THE HUMAN DIMENSIONS OF INVASIVE PLANT MANAGEMENT ON FAMILY FORESTLANDS: A CASE STUDY OF INDIANA

by

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A Dissertation

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

Department of Forestry & Natural Resources

West Lafayette, Indiana

August 2018

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This work is dedicated to my family and the wonderful community that has supported me throughout this journey.

ACKNOWLEDGMENTS

I am eternally grateful to the wonderful community of family, mentors and friends who have supported me on this journey. I would like to thank my family for their continued support through the good and bad times of this program. I am also very grateful and incredibly lucky to have Dr. Zhao Ma as my major professor. This would not have been possible without Dr. Ma's patience, guidance, support and overall professional mentorship throughout the entire program. I am also grateful to other mentors such as Rachel Reyna, Su Ann Schupp, Dr. Ann-Marie Nicely, Dr. Eva Haviorava and Dr. Sarah Church among many others at Purdue and beyond. I would also like to thank my graduate committee members: Dr. Erin Hennes, Dr. Stephanie Snyder, Dr. Torsten Reimer and Dr. Mike Jenkins for providing me with invaluable advice, constructive feedback on how to be a better researcher and scholar and their continued support. Many thanks also to the Human Dimensions Lab in the Department of Forestry and Natural Resources for their help with data collection and for their friendship and support as fellow graduate students. I would also like to express my gratitude to the administrative staff in the Department of Forestry and Natural Resources including Christine Hofmeyer, Dawn Oliver, Jennifer Spitznagle who have helped me with travels, grants and general logistics of graduate school. Finally, I am also very appreciative of the amazing friends who provide encouragement, adventure, laughter and a shoulder to lean on when I needed it. Thank you all very much!

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ABSTRACT

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Institution: Purdue University
Degree Received: May 2018
Title: The Human Dimensions of Invasive Plant Management on Family Forestlands: A Case Study in Indiana.
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Invasive plant management is an increasing concern in socio-ecological systems. Ecologically, invasive plants can displace native species, reduce forest health and productivity, and degrade recreational areas. From a socio-economic perspective, the United States spend approximately USD 137 annually in damage and control costs from invasive plants and animals. Despite these impacts, invasive plants continue to spread in forest ecosystems because of various anthropogenic factors like trade, transportation, climate change, and limited regulation in many states. It is pivotal to consider the role of family forest owners (FFOs) in invasive plant management in forest ecosystems because collectively they own 36% of forests in the United States. So far, a limited number of studies have focused on the human dimensions of invasive plant management, and even fewer studied FFOs.

To address this gap, we had three primary research objectives. First, we wanted to investigate the knowledge, attitudes, perceptions, and behaviors of FFOs (and forestry professionals) towards invasive plants and their needs and concerns regarding the prevention and control of invasive plants. Second, we wanted to assess factors that influence FFOs' perceptions, intentions, and individual actions regarding invasive plant management. Third, we wanted to assess the role of social influence and collective efficacy beliefs in shaping FFOs' perceptions towards cooperative management of invasive plants. To address these research objectives, we used a mixed-methods approach to collect and analyze both qualitative and quantitative data. The qualitative data was collected by conducting 25 face-to-face, semi-structured interviews with FFOs and forestry professionals who work with FFOs. The quantitative data was collected by conducting a mailed survey of 2,600 randomly selected FFOs in Indiana, USA.

We found that FFOs were moderately familiar with and concerned about invasive plants on their own and nearby properties. Although most FFOs expressed little confidence in their abilities to remove and prevent invasive plants, they also reported certain invasive plant

management actions including inspecting their woodlands, talking to families and other landowners, and removing invasive plants, all without much input from natural resource professionals. Furthermore, most FFOs indicated that they learned about invasive plants and how to manage them via their social networks and self-directed learning. The majority of FFOs also reported limited or no experience interacting with natural resource professionals and they also expressed little interest in such interactions in the future.

Our results also suggest that FFOs are influenced by perceived severity, perceived vulnerability, and perceived self-efficacy, which were all statistically significant predictors of FFOs' self-reported likelihood to manage invasive plants on their properties in the next five years. We also found that FFOs who had invasive plant management experience and those who were subject to social influence from families, friends and other woodland owners, tended to indicate a higher likelihood to remove invasive plants in the next five years. Unlike some of the previous studies, the only statistically significant demographic and ownership characteristics that predicted FFOs' self-reported likelihood to remove invasive plants was education level, owning woodlands for recreational purposes, and owning woodland to pass on to heirs. In terms of collective invasive plant management, we found that previous experience of talking to others about invasive plants, previous experience of working with neighbors, and perceiving a need for collective action to manage invasive plants, were all statistically significant predictors of FFOs' self-reported plan to work with their neighbors to remove invasive plants in the next five years. Perceived self-efficacy was also found to be a statistically significant predictor. However, none of the demographic or ownership characteristics except for woodland holding size, were statistically significant predictors of FFOs' likelihood to engage in cooperative management of invasive plants.

Based on our findings, we suggest that future invasive plant management policies and programs should develop innovative ways to build individual competency, self-confidence, a shared concern about invasive plants, and trust among FFOs. Our results also highlight the importance of applying the concepts of collective efficacy and social influence to better understand invasive plant management specifically and possibly forest management challenges in general. Overall, our results can be used to inform forestry professionals and organizations about potential strategies to engage FFOs in invasive plant management on their own properties and to work collectively with others to create healthier and more productive forested landscapes.

CHAPTER 1. WHAT ARE FAMILY FOREST OWNERS THINKING AND DOING ABOUT INVASIVE PLANTS?

1.1 Abstract

Effectively managing invasive plants across forested landscapes requires voluntary control by 10.7 million family forest owners (FFOs) who own 36% of forestlands in the USA. The literature on individual and collective invasive plant management has focused on farmers, ranchers, urban gardeners and community residents, with less attention on forestlands and the role of FFOs. By analyzing survey data from 1,422 FFOs in Indiana, USA, we provide a thorough assessment of FFOs' awareness, perceptions, behaviors and intentions towards invasive plants; as well as their needs and challenges. In our study, FFOs reported moderate familiarity with, concern about, and interest in invasive plant control on and around their properties. Despite a lack of confidence in their ability to manage invasive plants, FFOs reported having taken actions on the ground, including inspecting their woodlands, talking to families and other landowners, and removing invasive plants, all without much input from natural resource professionals. Most FFOs relied on self-directed learning and social networks for invasive plant-related information and advice. They generally had little or no experience or interest in interacting with natural resource professionals. This suggests a need for natural resource professionals to refocus their efforts on developing communication strategies to target specific segments of FFOs, stronger online presence to facilitate self-directed learning, and partnerships with non-profit organizations trusted by FFOs to encourage self-organization and sharing of information and resources. These results from Indiana can be used to inform how to engage FFOs to management invasive plants more broadly

1.2 Introduction

Nearly half of the forests in the eastern United States are infested by invasive plants (Oswalt et al. 2015). Invasive plants can displace native plants; reduce wildlife habitat; decrease forest health, productivity and resilience; and reduce the provisioning of various ecosystem services such as water quality protection and recreation (Coyle et al. 2016; Fei et al. 2014; Paini et al. 2016; Pejchar and Mooney 2009). Several invasive plants such as garlic mustard (*Alliaria petiolata*) and tree of heaven (*Ailanthus altissima*) can also alter soil chemical composition, making it difficult

for other seedlings to grow (Simberloff 2013; Peters and Meyer 2006). Despite their ecological impacts, invasive plants continue to spread via anthropogenic influences including agricultural, medicinal, and horticultural uses as well as transportation (Simberloff 2013).

Previous research has focused primarily on the ecological processes of nonnative plants including their reproduction, dispersal, and invasion patterns (e.g., Catford et al. 2009; Richardson et al. 2000). Studies have also assessed the effectiveness of various control (removal and prevention) strategies in managing specific invasive plant species, mostly on federal and state-owned land (e.g., Mangold and Sheley 2008; Miller et al. 2013). Despite an increase in scientific understanding and public awareness about invasive plants (Burt et al. 2007), there is still limited understanding about their impacts on recreation, culture, and community social values (Pejchar and Mooney 2009; Simberloff 2013). In fact, less than 1% of the total number of journal articles published from 1980 to 2013 (i.e., 125 out of 15,915 articles) on invasion biology and management examined the social dimensions of nonnative plant invasions, such as values and risk perceptions, resource management behaviors, and the philosophy and history of management (Estevez et al. 2015).

A growing number of researchers have started to recognize that managing invasive species is "as much a social issue, encompassing political and human factors, as it is a scientific one" (Bremner and Park 2007: 307; Epanchin-Niell et al. 2010; Head 2017; Kueffer 2010; Reaser 2011). As such, it becomes imperative to incorporate the social sciences and humanities to analyze people's conceptualization of invasive versus native plants, their attitudes, values and practices associated with invasive plant management, and the politics and policies underlining such management (Head 2017). Indeed, the past decade has seen an increase in using social science and humanities theories and methods to examine invasive plant management efforts in the United States and beyond (e.g., Sullivan et al. 2017a, 2017b; Epanchin-Niell et al. 2010; Ervin and Frisvold 2016; Hershdorfer et al. 2007; Niemiec et al. 2016, 2018; Yung et al. 2015).

Specifically, private landowners have been the focus of many such studies. This is because the success of invasive plant prevention and control relies on not only actions of public resource managers, but thousands of private individuals taking actions on their own properties. Failing to engage private landowners will compromise the overall effectiveness of invasive plant management on a landscape scale. Generally, previous landowner studies have highlighted the importance of raising landowner awareness and communicating invasive plant-related information in a way that

resonates with landowners and that is consistent with their management objectives (Aslan et al. 2009; Fischer and Charnley 2012; Ma et al. 2018; Niemiec et al. 2017a, 2017b; Steele et al. 2006, 2008). Several studies also show that landowners may have widely different perceptions of invasion risks, ranging from a lack of concern, to the belief that nonnative plants can be effectively controlled, to the view that invasions have gone out of control (Fischer and Charnley 2012; Yung et al. 2015). Previous research seems often ending with highlighting a need for locally adapted invasive plant management programs that provide education, technical assistance, and financial incentives to encourage invasive plant management by private landowners (e.g., Epanchin-Niell et al. 2010; Graham 2013; Hershdorfer et al. 2007; Howle and Straka 2010; Larson et al. 2011).

More recently, there has been increased effort to understand landowners' interest and ability to engage in collective and/or cooperative management of invasive plants beyond individual property boundaries (e.g., Epanchin-Niell et al. 2010; Graham 2013; Graham and Rogers 2017; Marshall et al. 2016; Niemiec et al. 2016, 2017a, 2017b; Sullivan et al. 2017a, 2017b; Yung et al. 2015). Collective, and/or cooperative invasive plant management tends to be more effective than individual, uncoordinated management (Epanchin-Niell and Wilen 2015; Hershdorfer et al. 2007;). So far, research has suggested that landowners' willingness to collectively manage invasive species is influenced by their knowledge of invasive species; access to relevant information; joint learning about the social and biophysical interdependencies; as well as time, money, and other resources they must contribute (Graham 2013). More importantly, their willingness to engage in collective and/or cooperative management also depends on their relationship with neighbors and a sense of community (Graham 2013; Graham and Rogers 2017; Marshall et al. 2016), past management by neighbors (Epanchin-Neill and Wilen 2015; Hershdorfer et al. 2007; Klepeis et al. 2009; McKiernan 2017 Yung et al. 2015), and social norms and community reciprocity (Graham 2013; Marshall et al. 2016; Niemiec et al. 2016). In government-organized cooperative weed management programs, the level of trust landowners have towards government employees can be a significant deciding factor in terms of landowners' decision to participate (Graham 2013).

