coefficients are statistically significant at the 10% level. With the

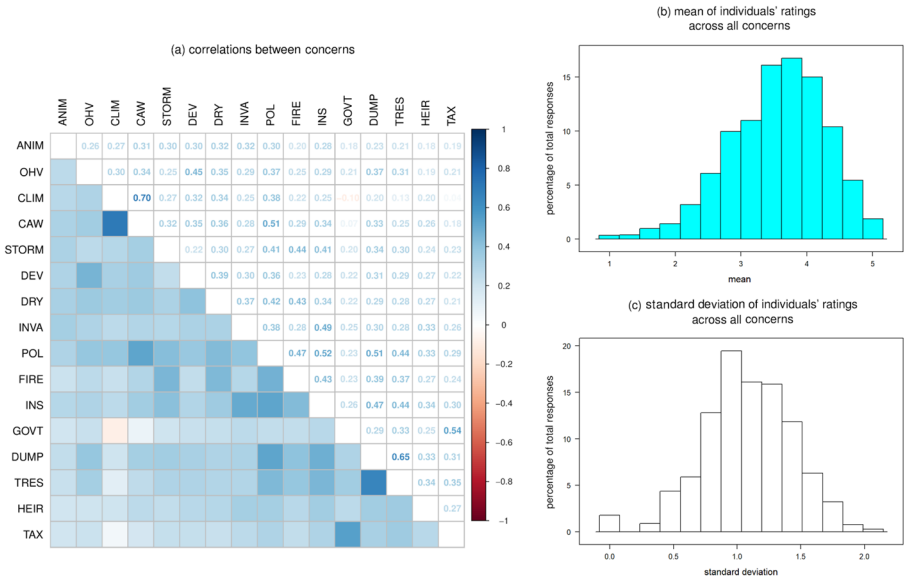

Fig. 1 Spearman correlation coefficients between pairwise combinations of concerns in the NWOS (**a**), paired with the distribution of aggregated concernsillustrated through a histogram of the mean (blue) (**b**) and standard deviation (white) (**c**) of individuals' ratings across concerns. Abbreviations for concerns are given as: clean air and water (CAW), climate change (CLIM), damage from animals (ANIM), development of nearby lands (DEV), drought or lack of water (DRY), damage or noise from off-road vehicles (OHV), government regulation (GOVT), high property taxes (TAX), invasive plants (INV), keeping land intact for future generations (HEIR), misuse of wooded land, such as vandalism or dumping (DUMP), trespassing or poaching (TRES), unwanted insects or disease (INS), water pollution (POL), wildfire (FIRE), and wind and ice storms (STORM). Color indicates the strength of the correlation, from red (negative) to blue (positive). All correlation coefficients were significant at the 10% level

lone exception of climate change and government regulation ($\rho = -0.095$), all pairwise combinations of risks and concerns are positively correlated with each other. The mean (standard deviation) correlation strength of positive interactions is 0.285 (0.116), with a minimum and maximum of 0.0447 (between climate change and high property taxes) and 0.696 (between clean air and water and climate change) respectively.

Total Aggregate Concern

Total aggregated concern exhibits an inverted U-shaped distribution centered around a mean of 56.74 (median of 57.00) with a standard deviation of 11.50, which scales one-to-one with the mean and standard deviation of each individuals' distribution of ratings across all individual variables (Fig. 1b, c; Supplemental Material A). That is, on average, family forest owners rated an intermediate level of concern for all concerns in the survey (though with some concerns rated more highly than others). Indeed, very few forest owners were completely ambivalent (not concerned with anything), and just over 1% were "fretty Betties" greatly concerned with everything.

Results of the Tobit regression are summarized in Table 2. When presenting the results of statistically significant variables below, we report their estimated regression coefficients and *p*-values as β and p respectively. Total concern is negatively associated with forest owner age ($\beta = -0.36$, $p=0.02$) and if the property was received as a gift ($\beta = -1.38$, $p=0.06$), *ceteris paribus*. In contrast, total concern is positively associated with the percentage of income coming from the woodland ($\beta=0.29$, $p=0.03$), if the forestland was the primary residence of the forest owner ($\beta=1.85$, $p=0.00$), number of owners ($\beta=0.36$, $p=0.02$), if the property is part of multiple parcels ($\beta=0.52$, $p=0.06$), if the property was purchased ($\beta=0.96$, $p=0.02$), inherited ($\beta=1.38$, $p=0.00$), or acquired by other means not listed in the survey ($\beta=3.29$, $p=0.06$), and if the property was enrolled in a conservation easement or green certification scheme, or cost-share program ($\beta=1.63$, $p=0.00$). While respondents with a high school education or higher tend to be more concerned (some college, $\beta=1.58$, $p=0.08$; Associate's degree, $\beta=2.29$, $p=0.01$), respondents with a Bachelor's or

