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Understanding invasive plant management on family forestlands: An application of protection motivation theory

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A B S T R A C T

Invasive forest plants are a growing concern because of their perceived and actual negative ecological, economic, and social impacts. To effectively manage invasive plants in forest ecosystems, it is paramount to understand the management decisions made by family forest owners (FFOs), who collectively own 36% of forestlands in the United States. We contribute to the growing literature on invasive plant management and the factors that influence FFOs' likelihood to manage invasive plants on their property by incorporating protection motivation theory (PMT; Rogers 1975). Protection Motivation Theory argues that the degree to which individuals protect themselves from a perceived threat varies as a function of the perceived severity of the threat, their vulnerability to the threat, their perceptions of self-efficacy to effectively mitigate the threat, and the degree to which they believe they have access to the resources needed to effectively respond to the threat. We surveyed a random sample of 2,600 FFOs in Indiana about their knowledge, perceptions, experience, and plans regarding invasive plants on their wooded lands. Consistent with PMT, we constructed a hierarchical binary logistic model and found that FFOs reported greater intentions to manage invasive plants when they perceived the problem to be more severe and also when they felt a stronger sense of self-efficacy to address the problem. Although perceived vulnerability was not significant in our final model, our results also show that FFOs who had previous invasive plant management experience, had a Bachelor's degree or higher level of education, owned woodlands for recreational purposes, and were more subject to normative social influence also tended to report greater intentions to manage invasive plants. Together, these results suggest that components of PMT (perceived severity and self-efficacy) may be used to inform potential strategies, programs, and outreach for engaging family forest owners in invasive plant management.

1. Introduction

Non-native invasive species are one of the biggest causes of global biodiversity loss and species extinctions (Early et al. 2016; IUCN 2017) and about one-fifth of the Earth's surface is highly vulnerable to non-native species invasion (Early et al., 2016; IPBES 2019). Invasive species also negatively impact public health by increasing human exposure to irritants and toxins (Mazza et al., 2014), and threaten human security (Tanentzap et al., 2009), wellbeing, and livelihoods globally (Early et al., 2016; Tanentzap et al., 2009). In the United States alone, it was estimated that the environmental and economic costs associated with invasive species was approximately $120 billion USD annually (Pimentel et al., 2005). Terrestrial invasive plants, as one type of invasive species, were introduced primarily through the horticultural and agricultural industries for landscaping, soil erosion control, or wildlife habitat improvement purposes (Simberloff 2013). While it is recognized that some invasive plants provide ecosystem services (Rai and Singh, 2020; Milanović et al., 2020; Vaz et al., 2017), like soil stabilization (Pejchar and Mooney 2009), many invasive plants have been documented to displace native species, alter soil characteristics, exacerbate the impacts of disturbances, and reduce ecosystem health and resilience (Simberloff 2013; Vaz et al., 2017).

Previous research on invasive species is primarily ecological (Estévez et al., 2015; Vaz et al., 2017). A systematic literature review from 1980 to 2013 shows that of 15,915 studies on biological invasions, only 124 incorporated human dimensions of invasive species management (Estévez et al., 2015). The latter studies investigated how awareness, beliefs, attitudes, perceptions, and culture affect invasive species management (e.g., Bardsley and Edward-Jones 2006; Estévez et al., 2015). A few empirical studies also applied social and behavioral theories to understanding resource managers' invasive species management practices (McLeod et al., 2015). In the U.S., most invasive plant management efforts and related research have focused on working with agricultural producers and ranchers to prevent and remove invasive weeds (e.g.,

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Aslan et al., 2009). Fewer studies have examined forest landowners' actions and their motivations and challenges to invasive plant management on forested landscapes (Clarke et al., 2019).

In this paper, we focus on how family forest owners (FFOs) approach invasive plant management. Family forests are privately-owned, "individual or family land with at least 10% cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated" (USDA Forest Service, 2019). It is important to engage FFOs in invasive plant management because they are the largest forest landowning group in the country—10.7 million FFOs collectively own 290 million acres of forestlands in the U.S. (Butler et al., 2016). Invasive plant management on family forestlands is challenging because many FFOs are inactive land managers who undertake minimal management activities on their land, or who prefer to leave their properties as is and continue enjoying its intangible benefits, such as scenic beauty, privacy, and family legacy (Butler et al., 2016). Additionally, family forestlands may bethreatened byfragmentation and subdivision partly because the average FFO landowner is 62 years old, which may signal impending intergenerational land transfers and important decisions regarding conservation-based estate planning as landowners age (Butler et al., 2016; Markowski--Lindsay et al., 2018). As such, the large number of FFOs, the forestlands that they collectively own, and their current demographic and landownership characteristics, suggest a critical need to understand their current and future forest management plans, especially regarding invasive plant management.

Extensive research has examined FFOs' general forest management behaviors and intentions, including timber harvesting, wildfire control, wildlife habitat improvement, and participation in various government-sponsored forestry programs (e.g., Floress et al., 2019; Huff et al., 2019). These studies suggest that FFOs' forest management behaviors are influenced by a wide range of factors. For example, previous studies have identified various landownership characteristics that influence decision making by FFOs, including forestland size, distance between forested property and landowner primary residence, land tenure, forest ownership objectives, whether or not landowners have a written forest management plan, and access to financial and technical assistance (e.g., Cai et al., 2016; Joshi and Arano 2009; Kilgore et al., 2008; Ma et al., 2012; Vokoun et al., 2006). Sociodemographic characteristics like age, education, gender, income, occupation, and membership in a landowner association or environmental organization also affect FFO's forest management decisions, although the effects of these factors are varied and generally inconclusive (e.g., Joshi and Arano 2009; Ma et al., 2012).