The aforementioned literature provides important insights into individual and collective invasive plant management on private lands; however, the focus of previous studies has been on farmers, ranchers, urban gardeners, and community residents (Head 2017). There is limited understanding of invasive plant management specific to forestlands, particularly the role of family forest owners (FFOs) in the United States FFOs are an important group to study in the context of

invasive plants management in forest ecosystems in the United States because a substantial portion of American forests (36%) are owned by 10.7 million FFOs, a subset of private forest landowners who are mostly forest-owning individuals, families, and family partnerships (Butler et al. 2016a). Although each FFO is only responsible for her property, they can have a strong cumulative influence on the outcome of invasive plant control efforts at the landscape scale. FFOs opting not to control invasive plants would allow their lands to act as invader propagule sources, increasing control costs for neighboring private and public landowners (Daab and Flint 2010, Epanchin-Niell et al. 2010; Hershdorfer et al. 2007). To date, only a handful of studies have examined FFOs' awareness, risk perceptions, and management intentions and behaviors with regard to invasive plants. For example, Howle et al. (2010) reported qualitative results from focus groups with FFOs in South Carolina regarding how they perceived Chinese privet (*Ligustrum sinense*) management, particularly the feasibility of herbicide control and treatment efficiency. Steele et al. (2006) and Steele et al. (2008) both focused on FFOs in West Virginia and found through their qualitative interviews and a mail survey that the majority of FFOs were aware of invasive plant problems, among which the majority had undertaken control measures. In a different study, Fischer and Charnley (2012) also reported results from a mail survey and qualitative interviews of FFOs in Oregon's ponderosa pine zone. Specifically, they show that being aware or concerned about invasive plants and holding a wildlife or biodiversity ownership objective were both important predictors of whether a FFO would control invasive plants on her property. As such, there is a knowledge gap in understanding how FFOs on the ground perceive and act towards invasive plants, particularly in the Midwestern United States where no study of invasive plants management on family forests have been conducted.

Beyond invasive plant management, substantially more research has been conducted to identify factors influencing FFO behaviors and decision making in other contexts such as timber harvesting, wildlife habitat improvement, fire management, and participation in government-sponsored assistance programs. These include landownership characteristics such as acreage, landowner absentee status, length of land tenure, landownership objectives, having a written forest management plan, and landowner past management activities (e.g., Fischer 2011; Joshi and Arano 2009; Ma et al. 2012a; Silver et al. 2015). Socio-demographic characteristics such as landowner age, education, gender, income, occupation, and membership in a landowner association or environmental organization, have also been found to influence FFO behaviors and decision making

in some contexts (e.g., Ma et al. 2012a; Joshi and Arano 2009). Finally, while knowledge and awareness is a precursor to taking actions, previous research has also shown that knowledge transfer to landowners is not sufficient to influence behavioral change (McLeod et al. 2015), and that other psychological, cognitive, social, economic, and institutional factors also play important roles such as environmental values (Farmer et al. 2015), social norms (Karppinen and Berghäll 2015), community structure and diversity (Paveglio et al. 2009), and having access to financial and technical assistance (Kilgore et al. 2015).

We draw upon findings from these studies that examined FFO behaviors, intentions and attitudes in a wide range of contexts to examine whether they are also instructive in helping to understand FFO perceptions and actions relative to invasive forest plants. With a focus on FFOs in Indiana, our study asks the following questions: (1) To what extent are FFOs aware of and concerned about invasive forest plants, including herbaceous plants, shrubs and trees? (2) What actions have FFOs taken to prevent and control invasive forest plants? (3) What are the challenges and opportunities FFOs face regarding invasive forest plant management? This study is descriptive in nature due to a lack of invasive plant-related research in the context of family forestlands; thus, there is need for a thorough descriptive study to establish a foundational understanding of FFOs' invasive plant-related awareness, risk perceptions, management intentions and behaviors. Descriptive research involves gathering data and using descriptive statistics to describe phenomena, events and processes (Glass and Hopkins 1984) and is aimed at finding out "what is" or "what the data shows" (Borg and Gall 1989). Descriptive research "often illuminates knowledge that we might not otherwise notice or even encounter" and creates opportunities for producing "new knowledge about value systems or practices" that may have not been identified previously (Knupfer and McLellan 1996: 1197). Such new knowledge then becomes the foundation for generating hypotheses and further pursuing various quantitative investigations (Grimes and Schulz 2002).

1.3 Methods

1.3.1 Study Site

Indiana has approximately 4.9 million acres of forestlands, comprising 20% of the state's land (Gormanson 2014), of which 3.6 million acres are owned by FFOs and the average size of

family-owned forestlands that are 10+ acres in Indiana is 37.8 acres (15 hectares) (Butler et al. 2016b). Hardwoods are the dominant species in Indiana's forests, and the oak/hickory forests are the most common, occupying 72% of all forestlands (Gormanson 2014). Within the state, several federal and state programs are available to provide technical, cost-share, and other financial assistance to help landowners improve wildlife habitat, protect wetlands, protect soil and water quality, and establish conservation easements. Some of these programs also assist landowners who want to control invasive plants, such as the Community and Urban Forestry Assistance Grant program operated by Indiana Department of Natural Resources and the Environmental Quality Incentives Program administered by the USDA National Resources Conservation Service. In addition, Indiana's Classified Forest and Wildlands Program provides landowners with a property tax reduction in exchange for developing and following a professionally written management plan that encourages timber production, watershed protection, and wildlife habitat management on private lands in Indiana.

1.3.2 Data Collection and Analysis

The data for this study were collected through a statewide mail survey of FFOs across Indiana. To assemble a sampling frame for the survey, we used statewide forest parcel data available through IndianaMap (http://www.indianamap.org/) and property ownership information from the Indiana Department of Local Government Finance to identify the forested parcels with landowner information. After deleting industrial and organizational owners and other erroneous entries, we obtained a list of 163,666 FFOs who own at least one acre (0.40 ha) of forested property categorized as "woodland" or "classified forest" in the state of Indiana as of 2014. Power calculations suggest that 2,600 FFOs will allow us to capture small effect sizes with 80% power assuming a 5% significance level (Cohen 1988). We then drew a random sample of 2,600 FFOs from this list and administered a mail survey following the Tailored Design Method (Dillman et al. 2014). Specifically, we sent out a pre-notification postcard, followed by a survey package that contained a cover letter explaining the purpose of our survey and inviting participation, a copy of the survey questionnaire, a pre-addressed, pre-stamped return envelope, and a $2 bill as a token of appreciation. We followed up with a reminder postcard and two more mailings of the survey package without additional $2 bills. The survey was administered from November to December

2015. Of the 2,600 initial FFOs contacted, 112 had inaccurate or unreachable addresses and 64 were deceased or no longer owning woodland, reducing the actual sample size to 2,424. Among these 2,424 FFOs, 1,422 completed the survey questionnaire, representing a response rate of 58.7%.

The questionnaire was informed by 23 face-to-face, semi-structured interviews with selected forestry professionals and FFOs in Indiana between February and May of 2015. The questionnaire contained 43 binary, Likert-scale, and multiple choice questions covering: (1) general characteristics of the woodlands owned by respondents, (2) their familiarity with invasive plants in general, on their properties, and on nearby woodlands, (3) previous invasive forest plant management actions and likelihood to take actions in the future, (4) perceived needs and opportunities for invasive plant management in Indiana, and (5) demographic characteristics of the respondents. We also provided a definition of invasive plants on the cover of the survey questionnaire to ensure a shared understanding of the concept. The study was approved by Purdue University's Institutional Review Board.

Potential non-response bias was examined. As a proxy for detecting differences between respondents and non-respondents, we compared responses from early (first 10%) and late (last 10%) survey respondents (Armstrong and Overton 1977) with respect to respondents' demographic characteristics, characteristics of their woodlands, familiarity and attitudes towards invasive plants, and their past management actions. No statistically significant differences ($p \leq 0.05$) were detected. Univariate descriptive statistics were computed for all variables to assess their distributions and determine if any outliers existed. Bivariate relationships were examined using the following tests: (1) Pearson Chi-square test, which assesses whether two categorical variables of interest are independent of each other; (2) Kruskal-Wallis H test, which is the nonparametric alternative to the one-way ANOVA; and, (3) Fisher's exact test, which is used when one or more assumptions of performing a chi-square test are violated. These statistical analyses were used to understand the relationships between FFOs' awareness, management actions, concerns, needs and preferences and to identify similarities and differences across FFO types. The software package used for the statistical analyses was Stata 12.0.

1.4 Results

1.4.1 Profile of Respondents

The average age of respondents was 63 years old. Seventy-nine percent respondents were male, almost half were retired (49%), and 36% had a Bachelor's or graduate degree. On average, respondents reported that one percent of their annual household income was derived from their woodland (Table 1). They also reported owning woodlands mostly for amenity reasons, and their top five reasons for woodland ownership were to: (1) enjoy scenery or beauty, (2) protect or improve wildlife habitat, (3) protect nature and biological diversity, (4) pass land onto children or other heirs, and (5) protect water resources. Only a third of the respondents owned their woodlands for the purpose of producing timber products, such as logs or pulpwood.

Respondents owned between 1 and 2,000 acres (0.40 – 809 ha) of woodland (mean=82 acres; SD=135.4). More specifically, 11% owned less than 10 acres, 14% owned 10-19 acres, 28% owned 20-49 acres, 22% owned 50-99 acres, and 25% owned 100 or more acres (Table 2). Over half (52%) of respondents shared landownership with their spouse or another individual, 36% had individual ownership, and the remaining 12% had joint ownership with two or more people. On average, respondents owned their woodland for 25 years, although 9% were new owners with five years or less experience and 8% were long-term owners with 50 years or more of experience. Thirty percent of respondents were considered absentee owners who lived more than one mile away from their woodland. Less than a quarter of respondents had a written forest management plan (21%), 35% had participated in the Indiana Classified Forest and Wildlands Program, and 13% were members of an environmental, conservation or woodland owner organization. Seventy-three percent of respondents indicated that their woodland was either currently (57%) or previously (16%) farmed.

1.4.2 Familiarity with and Concern about Invasive Plants

Respondents had varying levels of familiarity with invasive plants. Forty percent indicated that they could identify some or all invasive plant species around where they live, 26% knew about invasive plants but could not identify specific species, and 34% reported little to no familiarity. The three most common ways FFOs first became aware of invasive plants on their woodland were

from forestry or natural resource professionals (30%), through forestry newsletters or magazines (29%), and through learning about them from newspapers, television, radio, and other forms of mass media (22%). Those who could identify invasive plants reported noticing various species (Table 2): the most common were multiflora rose (*Rosa multiflora*), Asian bush honeysuckle (*Lonicera maacki*), Japanese honeysuckle (*Lonicera japonica*), autumn olive (*Eleagnus umbellata*), and garlic mustard (*Alliaria petiolata*).