Table 2 Tobit regression results for forest owner level of overall concernedness

Explanatory variable	Estimate	SE	z-value	Pr(>|t|)
Owner age	−0.36	0.15	−2.365	0.02
Owner education				
Less than 12th grade	–	–	–	–
High school/GED	1.08	0.87	1.25	0.21
Some college	1.58	0.86	1.83	0.08
Associate's degree	2.29	0.93	2.46	0.01
Bachelor's degree	−0.05	0.85	−0.055	0.97
Advanced degree	−0.46	0.85	−0.54	0.59
Perc. income from woodland	0.29	0.13	2.18	0.03
Primary residence	1.85	0.28	6.70	$2.04^{e}-11$
Number of owners	0.36	0.14	2.28	0.02
Own multiple properties	0.52	0.28	1.90	0.06
Acreage of woodland	−0.002	0.13	−0.02	0.98
Prop. of woodland	0.80	0.13	5.94	$2.88^{e}-9$
Number of years owned	0.030	0.16	0.19	0.85
Acquisition of property				
Purchased	0.96	0.43	2.25	0.02
Inherited	1.38	0.38	3.67	$2.00^{e}-4$
Gifted	−1.38	0.73	−1.89	0.06
Other	3.29	1.78	1.85	0.06
Enrollment in env. program(s)	1.63	0.27	6.13	$9.02^{e}-10$
Intercept	53.10	0.93	57.28	$<2^{e}-16$
Number of observations	7767			
Left-censored	24			
Right-censored	82			

Recall that we use the ten percent level as our threshold for statistical significance. Additionally, in order to improve convergence of the Tobit regression, we standardize or scale all continuous explanatory variables by their respective mean and standard deviation. Marginal effects of the explanatory variables are consistent with the raw estimates and can be found in Supplemental Material A. To aid in visualization, non-statistically-significant variables are colored in grey. Tobit regressions often include a scale or sigma parameter, which is given as the standard deviation of the residuals. In our case, the log of the scale parameter (*scale*=11.48) results in an estimate of 2.44 ($p<2^{e}-16$)

higher degree are not more concerned than respondents without a high school diploma (statistically-speaking). Many of these positive associations go hand-in-hand with a forest owner being more actively involved in various aspects of their forest property, including emotional and financial investment. For example, the associations associated with how the property was acquired imply that forest owners are less invested in the property if they were given their land as a gift. Acreage and the number of years owned were not statistically significant.

Discussion

We showed that family forest owners are concerned with a diverse array of concerns, many of which are well outside of the traditional risk topics of fire, storm, and drought. Not only do forest owners report non-negligible concern in terms of means and medians, but non-negative correlations for all but one pairwise combination of them—that is, relative to their respective mean values, an increase in concern for one variable occurs as the same time as an increase in the other. Our results support the claim that family forest owners at least perceive the potential of multiple types of hazards simultaneously. One interpretation of this trend is that forest owner attentions are divided over many things that they need to think about—which may represent a cognitive bias similar to other biases frequently observed for risk management (Montibeller and von Winterfeldt 2015). Over time, forest owners who are concerned about many topics may become accustomed to those concerns and resign themselves to the belief that action is not needed to address any one concern in particular. If this interpretation is correct, then forest policy's role is to elicit action among a willing population that could otherwise be cognitively overwhelmed by which topics to prioritize for forest management. Another interpretation could be that individuals respond that they are concerned about topics even if they do not demand attention every day. Family forest owners are, for example, similarly worried about government regulation as they are about catastrophic wildfire (Table 1).