Regarding invasive plants, previous research highlights that FFOs know relatively little and may have varied perspectives about their ecological impacts (Steele et al., 2006). Some FFOs are indifferent to the socioecological impacts of invasive plants, some are concerned, some think that invasive plants provide valuable services such as food for wildlife, and others believe that it is futile to try to manage them (Clarke et al., 2019; Fischer and Charnley 2012; Yung et al., 2015). These varying perspectives may affect FFOs' decisions to manage invasive plants. For example, FFOs were more likely to control invasive plants if they identified biodiversity and wildlife protection as part of their ownership objectives (Fischer and Charnley 2012), or if they perceived invasive plants as a threat to their forests (Estevez et al., 2015; Fischer and Charnley 2012; Steele et al., 2006). Studies have also found that FFOs are less likely to undertake invasive plant management if they think the investment of money and time required to remove invasive plants will be futile (Howle et al., 2010; Ma et al., 2018).

In addition, several studies documented that landowners' engagement in invasive plant management is influenced by social norms. In other words, landowners are motivated by what their peers are doing and by what they believe is expected of them among their peers (Clarke et al., 2021; Epanchin-Neill and Wilen 2015; Ma et al., 2018; Niemiec et al., 2016; Yung et al., 2015). Recently, research has focused on opportunities and barriers to coordinated invasive plant management and related collective-action initiatives (Epanchin-Niell and Wilen 2015; Graham 2013; Graham and Rogers 2017; Ma et al., 2018; Niemiec et al., 2017a; Yung et al., 2015). These studies found that landowners were observant of their neighbors' management activities and were more likely to manage invasive plants if they perceived that their neighbors were also managing them (Niemiec et al., 2017a; Yung et al., 2015). Furthermore, landowners perceive that invasive plant management is an essential activity to be a good neighbor (Ma et al., 2018; Yung et al., 2015).

While research on the human dimensions of invasive plant management is increasing (Clarke et al., 2019; Head 2017), few studies have addressed the psychological factors affecting landowners' decisions to manage invasive plants beyond social norms and perceived reciprocity (Niemiec et al. 2016, 2017b). Even fewer studies have examined how FFOs perceive invasive plants and the associated risks to their property, and how such perceptions shape their management intentions and behaviors (Clarke et al., 2019). This paper intends to contribute to the literature on invasive plant management on privately-owned forestlands by investigating the factors that influence FFOs' likelihood to manage invasive plants using conceptual constructs from protection motivation theory (PMT; Rogers 1975) and other factors supported by previous literature, including social norms and sociodemographic characteristics.

2. A new lens for examining invasive plant management: protection motivation theory

Protection motivation theory (PMT) was originally developed to understand how individuals react to a perceived health threat and protect themselves from the perceived threat (Rogers 1975). According to the PMT, an individual's decision to protect themselves from a threat is influenced by their combined appraisal of the threat itself and of the relevant coping mechanisms available to them (Milne et al., 2000). Threat appraisal is based on two factors: perceived severity of the threat (i.e., how seriously the individual believes the threat will impact them or their property) and perceived vulnerability of oneself to the threat (i.e., how susceptible the individual feels to a perceived threat) (Bockarjova and Steg 2014; Feng et al., 2017; Gebrehiwot and Van der Veen 2015; Milne et al., 2000).

The second factor, coping appraisal, refers to an individual's evaluation of a protective action for coping with or adapting to a perceived threat, which is itself based on three factors: response efficacy, response cost, and self-efficacy. Response efficacy is the individual's perception of whether a coping strategy will effectively reduce a threat, both in terms of the perceived severity and perceived vulnerability (Bockarjova and Steg 2014; Dang et al., 2014; Grothmann and Reusswig 2006). Response cost is the perceived costliness of implementing a coping strategy including money, time, and effort (Bockarjova and Steg 2014; Dang et al., 2014; Floyd et al., 2000; Milne et al., 2000). Self-efficacy reflects the individual's perception of their own ability to effectively carry out a coping strategy (Bockarjova and Steg 2014; Dang et al., 2014; Dittrich et al., 2016). Among different components and factors outlined in the PMT, self-efficacy beliefs have received significant attention from scholars (Bandura et al., 1980; Burnham and Ma 2017; Maddux and Rogers 1983). Self-efficacy beliefs describe whether an individual thinks that they can perform an action effectively (Bandura et al., 1980). Self-efficacy beliefs are shaped by: (1) the individual's own past experiences of successes or failures, (2) social observation of similar people who are succeeding or failing at the required task, (3) social and verbal reinforcement from others, and (4) the individual's psychological and emotional perceptions about their own ability (Bandura 1997).

Traditionally, PMT has been primarily used in health studies to examine pro-health behaviors (Rimal and Real 2003; Rogers 1975; Milne 2000). Additional studies have assessed the applicability of PMT in identifying and assessing people's responses to natural hazards and the associated risks like flood (Dittrich et al., 2016; Grothmann and Reusswig 2006), drought (Keshavarz and Karami 2016), and wildfire

(Martin et al., 2007; Westcott et al., 2017). Scholars have also suggested the utility of PMT in identifying and assessing factors that influence attitudes and adoption of pro-environmental behavior including water conservation (Kantola et al., 1983; Nelson et al., 2011), adoption of electric vehicles (Bockarjova and Steg 2014), and farmers' motivations to adapt to extreme weather events and climate change in general (Budhathoki et al., 2020; Dang et al., 2014; Feng et al., 2017; Ghanian et al., 2020).

On the other hand, few studies have applied a PMT framework to examine slow onset environmental risks that are harder to anticipate or experience (Bockarjova and Steg 2014; McLeod et al., 2015). Nonnative plant invasion tends to be a slow onset environmental risk because invasive plants can take many years to establish and become visible to landowners in an ecosystem (Simberloff 2013). If unmanaged, invasive plants may take over an entire property, reducing the property's ecological, amenity, and sometimes real estate value (Hershdorfer et al., 2007).