Some respondents reported little to no concern about invasive plants on their woodlands (23%) or neighboring/nearby lands (32%), but 42% were concerned or very concerned about invasive plants on their own woodland while 35% were concerned or very concerned about invasives on neighboring/nearby lands. Regarding potential negative impacts of invasive plants, half or more respondents were concerned about invasive plants negatively impacting new tree growth, decreasing the beauty of woodlands, reducing timber value and property value, and negatively impacts the use or enjoyment of woodlands. Fewer than half respondents were concerned about invasive plants' impacts on wildlife, hunting, or other recreational values of the woodlands (Figure 1).

Generally speaking, respondents' familiarity with invasive plants differed based on their socio-demographic characteristics (Table 4). Older and retired respondents were more likely to have little to no familiarity with invasive plants ($\chi^2 = 18.836$, $p < 0.001$ and $\chi^2 = 22.3968$, $p < 0.001$, respectively). Those with higher education levels, higher household incomes, and memberships in conservation, environmental or woodland owner organizations, were more familiar with invasive plants ($\chi^2 = 92.4097$, $p < 0.001$; $\chi^2 = 17.5420$, $p = 0.025$; Fisher's exact $p < 0.001$; respectively). Those who had more woodlands, who had a written management plan, whose woodlands were enrolled in the Indiana Classified Forest Program, and whose woodlands were currently or previously farmed, were also more familiar with invasive plants ($\chi^2 = 84.934$, $p < 0.001$; $\chi^2 = 137.6236$, $p < 0.001$; $\chi^2 = 82.0214$, $p < 0.001$; $\chi^2 = 26.4692$, $p < 0.001$; respectively). Familiarity with invasive plants was not, however, associated with respondents' gender ($\chi^2 = 9.3770$, $p = 0.052$), whether they were absentee landowners ($\chi^2 = 6.0899$, $p = 0.193$), or the length of their landownership ($\chi^2 = 1.843$, $p = 0.1747$).

Respondents' concerns with invasive plants also differed based on their socio-demographic characteristics (Table 4). The same set of variables are associated with both concerns about invasive plants on their own woodlands and concerns about invasive plants on neighboring or

nearby woodlands. Specifically, respondents with higher levels of education and memberships in conservation, environmental or woodland owner organizations, were more likely to be concerned about invasive plants (on own woodlands: $\chi^2 = 16.0492$, $p < 0.042$ and $\chi^2 = 38.6527$, $p < 0.001$, respectively; on neighboring/nearby woodlands: $\chi^2 = 27.4547$, $p = 0.001$ and $\chi^2 = 34.834$, $p < 0.001$, respectively). Those who had more woodlands, who had a written management plan, and whose woodlands were enrolled in the Indiana Classified Forest Program, were also more likely to be concerned about invasive plants (on own woodlands: $\chi^2 = 53.481$, $p < 0.001$; $\chi^2 = 52.0284$, $p < 0.001$; $\chi^2 = 45.4454$, $p < 0.001$; respectively; on neighboring/nearby woodlands: $\chi^2 = 38.454$, $p < 0.001$; $\chi^2 = 51.5573$, $p < 0.001$; $\chi^2 = 32.3284$, $p < 0.001$; respectively). Respondents' levels of concerns about invasive plants on their own or neighboring/nearby woodlands were not, however, associated with respondents' age ($\chi^2 = 1.649$, $p = 0.800$ and $\chi^2 = 4.632$, $p = 0.327$, respectively), retirement status ($\chi^2 = 5.0290$, $p = 0.284$ and $\chi^2 = 6.3225$, $p = 0.176$, respectively), gender ($\chi^2 = 6.5567$, $p = 0.161$ and $\chi^2 = 5.9983$, $p = 0.199$, respectively), income ($\chi^2 = 7.0986$, $p = 0.526$ and $\chi^2 = 14.2528$, $p = 0.817$, respectively), resident/absentee status ($\chi^2 = 4.7069$, $p = 0.319$ and $\chi^2 = 1.7963$, $p = 0.773$, respectively), the length of their landownership ($\chi^2 = 2.8433$, $p = 0.584$ and $\chi^2 = 7.4557$, $p = 0.114$, respectively), or whether their woodlands were currently or previously farmed ($\chi^2 = 6.3246$, $p = 0.611$ and $\chi^2 = 8.9867$, $p = 0.343$, respectively). Generally speaking, respondents who were more familiar with invasive plants were more concerned about them on both their own and neighboring/nearby woodlands ($\chi^2 = 86.6545$, $p < 0.001$ and $\chi^2 = 92.146$, $p < 0.001$, respectively).

1.4.3 Past and Future Invasive Plant Management Actions

Of the 14 possible invasive plant-related actions respondents could have taken in the past five years, the three most common were: pulling or cutting invasive plants on their woodlands (39%), inspecting their woodlands for invasive plants (34%), and applying herbicides to kill invasive plants on their woodlands (31%) (Figure 2). In contrast, only 2% of respondents had worked with their neighbors to remove invasive plants from both of their woodlands, although some had initiated discussions among peers about invasive plants. Specifically, 14%, 8%, and 10% of respondents, respectively, had talked to their family, neighboring landowners, and other non-neighboring landowners about invasive plants. Overall, 38% of respondents reported having done no invasive plant management in the past five years.

Forty-three percent of respondents reported that they were likely or very likely to undertake activities to prevent invasive plants from establishing on their woodlands in the next five years, while 50% were likely or very likely to remove invasive plants from their woodlands. Specifically, respondents reported that they were likely or very likely to inspect their woodlands for invasive plants (66%), pull or cut invasive plants on their woodlands (59%), and search for information on the Internet (47%) in the next five years (Figure 2). Additionally, larger proportions of respondents (43%, 26%, and 27% respectively) indicated plans (likely or very likely) to talk to their family, neighboring landowners, and other non-neighboring landowners about invasive plants than the proportions of respondents who had done so in the past five years.

A number of landowner socio-demographic characteristics were associated with respondents having managed invasive plants in the past five years (Table 4). Specifically, younger and male respondents were more likely to report having eliminated or reduced invasive plants on their properties ($\chi^2 = 4.738$, $p = 0.030$; $\chi^2 = 15.9963$, $p < 0.001$). Respondents with more education, higher household income, or membership in a conservation, environmental or woodland owner organization, were also more likely to report having managed invasive plants ($\chi^2 = 21.5930$, $p < 0.001$; $\chi^2 = 11.1372$, $p = 0.049$; $\chi^2 = 75.5487$, $p < 0.001$; respectively). Additionally, respondents who owned more woodlands, who had a written management plan, or whose woodlands were enrolled in the Indiana Classified Forest Program, were more likely to have managed invasive plants ($\chi^2 = 68.223$, $p < 0.001$; $\chi^2 = 175.6569$, $p < 0.001$; $\chi^2 = 139.1240$, $p < 0.001$; respectively).

Regarding future plans, the likelihood that respondents would remove invasive plants in the next five years was associated with a larger set of socio-demographic characteristics comparing to the case of their past efforts (Table 4). Specifically, older, retired, and longer-tenure respondents were less likely to report plans to remove invasive plants on their woodlands in the next five years ($\chi^2 = 41.459$, $p < 0.001$; $\chi^2 = 32.7863$, $p < 0.001$; $\chi^2 = 9.588$, $p = 0.048$; respectively). Respondents with higher education levels, higher household incomes, or memberships in a conservation, environmental or woodland owner organization, were more likely to report plans to remove invasive plants ($\chi^2 = 28.9215$, $p < 0.001$; $\chi^2 = 49.2861$, $p = 0.025$; $\chi^2 = 92.1092$, $p < 0.001$; respectively), as were males and those who lived on or near their woodlands ($\chi^2 = 33.3318$, $p < 0.001$ and $\chi^2 = 10.0517$, $p = 0.040$, respectively). Additionally, respondents who owned more woodlands, whose woodlands were currently or previously farmed, who had a written management plan, or whose woodlands were enrolled in the Indiana Classified Forest Program, were more

likely to report plans to remove invasive plants ($\chi^2 = 53.084$, $p < 0.001$; $\chi^2 = 17.5704$, $p = 0.025$; $\chi^2 = 140.1035$, $p < 0.001$; $\chi^2 = 72.2611$, $p < 0.001$; respectively). In terms of preventing invasive plants from establishing on one's woodlands, the likelihood of respondents taking actions in the next five years was associated with a similar set of socio-demographic characteristics as was the likelihood of removing invasive plants (Table 4). The only differences were that length of woodland ownership, resident/absentee status, and woodlands being farmed currently or previously, were not associated with likelihood of prevention ($\chi^2 = 4.5565$, $p = 0.336$; $\chi^2 = 5.9195$, $p = 0.205$; $\chi^2 = 13.9169$, $p = 0.084$; respectively). Overall, respondents' plans for prevention and removal were associated with their past experience of eliminating and reducing invasive plants ($\chi^2 = 217.3093$, $p < 0.001$ and $\chi^2 = 301.3028$, $p < 0.001$, respectively).

1.4.4 Confidence in Taking Action and Potential Barriers

Respondents were asked to indicate their levels of confidence in their ability to manage invasive plants. Fifty-nine percent felt little or no confidence in their ability to prevent invasive plants from establishing on their woodlands, while 49% felt little or no confidence in their ability to remove invasive plants from their woodlands. Respondents' levels of confidence were associated with various socio-demographic variables. Specifically, respondents who were male and who were members in conservation, environmental or woodland owner organizations were more confident in their own ability to manage invasive plants (prevention: $\chi^2 = 42.8470$, $p < 0.001$ and $\chi^2 = 12.9728$, $p = 0.011$, respectively; removal: $\chi^2 = 68.8369$, $p < 0.001$ and $\chi^2 = 24.9652$, $p < 0.001$, respectively). Those who had a written management plan were also more likely to be confident (prevention: $\chi^2 = 19.9943$, $p = 0.001$; removal: $\chi^2 = 34.1177$, $p < 0.001$). Respondents who were retired were less confident in their own ability to prevent or remove invasive plants ($\chi^2 = 13.6854$, $p = 0.008$ and $\chi^2 = 41.3686$, $p < 0.001$, respectively). Respondents' levels of confidence in their own ability to prevent or remove invasive plants were not, however, associated with respondents' age ($\chi^2 = 3.2833$, $p = 0.512$ and $\chi^2 = 1.1436$, $p = 0.887$, respectively), income ($\chi^2 = 3.6047$, $p = 0.165$ and $\chi^2 = 11.9872$, $p = 0.152$, respectively), or whether their woodlands were currently or previously farmed ($\chi^2 = 1.8061$, $p = 0.986$ and $\chi^2 = 2.0306$, $p = 0.980$, respectively). Several variables had different effects on respondents' levels of confidence. For example, owning more woodlands, being a resident owner, owning woodlands for a longer period of time, and

having land enrolled in the Indiana Classified Forest Program, were not associated with respondents' confidence in preventing invasive plants from establishing on their properties (χ^2 = 4.647, p = 0.326; χ^2 = 8.0573, p = 0.090; χ^2 = 3.0257, p = 0.554; χ^2 = 7.0642, p = 0.133; respectively); however, they were statistically significantly associated with higher levels of confidence in removing invasive plants (χ^2 = 6.297, p = 0.012; χ^2 = 10.2937, p = 0.036; χ^2 = 12.492, p = 0.014; χ^2 = 14.3237, p = 0.006; respectively). Interestingly, while education level was not associated with respondents' confidence in their own ability to remove invasive plants (χ^2 = 9.6451, p = 0.291), higher education level was statistically significantly associated with lower level of confidence in preventing invasive plants from establishing on one's property (χ^2 = 11.0144, p = 0.004).