Furthermore, we found that, in general, family forest owners felt a bit of concern for everything. Rarely did we find owners who exhibited no concern for anything, nor did we find many "worry bugs" or "fretty Betties" concerned about everything. While there is certainly variation across concerns, most family forest owners exhibited some concern for each concern variable. How can we explain these findings? On the one hand, the Forest Service constructed the NWOS over the decades (Butler et al. 2016). We could expect that the survey questions were chosen to be particularly relatable to forest owners, and would be worded in a way that can be understood by individuals owning diverse types of forestlands. On the other hand, concerns—unlike risks—are subjective. It is difficult to identify exactly what it means to be concerned about something at the individual level. Is it something that is actively on one's mind every day, that one manages constantly? Or is it something that is compartmentalizable and worried about only once in a while?

It is possible that "concernedness" is an attribute specific to each individual forest owner, with the characteristics of the land under ownership having important, albeit indirect, influences on measures of concernedness. It is clear that all ownerships face

different threats depending on the climatic, geographic, and political landscapes in which their land lies. Differences in the quantifiable risks faced by forest owners—such as differences in wildlife hazard potential between northeastern and western states, or development pressure along the wildlife-urban interface versus remote areas—stand in stark contrast to our finding that forest owners express similar levels of moderate concern for most topics. While we could expect some ownerships to be objectively vulnerable to the same threats, it is unlikely that they would all be vulnerable to every threat in the same ways. Baseline "concernedness" may then reflect something about an individual's propensity for worry or concern and *not* the objective risks facing their forestland. For example, the concern with the greatest variation at the sample level is the topic of climate change, which happens to be the one of the most politically-charged topics on the list. This result, that the concern with the greatest variation amongst forest owners may be politically driven, indicates that social or political influences may be stronger for owner concerns than the biophysical challenges impacting forests themselves. If true, this interpretation would shed additional light on why factors tied to strong emotional attachment to the land can be just as if not more influential in determining forest owner concern for different topics (see, for example, Danley et al. (2021), who found that emotional attachment to the land was at least as strong a determinant of wildfire concern as location-specific wildfire hazard potentials).

It should be possible in future studies to go deeper into the theory of what constitutes a concern and what makes individuals concerned about something or not, and to test those theories with real data. Is a concern an active thought or more of a passive process? How much are people influenced by others, the news, or social media? Much like individuals can be risk averse or risk seeking (Ait-Sahalia and Lo 2000; Arrow 1963; Eeckhoudt et al. 2005; Gollier 2001; Pratt 1964), are some forest owners inherently more or less concerned than others? If so, what is an individual's baseline level of concern, and what determines it? From our Tobit analysis, we could take an educated guess that our intercept term approximates the baseline total concern across all family forest owners in the survey—it is interpreted as the average level of total concern, all independent variables set to zero. In that case, family forest owners in the NWOS exhibit an intermediate level of baseline concern on average (52.65/80). If mapped back onto the original Likert scale presented in the NWOS questionnaire, this value would fall between "moderate concern" and "concern". Many of the former questions could be investigated in an experimental economics (laboratory) setting, which is a standard approach to establishing individuals' preferences for risk, ambiguity, or uncertainty (Charness et al. 2013). Alternatively, forest owner preferences for concerns could be elicited indirectly through a discrete choice approach, where preferences are revealed through a set of theoretical decision scenarios, or by weighing owners' stated management strategies (if we assume that inherent preferences carrying through to behavior) (Ajzen 1991; Lindenberg and Steg 2007; Stern 2000; Young and Reichenbach 1997). Other approaches (not necessarily with the NWOS) could map where forest owners get their information, e.g., their information or contact networks, and compare stated concerns with general trends of information diffused from these outlets (such as, for example, the Google Trends data). Future investigation is warranted.

Our results from the Tobit regression analysis reveal additional aspects of forest owner concerns. First, forest owner age is negatively associated with an individual's level of total concern, which implies that older individuals either tend to be less concerned in general about their forest properties, or that they have a more positive assessment of the future than their younger counterparts. This could arise from a myriad of reasons, such as the time perspective of older forest owners with respect to concerns or inherent differences in the mentality of older owners compared to younger individuals. For the former, while we interpret the timescale as the present, the concerns section of the survey does not explicitly specify a timescale, present or future. (We can compare this to the reason for owning section of the survey, for example, which specifies the *current* importance of reasons for owning forest property.) Forward-thinking behavior and discounting certainly matter in traditional resource economics problems (Conrad 1999; Conrad and Clark 1987), and it would be interesting to nail down at which timescales forest owners express their concerns in the National Woodland Owner Survey. For the latter, it could also be intriguing to disentangle whether our age effect is due to a difference in mentality from being at a specific stage in one's life (e.g., younger individuals participate in more physically active recreational activities; middle-aged individuals have a greater focus on raising a family; older individuals may soon transfer their property to the next generation) or if it is something specific to a particular generation of individuals (e.g., Baby Boomers, Generation X, or Millennials) (Butler et al. 2017). This could be done by grouping forest owners by age classes and evaluating their concerns, or looking at how concerns change over time for individuals that were surveyed across the current and previous iterations of the NWOS.