This presents an opportunity to apply PMT to examine how FFOs perceive this slow onset environmental risk and how their perceptions affect their willingness to manage invasive plants. The purpose of this paper is to investigate FFOs' perceived severity of nonnative plant invasion, perceived vulnerability to nonnative plant invasion, and self-efficacy to manage nonnative plant invasion, and how these factors affect their willingness to take protective actions to manage invasive plants on their forestlands. We hypothesize that FFOs who perceive invasive plants to be a more severe problem, who feel more vulnerable to invasive plants, but who have a higher level of self-efficacy to control invasive plants, will be more likely to take protective actions than landowners with lower perceived severity, perceived vulnerability, and self-efficacy. The results of our analysis will help identify opportunities and barriers to addressing invasive plant management challenges across forested landscapes, as well as demonstrate the use of PMT in the context of slow onset environmental risks.

3. Study design and methods

3.1. Data collection

The data used in this study were collected from a random sample of FFOs in Indiana using a mail survey. To develop survey questions, we first conducted in-person interviews with 11 forestry professionals and 12 FFOs in Indiana. Informed by the interview results, the following survey topics were developed: (1) general questions about the forestland owned, (2) FFO's familiarity with invasive plants on their land, (3) past invasive plant management activities and plans, (4) concerns about invasive plants and various management options, and (5) sociodemographic characteristics.[1] To ensure consistency and enhance accuracy, a definition of invasive plants was provided on the front cover of the survey questionnaire.[2] We recognize the potential bias associated with using self-reported data. However, our careful design of the mail survey questionnaire and multiple rounds of pilot testing allowed us to minimize suggestive words, increase clarity of our questions, and reduce recall period and mental burden on survey respondents (Althubaiti et al., 2016). We also emphasized the anonymity of the survey and used similarly constructed Likert-scale questions whenever possible to reduce potential bias (Podsakoff et al., 2003).

To create a sampling frame of all FFOs in the state, we first identified all forestlands using the statewide forest parcel data available through the IndianaMap initiatives and the property ownership information from the Indiana Department of Local Government Finance. After reviewing this forest ownership database, we deleted industrial and organizational owners and other erroneous entries and obtained a final list of 163,666 FFOs who owned at least one acre of forestlands categorized as "woodland" or "classified forest" in the state of Indiana as of 2014. We selected a random sample of 2,600 FFOs and administered a mail survey following the Tailored Design Method (Dillman et al., 2014). We sent five mailings to each FFO: (1) a pre-notification postcard, (2) the first survey packet including a questionnaire, a cover letter, a pre-stamped return envelope, and a $2 bill as a token of appreciation, (3) a reminder postcard, (4) the second survey packet without a $2 bill, and (5) the final survey packet without a $2 bill. We included a $2 bill in the first survey packet because previous research shows that having a pre-paid token of appreciation can help improve response rates (Dillman et al., 2014; Simmons and Wilmot 2004). Our study was approved by the appropriate Institutional Review Board (IRB Protocol #: 1501015622) and the survey was administered from November to December 2015. Of the 2,600 FFOs, 1,422 returned completed, usable survey questionnaire, while 112 had inaccurate or undeliverable addresses and 64 were deceased or no longer owned woodland. Therefore, our final response rate was 58.7%. This sample size is sufficient to observe standardized beta effects of smaller than 0.10 in a multiple regression with 80% power, assuming a 5% significance level (Cohen, 1988).

3.2. Empirical models and data analysis

Our goal for the analyses was to assess the role of our three PMT-informed key variables in shaping respondents' self-reported *likelihood* to remove invasive plants in the context of other factors that were previously identified in the literature as influential on FFOs' forest management behaviors and intentions. To do so, we constructed two hierarchical binary logistic regression models. For both models, the response variable measured respondents' self-reported likelihood to undertake activities to remove invasive plants from their woodlands in Indiana in the next five years, using a five-point Likert scale from 1 (very unlikely) to 5 (very likely). Overall, 12% of respondents indicated they were very unlikely to remove invasive plants, 11% were unlikely, 27% were undecided, 31% were likely, and 19% were very likely. We were primarily interested in understanding what factors would lead participants to be likely to remove invasive plants (vs. not) and that finer-grained understanding of willingness was not of substantive interest for this project. Therefore, we recoded this variable to be "1" if respondents indicated that they were "likely" or "very likely" to remove invasive plants and "0" otherwise.

The first model included only PMT-informed explanatory variables (i.e., perceived severity, perceived vulnerability, perceived self-efficacy). Applying PMT in the context of invasive plant management among FFOs, we measured *perceived severity* by averaging respondents' agreement with eight statements about potential impacts of having invasive plants on their woodlands using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). We measured *perceived vulnerability* by averaging respondents' agreement with two statements about how susceptible they feel to the spread of invasive plants and the difficulty of controlling them. We measured *self-efficacy* by averaging respondents' agreement with ten statements about their beliefs about their own ability to remove invasive plants from their woodlands (Table 1). We did not collect survey data on response efficacy and response cost, which tend to be related to specific management practices and vary from one invasive plant species to another. There is also some uncertainty among experts about the best approaches to managing specific invasive plant species (Ma et al., 2018). As such, the response cost (money, time, etc.) required for successful management and response efficacy would be context dependent and varying depending on the invasive plant species in question, the management practice

[1] A complete copy of the survey questionnaire can be found in the Supplemental Material.