Respondents' level of confidence and their likelihood to act were significantly associated (Table 4). The more confident respondents were in their own ability to prevent or remove invasive plants, the more likely they reported having plans to take preventative or removal actions in the next five years (χ^2 = 187.7202, $p < 0.001$ and χ^2 = 295.8218, $p < 0.001$, respectively). Furthermore, respondents' levels of confidence and their likelihood to act were both significantly associated with their familiarity with invasive plants (Table 4). The more familiar respondents were with invasive plants, the more confident they felt in their own ability to prevent or remove invasive plants (χ^2 = 61.5469, $p < 0.001$ and χ^2 = 302.1841, $p < 0.001$, respectively) and the more likely they were to report plans to prevent or remove invasive plants (χ^2 = 178.7766, $p < 0.001$ and χ^2 = 237.3655, $p < 0.001$, respectively).

Respondents also indicated ten factors that might limit their confidence levels regarding invasive plant management (Figure 3). More than half of respondents (52% and 55%, respectively) agreed or strongly agreed that they had sufficient time to inspect their woodlands for invasive plants and knew who to contact if they had questions about them. However, the majority of respondents disagreed or strongly disagreed that they knew about county, state or federal programs that assist woodland owners in removing invasive plants (82%); had sufficient knowledge to prevent and remove invasive plants (69%); or had sufficient money to remove invasive plants from their woodlands (64%).

1.4.5 Perceived Responsibility and Opportunities for Invasive Plant Management

Nearly all respondents disagreed with the statement that "Indiana as a whole is doing enough about preventing and removing invasive plants" from woodlands owned by private individuals and public entities (94% and 94%, respectively). While most (57%) respondents agreed or strongly agreed that Indiana needs some sort of coordinated effort to control invasive plants on publicly-owned woodlands, fewer (43%) agreed or strongly agreed about a similar need for privately-owned woodlands and an equal number of respondents (42%) were undecided. When asked about who should be responsible for managing invasive plants, most respondents believed that private woodland owners themselves should be responsible for prevention (78%) and removal (77%).

In terms of potential effort that the government could make, respondents were most supportive of educating woodland owners (82%) and school children (80%) about invasive plants in Indiana. Fewer respondents (40%) agreed or strongly agreed that removing invasive plants should from publicly-owned woodlands should be required by law in Indiana, and only 11% were supportive of such a law for privately-owned woodlands. Interestingly, respondents were more likely to agree to a law requiring private woodland owners to remove invasive plants if they were very familiar with invasive plants ($\chi^2 = 12.3041$, $p = 0.015$), were concerned or very concerned about invasive plants on their woodlands ($\chi^2 = 16.7929$; $p < 0.001$), felt very confident in their own ability to remove invasive plants ($\chi^2 = 20.3306$, $p < 0.001$), had experience removing invasive plants in the past five years ($\chi^2 = 24.2681$, $p < 0.001$), were more likely to remove invasive plants in the next five years ($\chi^2 = 37.1298$; $p < 0.001$), were members of a conservation, environmental or woodland owner organization ($\chi^2 = 22.2126$, $p < 0.001$), or had a written management plan ($\chi^2 = 10.5485$, $p = 0.032$). Surprisingly, respondents with more education were less supportive of requiring private woodland owners to remove invasive plants ($\chi^2 = 16.7236$, $p = 0.033$). In contrast, respondents were more supportive of regulations targeting the landscaping industries, specifically with laws preventing the sale of invasive plants by nurseries, greenhouses, and retail stores (69%) and requiring businesses to label plants for sale as native or non-native to Indiana (80%). Most respondents (74%) also believed that people should not buy plants that are invasive to Indiana.

When asked about working with others to manage invasive plants, respondents (50%) found working with a non-profit organization, such as a land conservation organization or woodland owner association, to control invasive plants on privately-owned woodlands appealing

or very appealing. This was closely followed by working with their neighbors (49% and 47% on prevention and removal, respectively) and other woodland owners in their town, city or county (46% and 43% on prevention and removal, respectively). Working with their town, city, county government (37%) or a state agency (41%) to control invasive plants were viewed slightly less favorably by respondents.

1.5 Discussion

Generally speaking, our survey respondents are similar to the average FFOs in Indiana and nationwide in terms of their socio-demographic characteristics with two possible meaningful differences (Table 2). First, a large proportion of our respondents (57%, in contrast to 38% nationally for family forestlands that are 10+ acres; Butler et al. 2016b) own woodlands as part of a current farm. Second, a large proportion of our respondents (21%, in contrast to 13% nationally for family forestlands that are 10+ acres; Butler et al. 2016b) have a written management plan. Regarding FFOs' attitudes and behaviors towards forest management and conservation, previous research has been inconclusive about the similarities and differences between FFOs whose woodlands are/were part of a farm and FFOs without connections to farming (e.g., Erickson et al. 2002; Hendee and Flint 2013; Fortney et al. 2011; Jagnow et al. 2006; Ma et al. 2012a; Sandberg and Jakobsson 2018; Silver et al. 2015; Snyder and Butler 2012; Steele et al. 2006). Our results show, however, that FFOs whose woodlands were currently or previously farmed were more likely to be familiar with the concept of invasive plants and to report a plan to remove invasive plants form their properties in the next five years. As such, our study contributes to the literature on the role of being a farmer or owning farmlands on forest management and conservation. Our study also suggests a need to further explore how FFOs perceive and manage invasive forest plants based on whether their woodlands are associated with farming. Anecdotally, FFOs with farmlands may have more familiarity with and/or opportunities to participate in government-sponsored outreach and assistance programs by virtue of owning two types of lands, each of which have different programs available to them, as well as peer and professional networks. Therefore, it will be important to empirically test these assumptions and assess the opportunities, as well as equity concerns, associated with potentially uneven access to resources among FFOs. Regarding the second difference between our sample and FFOs in the U.S. broadly, we discuss the potential

implications of having a larger proportion of FFOs in our sample with a written management plan in more detail below. Keeping this difference in mind, our results nonetheless provide a comprehensive assessment of FFOs' awareness, perceptions, actions and intentions regarding invasive plant management, which has not been thoroughly documented previously. This understanding is a foundation for generating hypotheses specifically about FFOs' behaviors towards invasive plants for further research.

Overall, our results suggest that many FFOs in Indiana are familiar with invasive forest plants, and are already taking actions on the ground, particularly through physical or chemical removal (Figure 2). This level of awareness and activity may be higher than what forestry professionals in the state have realized, as they generally estimated that less than 20% of Indiana FFOs would be aware of invasive plant problems and less than 5% would have done anything at all (Ma et al. 2018). While it is an encouraging finding that many respondents reported awareness and activity around invasive forest plants, 69% of our respondents also reported insufficient knowledge to prevent or remove invasive plants. This may be a problematic indication that many FFOs in our study are managing invasive plants even though they do not necessarily know how. This is particularly worrisome considering the number of FFOs who have already used or are contemplating using herbicides to control invasive plants, and the potential impacts of incorrect herbicide applications on ecosystem and human health. Further, our results show that few respondents have interacted with forestry or natural resource professionals about invasive plant management (Figure 2). With half of respondents indicating that they were likely or very likely to prevent and remove invasive plants in the next five years, efforts are needed to ensure that applicable professional advice and scientifically-based information can reach FFOs to address their specific needs *before* management occurs—a critical decision point identified by Kittredge (2004).

In addition to documenting a general interest in preventing and removing invasive plants among Indiana FFOs, our study suggests that such interest is associated with certain socio-demographic and landownership characteristics of FFOs. Specifically, our results suggest that older, retired, and longer-tenure FFOs may have little interest in invasive plant management, which may relate to how physically demanding managing some invasive plant species can be (Ma et al. 2018). This contention is potentially concerning because half or more Indiana FFOs fall into these demographic categories. On the other hand, newer and younger FFOs may be more receptive to information about invasive forest plants and relevant management programs. Our finding furthers

current debates about the relationship between length of land tenure and invasive plant management. For example, several studies have found that landowners with longer tenure were less likely to express interest in collectively managing invasive species (Niemiec et al. 2017a; McKiernan 2017), while Niemiec et al. (2017b) documented a positive but statistically insignificant relationship between longer-term residency and past invasive plant removal experience in the Puna District of Hawai'i.

We also found in our study that FFOs with higher income were more likely to have plans to remove invasive plants in the future, consistent with what other studies have found (Gulezian et al. 2010; Niemiec et al. 2018). This may be explained by that invasive plant management is generally costly and landowners with higher incomes may be more able to acquire assistance and services from forestry professionals and to purchase necessary equipment and herbicides for treatment. Also similar to previous studies (Klepeis et al. 2009; Niemiec et al. 2017b; Yung et al. 2015), our result shows that where FFOs live relative to their woodlands is associated with their interest in invasive plant management, with resident FFOs more likely to report having a plan to remove invasive plants on their property in the next five years. However, we did not find a significant relationship between where FFOs live and their level of familiarity with invasive plants or their past invasive plant management action. This may be due to the fact that invasive plants in forest ecosystems are still relatively new to FFOs (Ma et al. 2018), and there might have not been sufficient time for resident and absentee FFOs to differ in their knowledge and past actions. Additionally, FFOs who are already members in a conservation, environmental or woodland owner organization, and those who have enrolled in the Indiana Classified Forest Program, may be a prime audience for invasive plant-related outreach. These individuals are sometimes referred to as "model" owners, as they tend to be already connected with natural resource professionals and programs (Ma et al. 2012b). Nonetheless, they may need a nudge through outreach to prioritize invasive plant problems among the activities they consider for their woodlands. Once convinced and engaged, these individuals have the potential to serve as influencers to communicate through their networks and encourage invasive plant management in the broader FFO community (Kueper et al. 2013; Ma et al. 2012b).

Our results also highlight that FFOs with written forest management plans tend to have greater invasive plant awareness and interest in management, although it is unclear whether invasive plant management was an explicit element of these written plans or if respondents became

more aware of invasive plant problems through working with a professional forester to prepare a written plan. Our results confirm previous research showing that FFOs with management plans tend to be more engaged in forest management and conservation (Joshi and Arano 2009; Ma et al. 2012a). While it is unrealistic to assume that every FFO will develop a written plan, it may still be an important pathway to enhance invasive plant management among FFOs. For example, when communicating with FFOs about developing written forest management plans, natural resource professionals may consider incorporating specific examples of how invasive plants reduce the beauty, health, and values of woodlands that they would pass on to their children—an important landownership objective for many FFOs.