Second, in contrast to expectations that higher levels of education are associated with higher levels of environmental awareness (Shanafelt et al. 2022), education at the bachelor's level or above is consistently predictive of lower levels of environmental concern relative to most lower levels of educational attainment. The counterintuitive relationship between higher education and concern is also found in these same data for wildfire as a single concern (Danley et al. 2021), which together suggests that concern may be distinct from awareness. Furthermore, higher levels of education may entail higher incomes and/or an increased ability to access and interpret expert advice about threats to one's forestland, which may be the true driving cause our result (Hatcher et al. 2016).

Third, in contrast to other topics such as forest ownership objectives and decisions to harvest (Amacher et al. 2003; Beach et al. 2005; Silver et al. 2015), we find that the amount of forest under ownership is not significantly predictive of overall concernedness—a result that holds even if ownership size is the sole independent variable ($p = 0.998$). However, the greater proportion of one's total land ownership that consists of forestland, the higher the total level of concernedness. While our results do not allow us to infer exactly what our results about total forestland and the proportion of forestland under ownership means, we can posit a few possibilities. One possibility may be that landowners have something like a fixed account of concern to spread across their land ownership (Antonides and Ranyard 2017) and that concern for any given land cover type is given in proportion to how much of one's total ownership consists of that type of land cover. If this interpretation is correct, it means that

forest owner concernedness may depend on the importance of one's forest holdings relative to one's total land ownership. The fact remains that having more forests *per se* does not mean that forest owners will express a higher level of concern..

Finally, we find that inheritors of forestlands, on average, have higher levels of concern relative to those who purchase their properties. The literature on intergenerational forest transfer has investigated the challenges faced by forest inheritors and the desires of current forest owners who anticipate transferring some or all of their forestland in the near future (Catanzaro and Markowski-Lindsay 2022; Gruver et al. 2017; Stone and Tyrrell 2012). While it is not always the case, the challenges of inheriting forestlands can be burdensome for inheritors (Snyder and Kilgore 2018). For example, a study from the state of Washington found that inheritors tend to retain ownership of their forest properties for shorter periods of time relative to those who purchase their forestlands (Danley et al. 2024). Our results suggest that forest owners who purchase their properties tend to be less concerned overall about the challenges associated with their forest ownership. It is also possible that landowners who purchase their properties simply have more money and resources overall, e.g., many inheritors could be "land rich, cash poor" with greater anxiety about the future. Another interpretation is that those who purchase their land engage in a different decision process that requires them to have a better understanding of their risk tolerance. While inheritors might initially know more about the property or have a greater emotional connection to it, many may not have done the research as to what their responsibilities would be pre-inheritance or thought about what they are willing to take on in terms of risk. Purchasers, on the other hand, actively choose to be involved with the land, and thus might have engaged in actions to prepare them for potential concerns facing their properties.

Risk events can interact across space and time, leading to compounding or cascading effects (Buma 2015; Gallina et al. 2016). This could include interactions between different types of risk events, e.g., forest fires increasing the susceptibility of forests to wind storms (Platt et al. 2002) or beetle outbreaks (Jenkins et al. 2014; Kulakowski and Jarvis 2013), or risk events of the same type occurring in relatively quick succession, e.g., multiple forest fires negatively affecting tree regeneration (Brown and Johnstone 2012). Our results suggest that subjective concerns about risks may be similarly related. With the exception of government regulation and climate change, all concern topics are positively correlated (Fig. 1a). Among other reasons, this could be due in part to the fact that landowners communicate with each other and are influenced by the social norms of their community. If they know people who have been injured by something, or if they know people who are themselves concerned about something, their concern would likely increase. A deeper theory and typology of risks and concerns would be useful going forward in future studies. Based on our correlations, notable interactions between various hazards in the literature, and common threads in the nature of their causes, costs, and damages, we propose a classification of our concerns in Fig. 2. Specifically, we divide risks and concerns into three broad categories first based on their causes (anthropogenic, natural, or both) and then five sub-categories based on a deeper reflection of their causes and the nature of their costs and damages (eco-anthropogenic, natural hazards, political, pollution, or