[2] "Invasive plant species are introduced deliberately or unintentionally outside their natural habitats where they have the ability to establish, spread, sometimes crowd out native vegetation and the wildlife that feeds on it, and even change ecosystem processes. Invasive plants may have economic or environmental impacts on your wooded land."

appropriate for that species, the magnitude of invasion spread, time of the year, and other factors. Our survey was designed to capture FFOs' perceptions, actions, needs, and concerns regarding invasive plant management more broadly; therefore, we could not include variables measuring these two constructs in our analyses because we did not think that we could adequately and reliably estimate them with this general invasive plant species focus.

To ensure that findings regarding PMT-informed variables were not confounded with non-PMT factors, we estimated additional explanatory variables in Model 2 that were previously observed in the literature as influential on FFOs' forest management behaviors and intentions. Specifically, we added literature-informed covariates measuring *ownership objectives* (calculated using a principal component analysis; Table 2). We also added a covariate measuring the extent to which respondents were subject to *normative social influence* by averaging scores measuring their agreement with three statements about conforming to descriptive norms associated with invasive plant management (Table 3). We also added covariates that have been reported in other FFO studies as significant predictors of forest management behaviors and intentions, including past management practices, whether a respondent has a written forest management plan, woodland characteristics, and respondent demographics (see Table 4 for a description of variables).

We ran variance inflation factor (VIF) tests to check for multicollinearity in both models. The VIF score for the first model with only PMT-informed variables was 1.44, well below 4, a common rule of thumb criterion for multicollinearity (Vaske 2008). Before running the second model with PMT-informed and literature-informed variables, several strong correlations were found between self-efficacy and familiarity with invasive plants ($r_s = 0.52$; $p < 0.001$), between owning woodlands for family reasons and absentee ownership ($r_s = -0.61$; $p < 0.001$), and between age and retirement status ($r_s = 0.71$; $p < 0.001$). Generally, a correlation of 0.1 indicates a weak relationship, 0.3 indicates a moderate relationship, and 0.5 or larger indicates a strong relationship (Acock 2016). Consequently, we removed variables

Table 1
Survey items used to derive variables informed by protection motivation theory (i.e., perceived severity, perceived vulnerability, self-efficacy), means, standard deviations, and Cronbach's alpha.

Survey items used to derive variables informed by protection motivation theory	Mean (SD)	% of respondents agreeing or strongly agreeing	Cronbach's alpha
Perceived severity: How seriously an individual believes that invasive plants will be a threat to them or their properties (Feng et al., 2017; Gebrehiwot and Van der Veen 2015; Bockarjova and Steg 2014).			.90
How much do you agree with the following statements? (1 = strongly disagree, 5 = strongly agree)			
1. Invasive plants decrease the beauty of my wooded land.	3.74 (0.87)	61%	
2. Invasive plants are bad for wildlife on my wooded land.	3.48 (0.85)	43%	
3. Invasive plants reduce the property value of my wooded land.	3.54 (0.83)	50%	
4. Invasive plants prevent the growth of new trees on my wooded land.	3.76 (0.83)	63%	
5. Invasive plants reduce the value of timber on my wooded land.	3.57 (0.86)	51%	
6. Invasive plants negatively impact my use or enjoyment of my wooded land.	3.46 (0.97)	50%	
7. Invasive plants negatively impact my ability to hunt on my wooded land.	2.97 (0.98)	27%	
8. Invasive plants negatively impact my ability to recreate (other than hunt) on my wooded land.	3.21 (0.94)	38%	
Perceived vulnerability: How susceptible an individual feels to the threat of invasive plants (Bockarjova and Steg 2014; Martin et al., 2007)			.76
How much do you agree with the following statements? (1 = strongly disagree, 5 = strongly agree)			
1. Invasive plants from neighboring or nearby wooded lands will eventually spread onto my property.	3.78 (0.82)	65%	
2. If I don't remove invasive plants from my wooded land as soon as possible, they will become harder to remove later.	3.92 (0.77)	74%	
Self-efficacy: An individual's perceptions or beliefs about their own abilities to effectively carry out the recommended protective action (Bockjarjova and Steg 2014; Dang et al., 2014; Dittrich et al., 2016)			.88
How much do you agree with the following statements? (1 = strongly disagree, 4 = strongly agree)			
1. I know what invasive plants to watch for on my wooded land.	2.35 (0.82)	43%	
2. I have sufficient time to inspect my wooded land for invasive plants.	2.48 (0.81)	52%	
3. I have sufficient money to remove invasive plants from my wooded land.	2.20 (0.81)	36%	
4. I have sufficient knowledge to prevent and remove invasive plants from my wooded land.	2.15 (0.78)	31%	
5. I have access to the mechanical equipment needed to remove invasive plants from my wooded land.	2.24 (0.91)	42%	
6. I know how to apply herbicides to kill invasive plants on my wooded land.	2.37 (0.91)	49%	
7. I feel comfortable with using controlled burn/prescribed fire to remove invasive plants from my wooded land.	1.74 (0.77)	15%	
8. I know who to contact if I have a question about invasive plants.	2.51 (0.91)	55%	
9. I know who to contact to report sightings of invasive plants.	2.32 (0.89)	43%	
10. I know about county, state or federal programs that assist woodland owners like me in removing invasive plants.	1.88 (0.76)	18%	

Table 2
Description of survey items measuring family forest ownership reasons and the results of a principal component analysis[a].