Our results suggest that FFOs have a relatively low level of confidence in their ability to manage invasive plants on their properties. Although helping FFOs become more familiar with invasive plants and related management techniques may help boost confidence level, our study shows that additional factors such as lack of money and limited knowledge about landowner assistance programs, may also influence FFOs' self-confidence and self-efficacy. Similar factors have been identified by landowners in California's Sierra Nevada when discussing limitations to their ability to manage an invasive plant, yellow star-thistle (*Centaurea solstitialis*), on their rangelands (Aslan et al 2009). Noteworthy from our study, however, is that although over 60% of respondents reported being constrained by knowledge or money to control invasive plants, only a quarter expressed an interest in participating in a workshop, information session, financial assistance program, or technical assistance program. Such a mismatch between FFOs' need and interest seems to suggest that conventional models of financial assistance, technical assistance, and outreach or education programs to FFOs may not be effective for motivating FFOs to participate in these programs (Hershdorfer et al. 2007; Howle et al. 2010; Kapler et al. 2012; Sharp et al. 2011).

This low interest in government-sponsored programs is not unique to the management of invasive plants or FFOs in Indiana, as the USDA Forest Service's National Woodland Owner Survey (Butler et al. 2016b) also shows low participation rates in landowner assistance programs and interactions with forestry professionals among FFOs nationwide. These results could be explained by FFOs' lack of awareness about such programs, particularly among newer landowners. They could also be attributed to FFOs' disinterest or distrust in engaging in government-sponsored programs and activities. Specifically, previous research shows that FFOs who are aware of forest

management and conservation programs might be reluctant to participate if the application process is cumbersome or unclear (e.g., Gan et al. 2005), eligibility criteria or participation requirements are hard to meet (e.g., Markowski-Lindsay et al. 2011), incentives are minimal (e.g., Thomas et al. 2002), or program and landowner goals are misaligned or landowners distrust program goals stated by government agencies (Rouleau et al. 2016). Thus, more research is needed to identify the specific reasons that underlie the mismatch we observed between FFOs' great need for information and financial resources but little interest in outreach opportunities and assistance programs. For example, if distrust in government is identified as a limiting factor (Graham 2013; Graham and Rogers 2017), more effort would be needed to identify other entities that FFOs would trust as messengers and partners for invasive plant management. Since half of our respondents found it appealing or very appealing to work with a non-profit organization, it may be beneficial for natural resource agencies to work with a land conservation organization or a woodland owner association to motivate and assist FFOs to work on the invasive plant problems on their properties and in their communities.

Beyond a concern about invasive plants on their own properties, our study shows that FFOs are also concerned about invasive plants on neighboring or nearby woodlands. Most FFOs seem to be unsatisfied with what Indiana as a whole is doing about invasive plants, and a large proportion also see a need for coordinated efforts to control invasive plants on privately-owned woodlands. These results are particularly insightful considering that a very small proportion of FFOs have talked or worked with their neighbors about managing invasive plants, yet a large proportion find it appealing or very appealing to work with their neighbors and other woodland owners in their town/city/county on invasive plant problems. These results point to an opportunity to explore collective and/or cooperative invasive plant management efforts across property boundaries. Specifically, our results suggest that there may be a role for both government agencies and non-profit organizations to play in facilitating coordination and cooperation among FFOs to generate landscape-level invasive plant management outcomes (Graham and Rogers 2017; McKiernan 2017). For example, Graham and Rogers (2017) highlight that community leaders and supportive government staff that serve as a liaison between local groups and government agencies are pivotal to effective collective action. Locally-situated forestry and natural resource professionals (e.g., county Extension specialists), grassroots conservation organizations, and landowner associations may be able to use their existing social

networks within local communities to facilitate FFO meetings, creating an environment of trust, a sense of shared understanding and responsibility, and an opportunity for social learning about invasive plant management. As local FFO networks develop, there might be additional opportunities to facilitate sharing of labor, tools, and other resources necessary for invasive plant removal. However, as pointed out by McKiernan (2017), grassroots effort to collectively manage invasive plants is important; however, it can also become rigid and insular, preventing the integration of new values and collaborations with new landholders within local communities (McKiernan 2017). As such, strategies are needed to maintain conservation-oriented social norms and to obtain buy-in from newly arrived residents regarding community commitments to invasive plant management (McKiernan 2017).

Finally, our results suggest that FFOs' social networks (including families and friends), mass media (e.g., newspapers, television, radio), and the Internet are important sources of information about invasive plants. Previous research has suggested a strong landowner social network is important for effective invasive plant management (Fischer and Charnley 2012; Graham and Rogers 2017; Marshall et al. 2011; Niemiec et al. 2016; Niemiec et al. 2017a). FFOs may prefer to use the Internet, mass media, and their social networks to learn about invasive species and their control (Bodin and Corona 2009; Ma et al. 2012b), as these sources tend to be more convenient, less time consuming, and cheaper to access than seeking advice from natural resource professionals or traveling to workshops and information sessions. As such, natural resource agencies and organizations may need to consider innovative ways to develop their online presence to facilitate FFOs' learning, which is often self-directed and/or social in nature. For example, as a complement to current in-person or paper-based outreach and educational offerings, web-based learning opportunities that incorporate videos, virtual reality, and social media may attract FFOs who have not participated in traditional Extension or government outreach events.

1.6 Conclusion

The literature on individual and collective invasive plant management, so far, has focused on farmers, ranchers, urban gardeners, and community residents (Head 2017). Relatively little is known about invasive plant management specific to forestlands, particularly the role of family forest owners

(FFOs) in the United States. This paper provides a detailed description of FFOs' awareness, concerns, past actions, future plans, needs, and challenges related to invasive plant management. Such in-depth understanding is not only necessary for informing further development and testing of hypotheses associated with individual and collective invasive plant management, but provides important insight into potential invasive plant-related policies and programs targeting FFOs.

What is both encouraging and concerning is that FFOs in our study are generally familiar with and concerned about invasive plants and they are taking actions to address their perceived problems. However, much of the on-the-ground management occurs without professional inputs. Although tailored communication and outreach can be used to target FFOs who are younger and newer, who are involved in farming, and who have interacted with forestry and natural resource professionals and programs previously, most FFOs in our study have little experience or interest in interacting with natural resource professionals and programs. As such, natural resource agencies may consider ways to partner with local conservation organizations and landowner associations to motivate and assist FFOs. In particular, efforts to facilitate neighboring landowners and landowners within a community to work together—sharing information and resources and motivating and assisting each other when needed, may prove effective as a way to promote collective action and coordinated management. Both self-directed research and information seeking through social networks are important means of learning for FFOs. As such, natural resource agencies and non-profit organizations may need to consider developing a stronger online presence and identify effective strategies to facilitate FFOs' learning. The goal is not only to make easily-accessible, scientifically-based, and trustworthy information available to FFOs, but more importantly, to communicate such information with FFOs at various critical decision points as they consider their options for dealing with invasive plants.

Table 1.1: Demographic and landownership characteristics of survey respondents. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.

Characteristics (unit if applicable)	**Type of variable (categorical or continuous)**	**% or mean (std. dev.)**	**n**
Age (years)	20–40	3.4%	1,317
	41–60	33.6%	
	61–80	52.2%	
	>80	10.7%	
Retired	Yes	49.0%	1,350
Gender	Male	78.8%	1,329
Education	Less than high school/GED	2.8%	1,332
	High school/GED	33.0%	
	Some college	20.2%	
	Associate's degree	7.5%	
	Bachelor's degree	18.2%	
	Graduate degree	18.3%	
Income	Less than $25,000	9.1%	1,108
	$25,000–$49,999	25.5%	
	$50,000–$99,999	34.7%	
	$100,000–$149,999	15.7%	
	$150,000–$199,999	6.3%	
	$200,000 or more	8.7%	
Percent of household's annual income derived from woodland (%)	Continuous (range: 0-100)	0.98 (4.14)	1,205
Member of a conservation, environmental, or woodland owners' organization	Yes	12.8%	1,331
Size of woodland owned (acres)	Continuous	81.64 (135.44)	1,358
No. of people as part of woodland ownership	1	36.3%	1,359
	2	52.1%	
	3 or more	11.6%	
Primary residence on or within one mile of woodland	Yes	70.2%	1,374
Woodland as part of a farm	Yes, currently farmed	56.7%	1,368
	Yes, previously farmed	16.4%	
	No, not part of a farm	26.8%	
How woodland was acquired (categories not mutually exclusive)	Purchased	84.0%	1,374
	Inherited	24.4%	
	Received as a gift	2.3%	
Length of ownership (years)	Continuous	25.48 (15.71)	1,324
Having a written management plan	Yes	21.3%	1,370
Enrolled in the Indiana Classified Forest and Wildlands Program	Yes	35.4%	1,374

Table 1.2: A comparison of demographic and landownership characteristics of survey respondents, FFOs in Indiana, and FFOs in the United States. Data was collected using a mailed survey of family forest owners throughout the state of Indiana in November to December 2015.

Demographics of primary owner	**FFOs in this study**	**FFOs in Indiana**[a]	**FFOs in the United States**[a]
Age: <45	7%	7%	7%
Age: 45 - 54	16%	24%	20%
Age: 55 - 64	29%	30%	30%
Age: 65 - 74	28%	19%	25%
Age: 75+	19%	20%	18%
Retired	49%	51%	51%
Gender: male	79%	82%	79%
Education: less than high school/GED	3%	4%	6%
Education: high school/GED	33%	25%	25%
Education: some college	20%	27%	22%
Education: Associate's degree	8%	9%	9%
Education: Bachelor's degree	18%	20%	21%
Education: graduate degree	18%	15%	18%
Income: <$25,000	9%	8%	13%
Income: $25,000-$49,999	26%	33%	26%
Income: $50,000-$99,999	35%	45%	35%
Income: $100, 000-$199,999	22%	9%	17%
Income: >=$200,000	9%	5%	8%
Size of woodland holdings: 1-9 acres	11%	N/A	N/A
Size of woodland holdings: 10-19 acres	14% (16%)	43%	35%
Size of woodland holdings: 20-49 acres	28% (32%)	36%	35%
Size of woodland holdings: 50-99 acres	22% (25%)	14%	16%
Size of woodland holdings: 100-199 acres	15% (17%)	5%	9%
Size of woodland holdings: 200-499 acres	8% (9%)	1%	4%
Size of woodland holdings: 500-999 acres	1% (1%)	<1%	<1%
Size of woodland holdings: 1,000+ acres	1% (1%)	<1%	<1%
Having a written management plan Management Plan	21%	7%	13%
No. of people as part of woodland ownership: 1	36%	23%	31%
No. of people as part of woodland ownership: 2	52%	66%	58%
No. of people as part of woodland ownership: 3-5	10%	10%	9%
No. of people as part of woodland ownership: 6+	2%	2%	3%
Primary residence on or within one mile of woodland[b]	70%	72%	63%

Demographics of primary owner	FFOs in this study	FFOs in Indiana[a]	FFOs in the United States[a]
Woodland as part of a farm: currently farmed	57%	46%	38%
Woodland as part of a farm: previously farmed	16%	N/A/	N/A
Woodland not as part of a farm	27%	N/A/	N/A
Length of ownership (years): <10	17%	15%	19%
Length of ownership (years): 10-24	35%	45%	38%
Length of ownership (years): 25-49	40%	31%	36%
Length of ownership (years): 50+	8%	9%	7%
Eliminated or reduced invasive plants on own woodland in the past five years	28%	30%	24%
Plans to remove invasive plants from own woodland in the next five years	50%[c]	33%[d]	29%[d]

[a] The challenge is that the Indiana and U.S. descriptive statistics are not directly comparable to our sample descriptive statistics. This is because the descriptive statistics of FFOs in Indiana and FFOs in the U.S. are based on the U.S. Forest Service, Forest Inventory and Analysis Program, National Woodland Owner Survey (NWOS) results from 2011 to 2013 (https://www.fia.fs.fed.us/nwos/results/). The NWOS summary tables released by the U.S. Forest Service are only for family forestlands that are 10+ acres. This needs to be taken into consideration when reading Table 2.