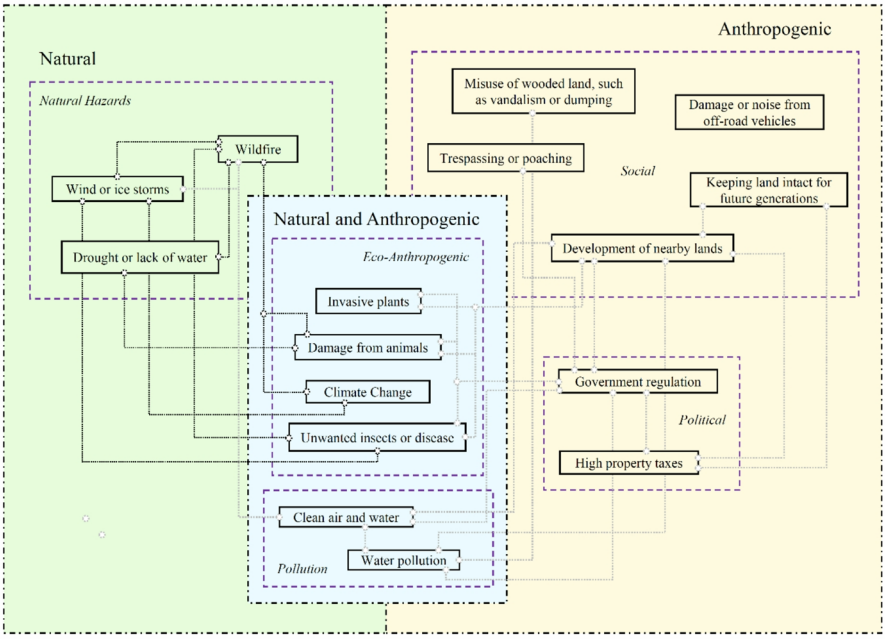

Fig. 2 Classification framework of risks and concerns. Risks and concerns are divided into three broad categories based first on their causes, and then five sub-categories based on a deeper reflection of their causes and the nature of their costs and damages. We illustrate some well-established interactions between natural risks and hazards using black, dotted connections between each risk and concern, and would direct the reader to reviews by Buma (2015), Montagné-Huck and Brunette (2018) and Bastit et al. (2023) for details. We hypothesize potential interactions between anthropogenic risks and concerns using grey dotted linkages. These could include, for example, the spatial distribution of non-point pollutants like smoke or fertilizers via wind and water (interactions between clean air and water and wildfire, water pollution, and wind and ice storms) or the introduction of unwanted insects, disease, and invasive plants due to the development of nearby lands. We have added nodes to aid the reader in identifying the different connections between risks and concerns

social). A true testing of our framework via statistical or clustering analysis, and case studies is left for future work.

Like any survey, our study is not without its limitations. We discuss three of these in turn. First, there are limits to how much respondents can express on a Likert scale, where individuals are asked to rate their level of concern on what is assumed to be a linear ranking system (e.g., the distance between "no concern" and "of little concern" is the same as "concern" and "great concern"). In reality, how forest owners weight their concerns can be a much more complex story that goes beyond the linear scaling of the Likert scale. The response "no concern" is a good example of this. When individuals say that that have "no concern" for something, are they really aware of it and not concerned by it, or is it rather a concern that they do not think about every day? Or, perhaps is it that those individuals actually value the concern variable, such as enjoying taking off-road vehicles into the forest or finding introduced species pleasing to hunt or admire? To use the language of a "risk", do they have low concern because their perception of the probability of it occurring is low or that the magnitude

of damages is low or negative (e.g., a benefit)? Similarly, the Likert scale is an ordinal ranking system. When calculating the summary statistics of our concerns, they are treated as numeric, which will introduce a slight bias in the summary statistics as individuals cannot rate their concerns in-between the ordinal rankings (though this will probably average out across all individuals of the study). Future iterations of the survey could ask forest owners to rate their responses on a continuous spectrum, which, while still truncated at a lower and upper bound, is more flexible than the Likert scale.