Survey item[b]	Mean (SD)	% of respondents considering it important or very important	Rotated principal component loading[c]				Cronbach's alpha
			PC_1	PC_2	PC_3	PC_4	
Ownership_nature							.88
To protect nature or biological diversity	3.94 (1.06)	69%	.91				
To protect or improve wildlife habitat	4.04 (1.05)	73%	.87				
To protect water resources	3.69 (1.15)	60%	.80				
To enjoy beauty or scenery	4.20 (1.00)	79%	.76				
Ownership_family							.75
Is part of my home site/primary residence	3.39 (1.65)	58%		.83			
To raise my family	3.17 (1.58)	51%		.78			
For privacy	3.66 (1.42)	63%		.65			
Ownership_recreation							.65
For hunting	3.28 (1.49)	50%			.73		
For recreation, other than hunting	3.36 (1.34)	51%			.68		
Is part of my cabin or vacation home site	2.00 (1.43)	19%			.57		
For nontimber forest products, such as tree nuts, mushrooms, or berries	2.67 (1.32)	28%			.53		
Ownership_utilitarian							.50
For timber products, such as logs or pulpwood	2.77 (1.41)	33%				.79	
Is part of my farm	3.45 (1.58)	59%				.62	
For land investment	3.43 (1.28)	53%				.50	
Survey items that did not load onto any PCs (loadings<0.50)							
To pass land onto my children or other heirs	3.83 (1.37)	68%					
For firewood	2.69 (1.37)	30%					

[a] We used sixteen survey items to measure family forest ownership objectives, similar to previous studies (e.g., Butler et al., 2016). Due to observed high levels of pairwise correlations, a principal component analysis was used to reduce the dimensionality of data from these survey items.
[b] All survey items were measured on a five-point scale (1 = Not important, 2 = Of little importance, 3 = Moderately important, 4 = Important, 5 = Very important).
[c] Rotated principal component loadings smaller than 0.50 are left blank.

Table 3
Survey items used to derive the variable measuring normative social influence, means, standard deviations, and Cronbach's alpha.

Survey item	Mean (SD)	% of respondents agreeing or strongly agreeing	Cronbach's alpha
How much do you agree with the following statements? (1 = strongly disagree, 5 = strongly agree)			.93
If my neighbors are controlling/removing invasive plants from their wooded lands, I will feel the need to do the same.	3.77 (0.85)	71%	
If other woodland owners (not necessarily my neighbors) are controlling/removing invasive plants from their property, I will feel the need to do the same.	3.57 (0.87)	57%	
If my family and friends are controlling/removing invasive plants from their wooded lands, I will feel the need to do the same.	3.66 (0.88)	63%	

measuring familiarity with invasive plants, absentee ownership, and retirement status. After removing these three variables, the VIF score for the second model was 1.77, also well below 4 (Vaske 2008). All data analyses were conducted using Stata 12.0.

4. Results

In this section we first report descriptive results to provide an overview of our study participants and their woodland properties. This is followed by descriptive results of PMT-informed variables and inferential results from the model with both PMT-informed and literature-informed variables. First, in terms of FFOs' sociodemographic characteristics, our respondents were generally comparable to average FFOs in Indiana and nationwide in terms of their sociodemographic characteristics (Clarke et al., 2019). As shown in Table 4, the average age of our respondents was 63.3 years old and about half were retired (49%). Seventy-nine percent of the respondents were male, and 36% had a bachelor's or graduate degree. A third of the respondents reported owning their woodlands for timber products, while the majority of respondents reported owning woodlands for a variety of non-timber related amenity reasons (Table 2). On average, respondents reported having less than 1% of their annual household income coming from their woodlands. In terms of the woodland characteristics, respondents

Table 4
Descriptive statistics for all explanatory variables used in the empirical models for estimating respondents' likelihood to remove invasive plants from their woodlands in Indiana in the next five years.

Explanatory variable	Description	Mean (SD) or %
Perceived severity	Continuous (range: 1–5) – composite score calculated by averaging ratings of eight statements about perceived severity (see Table 1)	3.47 (0.69)
Perceived vulnerability	Continuous (range: 1–5) – composite score calculated by averaging ratings of two statements about perceived vulnerability (see Table 1)	3.84 (0.72)
Self-efficacy	Continuous (range: 1–4) – composite score calculated by averaging ratings of ten statements about perceived self-efficacy (see Table 1)	2.24 (0.60)
Ownership_nature	Continuous (range: -3.41–1.73) – protecting nature as ownership objective (principal component loadings, see Table 2)	0.00 (1.00)
Ownership_family	Continuous (range: -2.49–2.22) – family purposes as ownership objective (principal component loadings, see Table 2)	0.00 (1.00)
Ownership_recreation	Continuous (range: -2.52–2.86) – recreation as ownership objective (principal component loadings, see Table 2)	0.00 (1.00)
Ownership_utilitarian	Continuous (range: -2.97–2.51) – utilitarian reasons as ownership objectives (principal component loadings, see Table 2)	0.00 (1.00)
Ownership_heir	Ordinal – passing land on to children or other heirs as a reason for owning woodlands in Indiana. 1 if not important; 2 if of little importance; 3 if moderately important; 4 if important; 5 if very important	12% (not important) 6% (of little importance) 14% (moderately important) 24% (important) 44% (very important)
Ownership_firewood	Ordinal – collecting firewood as a reason for owning woodlands in Indiana. 1 if not important; 2 if of little importance; 3 if moderately important; 4 if important; 5 if very important	26% (not important) 22% (of little importance) 22% (moderately important) 17% (important) 13% (very important)
Social influence	Continuous (range: 1–5) – composite score calculated by averaging ratings of three statements about being subject to descriptive social norms associated with invasive plant management (see Table 3)	3.67 (0.81)
Familiarity[a]	Ordinal – level of familiarity with invasive plants. 1 if not familiar (i.e., I've never heard of invasive plants before this survey); 2 if low familiarity (i.e., I've heard of invasive plants but do not know much about them); 3 if moderately familiar (i.e., I know about invasive plants but cannot identify specific invasive plant species); 4 if familiar (i.e., I can identify some invasive plant species around where I live); 5 if very familiar (i.e., I can identify all invasive plant species around where I live)	1 = 13% 2 = 21% 3 = 26% 4 = 35% 5 = 5%
Past management	Binary – 1 if reduced or eliminated invasive plants on their property in the past five years; 0 if otherwise	28%
Management plan	Binary – 1 if having a written forest management plan or stewardship plan; 0 if otherwise	21%
Farm history	Binary – 1 if currently or previously farmed; 0 if otherwise	73%
Acreage	Continuous (acres; range: 1–2,000) – forest acreage owned in the state	81.6 (135.4)
Tenure	Continuous (years; range: 0–85)	25.5 (15.7)
Membership	Binary – 1 if member of an environmental, conservation or woodland owner organization; 0 if otherwise	13%
Age	Continuous (years; range: 20–99)	63.3 (12.7)
Retirement[a]	Binary – 1 if retired; 0 if otherwise	49%
Gender	Binary – 1 if male; 0 if otherwise	79%
Education	Ordinal – 1 if education level was high school or less, 2 if education level is some college or Associate degree, 3 if education level is bachelor's degree or higher	1 = 36% 2 = 28% 3 = 36%
Income	Ordinal – 1 if income < $50,000, 2 if income is $50,000- $149,999, 3 if income is ≥ 150,000	1 = 35% 2 = 50% 3 = 15%
Absentee ownership[a]	Binary – 1 if home (primary) residence is more than one mile away from their wooded land in Indiana; 0 otherwise	30%