[b] In our survey this question was stated as "Is your wooded land part of a farm that is currently farmed or that was previously farmed?" Options provided to respondents were: "yes, currently farmed," "yes, previously farmed," and "no, not part of a farm." However, there was no equivalent question asked in the NWOS. The closest question in NWOS was a question about ownership reasons broadly with a line item being "Is part of my farm or ranch." The question was stated as "How important are the following as reasons for why you currently own your wooded land in Indiana?" Options provided to respondents for each line item were: "very important," "important," "moderately important," "of little importance," "not important," and "not applicable." The percentage presented here for Indiana and the U.S. were the combined percentages of respondents who chose "very important" and "important."

[c] In our survey this question was stated as "Generally speaking, how likely are you to undertake activities to remove invasive plants from your wooded land in Indiana in the next five years?" Options provided to respondents were: "very likely," "likely," "undecided," "unlikely," "very unlikely," and "not applicable." The percentage presented here was the combined percentages of respondents who chose "very likely" and "likely."

[d] There was no equivalent question asked in the NWOS. The closest question in NWOS was stated as "How important are the following as reasons for why you currently own your wooded land in Indiana?" with a line item being "Eliminate or reduce invasive species." Options provided to respondents were: "extremely likely," "likely," "undecided," "unlikely," and "extremely unlikely." The percentage presented here was the combined percentages of respondents who chose "extremely likely" and "likely."

Table 1.3: Invasive plant species that survey respondents reported noticing on their woodlands in Indiana. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.

Invasive plant species identified	**% of respondents**
Multiflora rose *(Rosa multiflora*)	64%
Asian bush honeysuckle *(Lonicera maackii*)	33%
Japanese honeysuckle *(Lonicera japonica)*	29%
Autumn olive *(Eleagnus umbellata)*	28%
Other written-in examples: Russian olive *(Elaeagnus angustifolia),* wild grape *(Vitis vinifera),* canary grass *(Phalaris canariensis),* etc.	23%
Garlic mustard *(Alliaria petiolata)*	20%
Tree of heaven *(Ailanthus altissima)*	19%
Burning bush *(Euonymus alatus)*	13%
Common buckthorn *(Rhamnus cathartica)*	8%
Japanese stilt grass *(Microstegium vimineum)*	6%
Periwinkle *(Vinca minor)*	6%
Winter creeper *(Euonymus fortunei)*	5%
Japanese barberry *(Berberis thunbergii)*	4%
Callery pear or Bradford pear *(Pyrus calleryana)*	4%
Privet *(Ligustrum vulgare)*	4%
Glossy buckthorn *(Rhamnus frangula)*	2%
Paulownia *(Paulownia tomentosa)*	1%

Table 1.4: Summary of bivariate relationships between landowner/landownership characteristics and FFOs' familiarity with and concern about invasive plants (IPs), as well as their level of confidence in, interest in and support for invasive plant management. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.

	Familiarity with IPs	Concerns about IPs on own woodlands	Concerns about IPs on neighboring/nearby woodlands	Confidence in own ability to prevent IPs	Confidence in own ability to remove IPs	Having eliminated or reduced IPs in the past five years	Likelihood to prevent IPs in the next five years	Likelihood to remove IPs in the next five years	Agreement with statement "removing IPs from privately-owned wooded land should be
Age (older)	-	NS[a]	NS	NS	NS	-	-	-	NS
Retired	-	NS	NS	-	-	NS	-	-	NS
Gender (male)	NS	NS	NS	+	+	+	+	+	NS
Education (higher)	+	+	+	-	NS	+	+	+	-
Income (higher)	+	NS	NS	NS	NS	+	+	+	NS
Membership in a conservation, environmental or woodland owner organization	+	+	+	+	+	+	+	+	+
Acreage (larger)	+	+	+	NS	+	+	+	+	NS
Being a resident owner (not an absentee owner)	NS	NS	NS	NS	+	NS	NS	+	NS
Length of ownership (longer)	NS	NS	NS	NS	+	NS	NS	-	NS
Woodlands previously or currently farmed	+	NS	NS	NS	NS	NS	NS	+	NS
Having a written management plan	+	+	+	+	+	+	+	+	+
Enrolled in the Indiana Classified Forest Program	+	+	+	NS	+	+	+	+	NS
Familiarity with IPs (more familiar)		+	+	+	+		+	+	+
Concerns about IPs on own woodlands							+	+	+
Concerns about IPs on neighboring/nearby woodlands									+
Confidence in own ability to prevent IPs							+		
Confidence in own ability to remove IPs								+	+

	Familiarity with IPs	Concerns about IPs on own woodlands	Concerns about IPs on neighboring/nearby woodlands	Confidence in own ability to prevent IPs	Confidence in own ability to remove IPs	Having eliminated or reduced IPs in the past five years	Likelihood to prevent IPs in the next five years	Likelihood to remove IPs in the next five years	Agreement with statement "removing IPs from privately-owned wooded land should be
Having eliminated or reduced IPs in the past five years							+	+	+
Likelihood to prevent IPs in the next five years									
Likelihood to remove IPs in the next five years									+

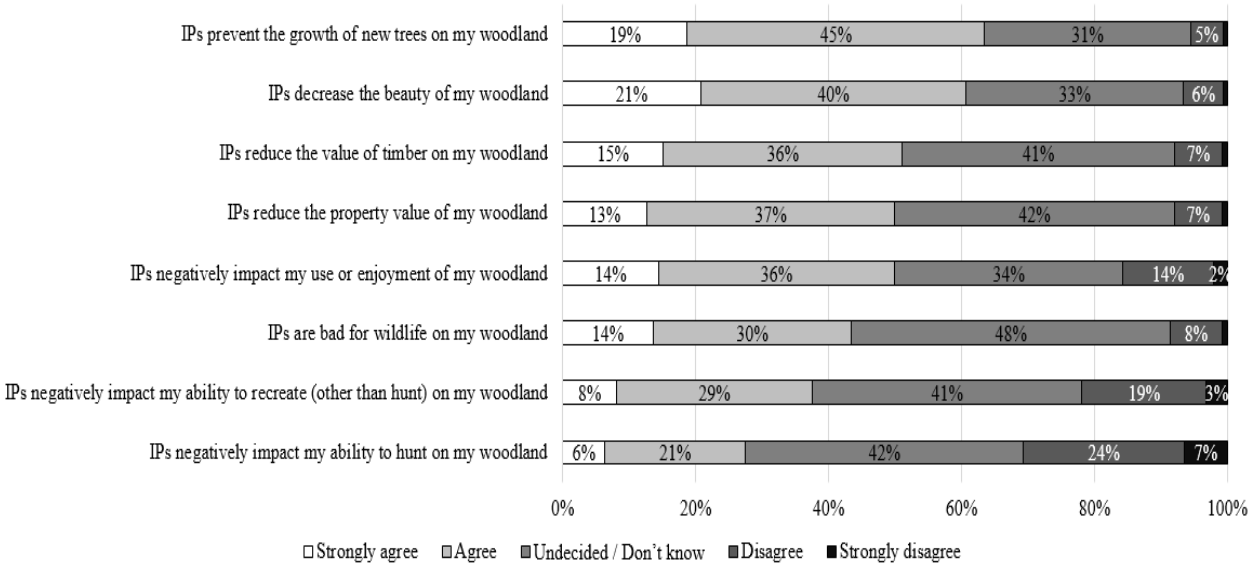
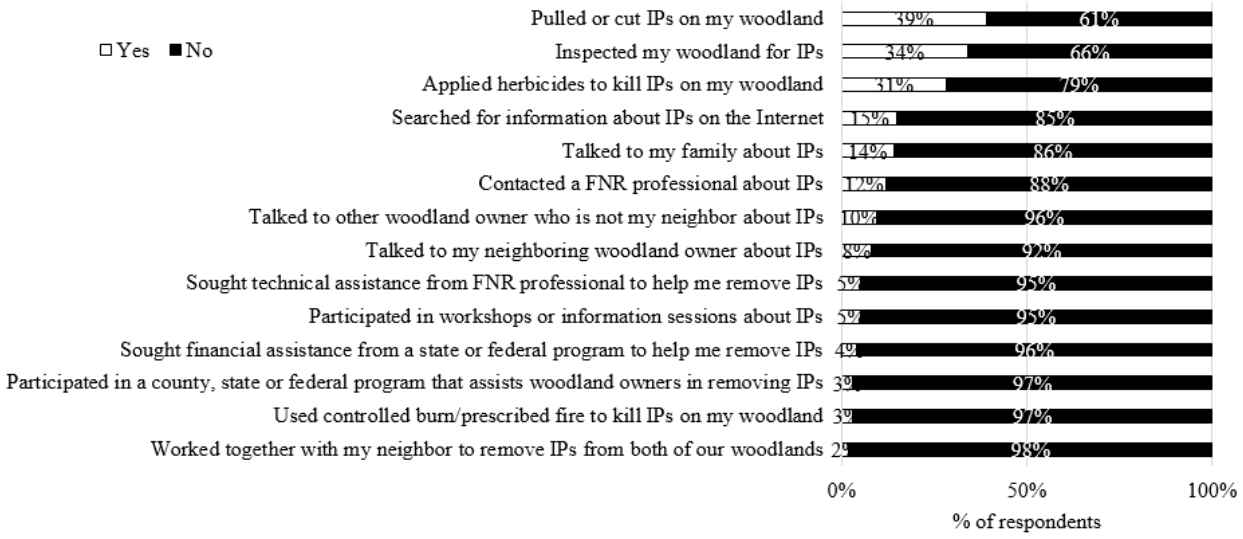


Figure 1.1: Survey respondents' perceptions of potential negative impacts of invasive plants (Notes: IP stands for invasive plant. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.)