Second, there is the potential for an ordering or anchoring effect in the survey. The order of the presentation of concerns is always the same, with climate change being first and wind and ice storms being last, which could influence their responses. One way to test for this is to test if how a forest owner responds to the first concern question informs their responses to the others and total concern. We leave this for future work. Third, while we believe that we have accounted for it in our statistical analysis of total concern, there is always the potential for endogeneity—specifically, omitted variables bias (Angrist and Pischke 2009; Cameron and Trivedi 2005). The National Woodland Owner Survey, while quite comprehensive in its breadth and scope, does not include data like wealth and income (which might explain some of our acreage result, which is not statistically significant) nor forest owner awareness of concern variables (which may be a meaningful factor in determining their level of concern).

Finally, while we believe that our measure of total concern captures how individuals distribute their concerns across all concern variables and provides at least a decent approximation of total concernedness, it is but one of many possible formulations. When we sum our concerns together, we make an implicit assumption that they are independently-distributed from each other (and weighted equally). If they are not, then we risk inflating our measure of total concern, which will carry over as bias in our Tobit analysis. (Similarly, if two concerns measure fundamentally the same thing, then including both of them or "double counting" will inflate the aggregate index of total concern.) However, it is often difficult to establish whether concerns are truly interdependent or whether forest owners simply independently assign levels of concern that are highly correlated. It is a straightforward exercise, for example, to independently generate random variables that exhibit strong degrees of correlation, and there are many examples of clearly independent but highly correlated events[4]. High correlations between individual concerns could be a sign of dependence, or they could simply be correlations, which reflect the fact that many people experience elevated levels of concern for each that disproportionally effects total concern.

One way to address this is to drop concerns that exhibit strong correlations with others. However, doing so could actually introduce bias into the measure by inflating or deflating the value of total concern. The covariance between two variables—which is a driving factor when calculating a correlation—is defined as how one variable deviates from its mean as another variable also deviates from its respective mean. It is scale independent. It is possible that two variables are strongly correlated, with one contributing much to total concern while the other very little, with their relative deviations from their means going in the same directions. In this case, dropping

[4] https://www.tylervigen.com/spurious-correlations.

the highly contributing correlated variable would deflate total concern; dropping the lowly contributing variable will change little of our analysis. Another method would be to cluster concern variables based on their correlations, then then construct an individual's total concern based on the means of each cluster rather than the sum of each of their raw concern variables. However, this would require a true clustering analysis to determine the most appropriate clustering algorithm (e.g., finite mixture models, hierarchical clustering, or K-means clustering) and the number and structure of clusters, which goes well beyond this paper. We provide two alternative measures of total concern—the first dropping concerns with correlations greater than 0.5, the second grouping concerns into ten clusters via a hierarchical clustering algorithm in provided in the '*corrplot*' R package—in Supplemental Material A. We find little or no changes from our results in Table 2.

Our analysis highlights one of the challenges in forestry—how can one properly devise a policy that accounts for all of the potential concerns family forest owners? In order to be effective, forest management policy often aims to properly account for the full suite of owner preferences, benefits, and costs. While the heterogeneity of family forest owners is well-documented, these results suggest the vast majority of forest owners tend to be moderately concerned about most topics in the National Woodland Owner Survey. While concern is often a variable measured in forest owner surveys, greater study is needed to understand what these really mean to forest owners, better ascertain their costs and damages, and relate them to forest owner management. Understanding the weight of each risk or concern in the overall forest owner portfolio is an important step for defining efficient forest management policies—a difficult task when many of the costs and damages of concerns are indirect, social, or emotional, and many of which can be difficult to quantify or are kept privately by the forest owners themselves. Indeed, we are not claiming that any forest policy could fully address all forest owner concerns. That would be infeasible, expensive, and not cost-effective. Policy makers will always be faced with needing to identify and choose which concerns to address while avoiding mismatches between hazards considered by the policy and the set of owners' actual concerns. By understanding what forest owners are concerned about, forest policy can better guide owners through outreach or education to understand the true threats to their forests, and incentivize them to prioritize the management of concerns most in-line with social welfare. By approaching forest owners more holistically, policy makers can play a role in engaging forest owners to take meaningful actions on their forestlands, overcoming possible cognitive burdens, feeling overwhelmed, or ambivalence. Furthermore, researchers, technical experts, and policy makers can tailor landowner education to satisfy their personal concerns and put the technical aspects of forest damage in proper context.

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