[a] Variables deleted from the final model with both PMT-informed and literature-informed variables because of strong correlation with other variables.

owned between 1 and 2,000 acres (0.40–809 ha) of woodland (M = 81.60 acres; SD = 135.40). On average, respondents owned their woodland for 25.5 years (SD = 15.70). Thirty percent of respondents were considered absentee owners who lived more than one mile away from their woodland. The majority of respondents (79%) did not have a written forest management plan.

Respondents were asked to report their likelihood to undertake activities to remove invasive plants from their woodlands in Indiana in the next five years. While 23% of respondents indicated they were unlikely or very unlikely to engage in invasive plant management, 27% were undecided, and 50% reported that they were likely or very likely to act. When looking at the survey questions that were used to derive PMT-informed variables, our results show that on average our respondents perceived threats from invasive plants and felt vulnerable to these threats. They indicated relatively low levels of self-efficacy to take protective actions against these threats and potential impacts (Table 1). Of all the potential threats associated with invasive plants, the ones respondents rated as most severe were invasive plants preventing the growth of new trees on FFO's woodlands and decreasing the beauty of their woodlands (63% and 61% agreed or strongly agreed to these two statements; Table 1). Respondents rated the threat of invasive plants negatively impacting FFOs' ability to hunt on their properties as the least severe (27% agreed or strongly agreed to this statement; Table 1). Of the potential ways in which FFOs could take protective actions, the two items that were ranked highest were knowing who to contact to ask a question about invasive plants and having sufficient time to inspect woodlands for invasive plants (55% and 52% agreed or strongly agreed to these two statements, respectively; Table 1). The two items that were ranked lowest were ability to use prescribed fire to remove invasive plants and knowing about governmental programs that assist landowners to remove invasive plants (15% and 18% agreed or strongly agreed to these two statements, respectively; Table 1).

Both of the binary logistic regression models for assessing FFOs' likelihood to remove invasive plants from their woodlands in the next five years were significant at the 0.05 level (Table 5). As hypothesized, respondents were more likely to remove invasive plants if they perceived a higher level of threat from invasive plants (i.e., perceived severity; $p < 0.001$), felt more vulnerable to the threat of invasive plants

Table 5
Logistic estimates of the empirical models for estimating family forest owners' likelihood to remove invasive plants from their woodlands in the next five years.

Explanatory variable	Odds ratio[1]	Standard error	Odds ratio[1]	Standard error
Perceived severity	1.762**	0.222	1.587*	0.305
Perceived vulnerability	1.866**	0.235	1.407	0.276
Self-efficacy	8.583**	1.360	4.743**	1.096
Acreage			1.000	0.001
Farm history			1.128	0.277
Tenure			0.993	0.009
Management plan			1.430	0.393
Past management			3.383**	0.861
Normative social influence			2.048**	0.332
Ownership_nature			1.171	0.134
Ownership_family			1.221	0.164
Ownership_recreation			1.297*	0.164
Ownership_utilitarian			1.063	0.155
Ownership_heir_little importance[3]			0.708	0.348
Ownership_heir_moderately important[3]			0.553	0.215
Ownership_heir_important[3]			0.840	0.311
Ownership_heir_very important[3]			0.396*	0.157
Ownership_firewood_little importance[3]			1.130	0.331
Ownership_ firewood _moderately important[3]			0.906	0.285
Ownership_ firewood _important[3]			1.081	0.419
Ownership_ firewood _very important[3]			1.121	0.543
Membership			0.734	0.239
Age			0.993	0.010
Gender			1.451	0.392
Education_ some college or Associate[3] degree			1.486	0.382
Education_bachelor's degree or higher[3]			1.714*	0.448
Income_$50,000- $149,999[3]			0.647	0.157
Income_ ≥ 150,000[3]			0.601	0.200
# of observations	1,233		717	
LR chi-squared	429.32**		329.87**	
Pseudo R[a]	0.2512		0.3342	

[1] *$p < 0.05$, **$p < 0.01$.
[a] The omitted category for variable ownership_heir is "not important"; the omitted category for variable ownership_firewood is "not important"; the omitted category for variable education is "high school or less"; the omitted category for variable income is "< $50,000."