(a) Past actions



(b) Future actions

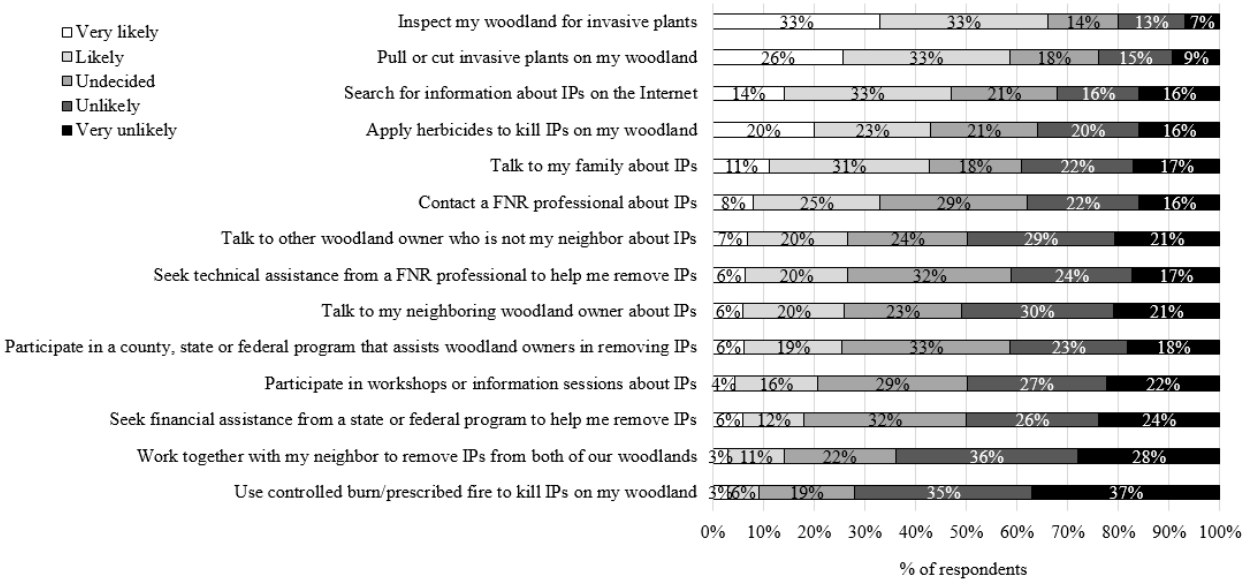


Figure 1.2: Survey respondents' self-reported (a) invasive plant management-related activities in the past five years, and (b) their likelihood to undertake these activities in the next five years. (Notes: FNR stands for forestry and natural resources. IP stands for invasive plant. 'None of above' stands for not having taken any action listed in this survey question. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.)

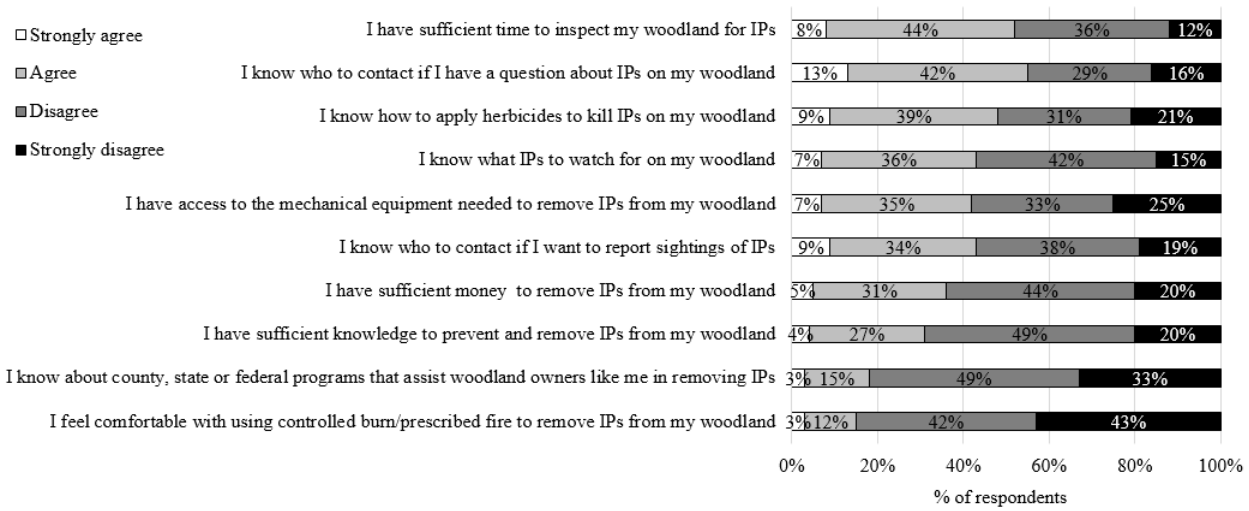


Figure 1.3: Factors that might limit the level of confidence survey respondents had with regard to managing invasive plants. (Notes: IP stands for invasive plant. Data was collected using a mailed survey of family forest owners throughout the state of Indiana. The survey was administered during November to December 2015.)

CHAPTER 2. APPLYING THE PROTECTION MOTIVATION THEORY TO UNDERSTAND INVASIVE PLANT MANAGEMENT ON FAMILY FORESTLANDS

2.1 Abstract

Invasive plant management is a growing concern because of their ecological, economic and potentially social impacts. Terrestrial invasive plants are widespread in forest ecosystems in the United States and beyond. To effectively manage invasive plants in forest ecosystems, it is paramount to engage family forest owners' participation because they collectively own 36% of forestlands in the United States. We surveyed a random sample of 2,600 family forest owners in Indiana about their knowledge, perceptions, experience, and plans regarding invasive plants on their wooded lands. Informed by the Protection Motivation Theory and previous literature on invasive species management specifically and forest management in general, we examined family forest owners' likelihood to manage invasive plants and various factors that influence such likelihood. Our results suggest that family forest owners' perceived severity, perceived vulnerability, and perceived self-efficacy were all statistically significant factors influencing their future intentions to manage invasive plants. Our results also show that those who had invasive plant management experience and those who were subject to social influence from families, friends and other woodland owners tended to indicate a higher likelihood to remove invasive plants in the next five years. Unlike some of the previous studies, we found that few demographic and ownership characteristics mattered in predicting family forest owners' self-reported intentions to remove invasive plants, with the exception of education level, owning woodlands for recreational purposes, and owning woodland to pass on to heirs. These results can be used to inform forestry professionals, programs, and organizations about potential strategies for engaging family forest owners in invasive plant management on their own properties in an attempt to generate invasive plant control benefits across forested landscapes.

2.2 Introduction

Invasive species are one of the leading threats to biodiversity, conservation, agriculture and the economic gains. Following habitat degradation, invasive species are the second highest cause of biodiversity loss (Lever 2009) and cost the U.S. economy approximately $137 billion annually because of environmental damage and control expenses (Pimentel et al. 2005). They also negatively impact people's health by increasing their exposure to irritants and toxins (Mazza et al. 2016); some are even categorized as a threat to national security (Tassin and Kull 2015). Among various invasive species are terrestrial invasive plants. They have been introduced primarily through the horticultural and agricultural industries for landscaping, soil erosion control, or to improve wildlife habitats (Reichard and White 2001). Invasive plants continue to spread to new geographic areas and are predicted to increase because of climate change and globalization (Early et al. 2016; Simberloff 2013:265). While some invasive plants may provide ecosystem services (Vaz et al. 2017), many displace native species, degrade ecosystems, alter soil characteristics, lead to species extinctions, exacerbate the impacts of disturbances and reduce the availability of various ecosystem services (Hulme 2009; Pejchar and Mooney 2009; Peters and Meyer 2006; Simberloff 2013; Vaz et al. 2017).

Previous studies on invasive species in general and invasive plants are 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 of them incorporated the human dimensions of invasive species management (Estévez et al. 2015). These studies have investigated how attitudes, perceptions, perceived risks, beliefs, and culture affect invasive species management (Bardsley and Edward-Jones 2006; Estévez et al. 2015; Kapler et al. 2012), although few studies have explicitly connected public and resource managers' invasive species management behavior to social and behavioral theories using empirical data (McLeod et al. 2015). In the United States, much of the existing invasive plant management efforts and related research have focused on working with agricultural producers and ranchers to prevent and remove invasive weeds. Fewer studies have examined forest landowners and their motivations, actions, and challenges associated with invasive plant management on forested landscapes.

In this paper, we focus specifically on how family forest owners (FFOs) approach invasive plant management on their properties. 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" (Butler et al. 2016). It is important to engage FFOs in invasive plant management because 10.7 million FFOs own 290 million acres of forestlands, the largest proportion in the United States (Butler et al. 2016). Invasive plant management on family forestlands is particularly challenging because of increasing fragmentation with multiple landowners (Epanchin-Niell et al. 2010; Klepeis et al. 2009). In fact, family forestlands are predicted to experience further subdivision and fragmentation due to the older profile of current FFOs and their upcoming needs to transfer land to the next generation of owners (Butler et al. 2016; Markowski-Lindsay et al. 2016). The large number of FFOs, their collective size of ownership, and their demographic characteristics suggest that landscape-scale invasive plant management will be ineffective without them. Therefore, it is pivotal to understand FFOs' current and future forest management activities, especially their plans and challenges regarding invasive plant management.

2.2.1 Family Forest Owners' Decision-Making About Forest Management in General

Extensive research has been conducted to examine FFOs' perceptions and actions towards forest management, particularly in the contexts of timber harvesting, wildfire control, wildlife habitat conservation, and provisioning of various ecosystem services. These studies have suggested that forest management behaviors of FFOs, or more broadly non-industrial private forest owners are influenced by: distance between forested property to the landowner's primary residence (Conway et al. 2003; Fischer et al. 2011; Petrzelka et al. 2013), how the forested property was acquired (Conway et al. 2003), and the size of forest holdings (Amacher et. al 2003; Joshi and Arano 2009; Kilgore et al. 2008; Ma et al. 2012). Other factors that have been shown to influence FFOs' forest management behavior include FFOs' forest ownership objectives (Khanal et al. 2017; Kilgore et al. 2008), land tenure (Niemiec et al. 2017a; Vokoun et al. 2006), whether they had a written forest management plan (Amacher et. al 2003; Brook et al. 2003; Cai et al. 2016; Joshi and Arano 2009; Kilgore et al. 2008; Silver et al. 2015), and access to financial and technical assistance (e.g., Amacher et. al 2003; Brook et al. 2003; Cai et al. 2016; Joshi and Arano 2009; Khanal et al. 2017; Kilgore et al. 2008, 2015; Ma et al. 2012; Silver et al. 2015).

2.2.2 Family Forest Owners' Decision-Making About Invasive Plants

Invasive plant management demands the contribution of many uncoordinated individual FFOs, majority of whom may know or care very little about invasive plants (Daab and Flint 2010; Steele et al. 2006, 2008). FFOs may have different perspectives on invasive plants. Some FFOs are indifferent to their socio-ecological impacts, some are concerned, some think they provide valuable services such as food for wildlife, and others believe it is futile to try and manage them (Fischer and Charnley 2012; Ma et al. 2018; Yung et al. 2015). These varying perspectives can hinder or boost FFOs' decisions to manage invasive plants. For example, FFOs are more likely to control invasive plants if they have identified biodiversity and wildlife protection as part of their ownership objectives (Fischer and Charnley 2012) or if they associate invasive plants with being a threat to their forests (Estevez et al. 2015; Fischer and Charnley 2012; Kapler et al. 2012; Robbins 2004; Steele et al. 2006).