($p < 0.001$), and had a higher level of self-efficacy ($p < 0.001$) regarding their own abilities to manage invasive plants. After adding additional explanatory variables informed by the literature, perceived severity and self-efficacy remained statistically significant ($p = 0.015$ and $p < 0.001$, respectively), while perceived vulnerability was no longer statistically significant at 0.05 level. In addition, respondents who: (a) who had eliminated or reduced invasive plants on their woodlands in Indiana in the past five years ($p < 0.001$); (b) who reported higher levels of normative social influence from their families, friends, neighbors, and other woodland owners ($p < 0.001$); (c) who owned their woodlands for recreational reasons ($p = 0.040$), and (d) who had a bachelor degree or higher level education ($p = 0.039$), were *more* likely to report a plan to remove invasive plants in the next five years. Those who reported passing land on to their children or other heirs as a very important ownership reason were *less* likely to report a plan to remove invasive plants compared to those who reported this to be unimportant ($p = 0.019$).

5. Discussion

The aim of this paper was to investigate the factors that influence FFOs' willingness to manage invasive plants on their properties through the lens of protection motivation theory. Our results provide empirical evidence that at least two key components of protection motivation theory (i.e., perceived severity, self-efficacy) are associated with FFOs' likelihood to remove invasive plants from their woodlands while considering a wide range of landowner and landownership characteristics. While FFOs in our study perceived a variety of threats from invasive plants and felt vulnerable to these threats, the majority of FFOs did not have a strong sense of self-efficacy regarding different aspects of managing invasive plants on their woodlands (Tables 1 and 4). However, those with higher perceived self-efficacy did report higher likelihood to manage invasive plants than FFOs with lower perceived self-efficacy. Specifically, a one-unit increase in self-efficacy put a FFO at 4.743 times greater odds of reporting being likely or very likely to remove invasive plants ($p < 0.001$), while holding all the other explanatory variables constant. This result is consistent with previous research that shows perceived self-efficacy is a strong determinant of pro-environmental behaviors such as the adoption of electric vehicles (Bockjarjova and Steg 2014) and wildland fire prevention (Martin et al., 2007). Our study further sheds light on opportunities for educational, outreach and assistance programs to help build and enhance self-efficacy among FFOs regarding invasive plant management, which can be beneficial in inducing invasive plant management activities. It is also important to note that our regression results were not conclusive regarding the role of perceived vulnerability in shaping FFOs' likelihood to remove invasive plants from their woodlands. In our analyses, two-way correlations between perceived vulnerability and the additional explanatory variables informed by the literature were small (Acock 2016). This suggests that further research is needed to understand how perceived vulnerability interacts with other possible determinants of likelihood to remove invasive plants.

Most FFOs in our study were not aware of county, state, or federal programs that assist landowners like themselves in removing invasive plants. Raising awareness about such programs and other available resources can be a relatively straightforward goal at the local and state levels. FFOs may also gain a sense of self-efficacy through seeing successful reduction in invasive plants achieved by other landowners (Graham 2013; Prinbeck et al., 2011). This may be achieved by demonstration projects and field days organized by local and state forestry professionals (Presternon 1986; Bruynis et al., 2014). However, because some invasive plants require persistent efforts to be reduced or removed, it is important for various educational, outreach and assistance programs to effectively communicate with FFOs about the long-term nature of invasive plant management. These landowner programs may also consider developing long-term strategies to motivate FFOs over time and help reinforce their determination to act particularly when it is not possible to immediately reduce or eliminate invasive plants (Ma et al., 2018; Graham 2013; Niemiec et al., 2017). It is equally important for these programs and their donor organizations to *not* measure landowner success or their own program or organizational success solely based on immediate reduction or elimination of invasive plants.

Although normative social influence is not a component of PMT, we included it in our second model because previous studies have shown an association between social norms and landowner behaviors around the management of invasive plants (Graham 2013; Graham and Rogers 2017; Hershbdorfer et al., 2007; Ma et al., 2018; Niemiec et al., 2016; Yung et al., 2015). For example, landowners have been found to be motivated by community reciprocity and whether their neighbors are also managing invasive plants on their properties (Ma et al., 2018; Niemiec et al., 2016). As an invasion source, landowners identified invasive plant seedlings from neighboring properties to be a significant cause of invasion on their own properties (Yung et al., 2015). Our study provides additional evidence that the more strongly FFOs are influenced by descriptive social norms around invasive plants, the more likely they are to manage invasive plants. In fact, descriptive social norms were the

third most important predictor in our model, following perceived self-efficacy (odds ratio = 4.743; $p < 0.01$) and past management experience (odds ratio = 3.383; $p < 0.01$). Specifically, a one-unit increase in social influence put an FFO at 2.048 times greater odds of reporting being likely or very likely to remove invasive plants ($p < 0.01$), while holding all the other explanatory variables constant. As such, emphasizing these descriptive social norms, as well as expectations from relevant others (i.e., injunctive social norms) as part of FFO educational, outreach and assistance programs could potentially boost both individual and collective action around invasive forest plant treatment.

Our work also indicates that two ownership reasons were significantly associated with FFOs' intentions to manage invasive plants. First, those who owned their land for recreational pursuits were more likely to remove invasive plants. Invasive plants can have negative impacts on recreational activities like hiking, hunting, and observing wildlife (Eiswerth et al., 2005), which could explain the positive association between ownership for recreation and intentions to remove invasive forest plants. For example, invasive plants like tree of heaven (*Ailanthus altissima*) may cause skin irritations (Kowarik and Säumel, 2007) while other species like multiflora rose (*Rosa multiflora*) may even cause injury to people because of their thorny thickets and increase the prevalence of Lyme disease pathogen (Adalsteinsson et al., 2018), thereby making it more difficult for landowners to use and enjoy their property for recreational purposes. Therefore, outreach efforts that emphasize the impacts that invasive plants can have on recreational activities like hunting and hiking might be an effective strategy for encouraging management behavior among certain segments of FFOs. In contrast, owning woodlands for the protection of nature (such as biological diversity and wildlife habitat) was not significant in our model for estimating FFOs' likelihood of removing invasive forest plants. This may suggest a disconnect in FFOs' understanding about the relationship between invasive plants and forest health, biological diversity, and wildlife habitat quality.

The second ownership reason that was significantly associated with FFOs' intentions to manage invasive plants was passing land on to children and other heirs. Specifically, FFOs who highly valued their woodlands as something to pass on to heirs were less likely to report a plan to remove invasive plants. These results may suggest that complex factors such as parcelization (Metcalf et al., 2016) and uncertainties about the future ownership of the property (Mater 2001; Greene et al., 2014) may discourage landowners from spending additional resources and planning required to manage invasive forest plants. Another explanation for this negative association between likelihood to remove invasive plants and the heir ownership reason is if land transfer is imminent, or if landowners feel forced to subdivide their forest properties among heirs because of financial or legal reasons, they may not have the capacity, means, or interest in future land management activities (Gruver et al., 2017; Hitchner et al., 2017). As such, our results suggest a need for increased communication with FFOs about the long-term negative impacts on the health and productivity of family forests that heirs may inherit if invasive plants remain unmanaged.

Although the percentage of our respondents with a written management plan (21%) is higher than the 13% national average for FFOs with 10+ acres of woodlands (Butler et al., 2016), our study did not find that having a written forest management plan was a statistically significant variable in our model. This result was surprising because previous studies have found that FFOs with written management plans are more likely to engage in other forest management activities (Cai et al., 2016; Joshi and Arano 2009). This finding could suggest that invasive plants may not be typically addressed in forest management plans and/or prioritized by FFOs.

Our results support previous research which found that landowners with higher education are more likely to manage invasive species (Niemiec et al. 2017b, 2018; Steele et al., 2006). However, other sociodemographic variables like age, gender, income, and membership in an environmental, conservation, or woodland owner organization were not statistically significant. Previous studies have found variables like these to be significant predictors of FFO behavior (Butler et al., 2018; Ma et al., 2012). The lack of significance of these variables could suggest that other factors like perceived severity about the threat of invasive plants, self-efficacy about one's own ability to control invasive plants, and descriptive social norms associated with invasive plant management, are more influential in shaping FFOs' plan to remove invasive plants than sociodemographic factors.

We also acknowledge that we were only able to measure three components of the PMT in the context of invasive plant management. Future studies may benefit from examining the role of other PMT components, namely perceived response efficacy and response cost, in shaping FFOs' likelihood to manage invasive plants. Another area for research is to gain a better understanding of how landowners engage with their forestlands affect their perceptions and behaviors towards invasive plants. Scholars have increasingly noted the phenomenon of "extinction of experience," that is, the decrease in the frequency and quality of people's direct interactions with nature (Soga and Gaston 2016; Soga et al., 2019). Soga and Gaston (2018, p.351) warned that the decreasing direct and regular contact with local flora "may contribute to a reduced ability to perceive the changes in the condition of the neighborhood natural environment, which can ultimately lead to an increased societal tolerance for progressive environmental degradation." As such, it will be important to investigate the extent to which landowners' interactions with nature and their forestlands have changed over time and how such changes may impact landowners' perceptions of invasive plants and resulting management decisions.

Finally, previous studies showed that landowners could perceive both risks and benefits of invasive plants, with the latter potentially including invasive plants being aesthetically pleasing, providing food for wildlife, and contributing to landowners' sense of place (Niemiec et al., 2017b). We did not ask FFOs about perceived benefits of invasive plants. It would be informative for future research to further evaluate both ecosystem services and disservices associated with invasive plants and to consider both when seeking to understand landowner behavior around invasive plant management (Barney et al., 2013; Milanović et al., 2020; Vaz et al., 2017).

6. Conclusion

Invasive plant management on family forestlands is becoming increasingly important because of the large number of FFOs and the complexities involved in FFO decision making. To date the literature has focused primarily on general forest management behaviors and intentions of FFOs, with few examining the role of psychological factors in their decisions to manage invasive plants. Our study drew from a social psychological theory—protection motivation theory—to better understand FFOs' likelihood to manage invasive plants. We found that two components of PMT (i.e., perceived severity of invasive plants as a threat, perceived self-efficacy to take protective actions to reduce or eliminate the threat), were statistically significant factors associated with FFOs' intention to remove invasive plants. Our study suggests that it is important to consider these psychological factors, and potentially others, when communicating with FFOs about invasive plant management. Our study suggests it may be productive to develop opportunities to enhance FFO's self-efficacy around invasive plant management. Such opportunities may include raising awareness of landowner invasive plant control programs at the local, state and federal levels and enhancing FFOs' confidence and commitment by showing them successful invasive plant control efforts made by their peer landowners. Overall, our study shows that elements of PMT provide a useful lens for identifying psychological factors that influence FFOs' management decisions to remove invasive plants, and potentially their decisions to take protective actions to address other slow onset environmental risks.

Credit author statement

Mysha Clarke: Conceptualization, Methodology, Writing – original draft, Project administration, Formal analysis, Investigation, Data curation, Zhao Ma: Conceptualization, Methodology, Writing – review & editing, Funding acquisition, Project administration, Resources, Data curation, Formal analysis, Investigation, Supervision, Stephanie Snyder: Methodology, Writing – review & editing, Funding acquisition, Erin Hennes: Methodology, Writing – review & editing, Funding acquisition

Declaration of competing interest

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

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