Broadly speaking, landowners in general (beyond FFOs) can be motivated to manage invasive plants because of intrinsic and/or extrinsic factors. Some scholars argue that there should be more educational or technical assistance programs available for landowners to learn about and engage with invasive plant management (Garcia-Llorente et al. 2011), and others advocate for incentive programs to motivate landowners to engage in invasive plant control (Epanchin-Niell et al. 2010; Graham et al. 2013; Ma et al. 2018; Perrings et al. 2002). Studies have found that landowners are less likely to undertake invasive plant management if they believe that the monetary and time investment required to remove invasive plants will produce futile results (Howle et al. 2010; Ma et al. 2018). Studies have also shown that landowners' environmental attitudes and beliefs shape their invasive plant management actions (Sharp et al. 2011).

More recently, scholars have focused on opportunities for, and barriers to coordinated invasive plant management (Epanchin-Niell and Wilen 2015; Graham 2013; Graham and Rogers 2017; Niemiec et al. 2017; Yung et al. 2015). They find that landowners' engagement in invasive plant management is influenced by subjective social norms (Niemiec et al. 2016). For instance, landowners who control invasive plants also believe that their neighbors would see their management actions and reciprocate (Niemiec et al. 2016). This finding that landowners are motivated by whether their neighbors are also managing invasive plants is highlighted in other studies like Epanchin-Neill and Wilen 2015; Ma et al. 2018 and Yung et al. 2015. Furthermore, landowners who have strong social bonds or neighborhood attachment are likely to remove

invasive plants while landowners who have strong sense of place or place attachment may be less likely to remove invasive plants (Niemiec et al. 2017a). Other studies also found that if landowners perceive invasive plants as a risk to their property or collective good it can also be important in their decisions to manage them (Colton and Alpert 1998; Daab and Flint 2010; Sharp et al. 2011; Norgaard 2007; Van Wilgen 2012; Niemiec et al 2016). While research into the social sciences of invasive plant managing is increasing (Head 2017), few studies have addressed the psychological barriers and factors affecting individual landowners' decisions to manage invasive plant management on their own property (Niemiec et al. 2017, 2016).

2.2.3 Potential Insights from the Protection Motivation Theory

The Protection Motivation Theory (PMT) was first developed by Rogers (1975) to understand how people protect themselves, particularly the role of fear appeals; it was later adapted to become a general theory of persuasion and decision-making (Rogers 1983). PMT has been applied mostly to examine pro-health behaviors (Rimal and Real 2003; Rogers 1975; Milne 2000; Pechman et al. 2003; Van der Velde and Van der Pligt 1991), and people's responses to technological and natural hazards (e.g., Bockarjova and Steg 2014; Maddux and Rogers 1983; Westcott et al. 2017; Keshavarz and Karami 2016; Gebrehiwot and Van der Veen 2015; Grothmann and Reusswig 2006). Several scholars have suggested that PMT has utility in understanding factors that influence attitudes and adoption of pro-environmental behavior (e.g., Bockarjova and Steg 2014; Keshavarz and Karami 2016). While PMT has been applied to understand how people protect themselves from catastrophic events or environmental threats that can be seen or experienced (e.g., Martin et al. 2007; Grothmann and Reusswig 2006; Westcott et al. 2017), few have used PMT to study slow onset environmental risks that are harder to understand or anticipate (Bockarjova and Steg 2014) such as nonnative plant invasions (McLeod et al. 2015). Nonnative plant invasions can be considered a slow onset environmental risk because invasive plants can take many years to establish and become visible to landowners in an ecosystem (Simberloff 2013). The establishment of invasive plants in an ecosystem can affect people's risk perceptions because if there are immediate visible impacts, people may not perceive it as a threat. In this paper, we apply the lens of PMT to examine invasive plant management on family

forestlands to better understand how FFOs perceive and manage slow onset environmental risk and to identify opportunities for combating invasive plant problems across forested landscapes.

According to PMT, an individual's decision to "protect" themselves has two main components: threat appraisal and coping appraisal (Milne et al. 2000; Figure 1). Threat appraisal is the individual's assessment of the extent to which a threat will occur and have an impact based on two factors: (1) perceived severity of the threat and (2) perceived vulnerability of the individual to the threat (Feng et al. 2017; Milne et al. 2000). Perceived severity is how seriously an individual believes the threat will impact them or their properties (Bockarjova and Steg 2014; Feng et al. 2017; Gebrehiwot and Van der Veen 2015). Perceived vulnerability refers to the perceived probability of occurrence and how susceptible an individual feel that they will be to a threat (Bockarjova and Steg 2014; Martin et al. 2007; Zhao et al. 2016).

Coping appraisal is the second component of PMT. It refers to an individual's evaluation of a protective action for coping with or adapting to a threat based on three factors: response efficacy, response cost, and self-efficacy. Response efficacy is the individual's perception of whether a coping strategy (or protective action) will effectively reduce a threat (both in terms of their vulnerability and perceived severity) (Bockarjova and Steg 2014; Dang et al. 2014; Grothmann and Reusswig 2006). Response cost is the perceived costliness of implementing a coping strategy or protective action including money, time, and effort (Bockarjova and Steg 2014; Dang et al. 2014; Floyd et al. 2000; Milne et al. 2000). Self-efficacy is an individual's perception of their own ability to effectively carry out a coping strategy or protective action (Bockarjova and Steg 2014; Dang et al. 2014; Dittrich et al 2016). According to PMT, people will decide whether to adapt their current behavior or adapt a new behavior to cope with or protect themselves from a threat based on their perceived vulnerability, perceived severity, and an appraisal of possible or recommended management approaches to the threat. However, the outcome of such decision making (i.e., effective adaptation or maladaptation) is beyond the scope of PMT.

Among different components of PMT, self-efficacy beliefs have received significant attention from scholars. Self-efficacy beliefs describe whether an individual think that they can perform an action effectively (Bandura 1977, 1980). Self-efficacy beliefs depend on: (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 persuasion from others, which reinforces that individual's beliefs in their own ability, and (4) the individual's

psychological and emotional perceptions about their own ability (Bandura 1997). People are motivated to behave a certain way based on their beliefs about the situation rather than just the reality of it (Bandura 1997). Previous studies on PMT and self-efficacy beliefs were primarily done in health research (Rimal and Real 2003), and studies show that self-efficacy beliefs and changes in behavior are positively correlated (Bandura et al. 1980; Burnham and Ma 2017; Condiotte and Lichtenstein 1981; Maddux and Rogers 1982).

PMT and the concept of self-efficacy can provide potentially important insights to understand family forest owners' perceptions of invasive plants and related management behavior. PMT is applicable in this context because invasive plants are a threat to landowners' property, recreational use of their forests, and the overall forest health and productivity about which the majority of FFOs care deeply (Butler 2008; Clarke et al. in review). If unmanaged, invasive plants will eventually become problematic for landowners (Hershdorfer et al. 2007). Unlike sudden threats such as earthquakes or floods, invasive plants are a slower, more incremental threat that can have long-term impacts on forest ecosystems, economy and society. In the context of invasive plant management and FFOs, threat appraisal can be considered as how FFOs perceive their vulnerability to invasive plants on their property and threat from their neighboring forested properties, as well as how they perceive the severity of the impacts of invasive plants on their forests and ownership objectives (Figure 1).

Coping appraisal can be described as how an FFO perceives their own ability to undertake invasive plant management activities, the effectiveness of various invasive plant management options to solve the problem, and the resources needed to effectively manage invasive plants including knowledge, time, money, equipment and such. By applying the PMT lens to analyze empirical data on FFOs' decisions regarding invasive plant management on their property, this study will contribute to building knowledge about how FFOs perceive invasive plants and related management and identifying strategies that forest professionals and policy makers could use to motivate FFOs to manage invasive plants in the future.

2.3 Methods

2.3.1 Data Collection

The data used in this study was collected from a random sample of FFOs in Indiana using a mail survey. To develop the survey questionnaire, we first conducted in-person, face-to-face interviews with 11 forestry professionals and 14 FFOs in Indiana. Informed by the interview data, the survey questionnaire includes the following topics: (1) general questions about FFOs' forested properties (referred to as "wooded lands" in the survey), (2) FFO's familiarity with invasive plants on their lands, (3) past invasive plant management activities and future plans for managing invasive plants, (4) FFO's concerns about invasive plants and various management options, and (5) socio-demographic information. For consistency reason, we provided a definition[1] of invasive plants on the front cover of the survey questionnaire.

To create a sampling frame of all FFOs in Indiana, we first identified forestlands in the state 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 own at least one acre of forested property categorized as "woodland" or "classified forest" in the state of Indiana as of 2014. We then selected a random sample of 2,600 FFOs and administered a mail survey following the Tailored Design Method (Dillman et al. 2014).

By following the Tailored Design Method, we sent a total of five mail to each FFO: (1) a pre-notification postcard, (2) the first survey questionnaire with 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 including a questionnaire, a cover letter, and a pre-stamped return envelope, and (5) the final survey packet. We included a $2 bill in the first survey packet because previous research shows that having pre-paid token of appreciation can help improve response rates (Dillman et al. 2014; Simmons and Wilmot 2004). Our study was approved by Purdue University Institutional Review Board (IRB) and administered from November to December 2015. Of the 2,600 FFOs,

[1] "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."

1,422 completed and returned the survey questionnaire, while 112 had inaccurate or unreachable addresses and 64 were deceased or no longer owning woodland. Therefore, our response rate was 58.7%. We analyzed the survey data using STATA 12.0 statistical software.

2.3.2 Empirical Models

We constructed two empirical models to assess the role of PMT on landowners' likelihood to remove invasive plants in the future. In both models, the dependent variable is measured by asking respondents to indicate their likelihood to undertake activities to remove invasive plants from their wooded land in Indiana in the next five years using a five-point Likert scale from 5 (very likely) to 1 (very unlikely). We recoded this variable to be "1" if respondents indicated that they were "likely" or "very likely" to manage invasive plants in the next five years and "0" if they indicated otherwise.

The first model only focused on the PMT components (perceived self-efficacy beliefs, perceived vulnerability and perceived severity) as independent variables (Table 1; Table 2) to investigate the effects of PMT components without other variables. The second model was built upon the first model by adding several additional independent variables to the PMT-related variables (Table 2). We measured perceived severity (variable name: severity_impact) by averaging scores measuring respondents' levels of agreement with eight statements about potential impacts of having invasive plants on their woodlands in Indiana using a five-point Likert scale from 5 (strongly agree) to 1 (strongly disagree). We created this composite core because these eight items were highly correlated with an Cronbach's alpha of 0.8991 (Table 3). We measured perceived vulnerability (variable name: vulnerability) by averaging scores measuring respondents' levels of agreement with two statements about how susceptible they feel to the spread invasive plants and difficulty of control invasive plants (Table 3). Similarly, scores measuring respondents' levels of agreement with ten statements about their beliefs about their own ability to remove invasive plants from their woodlands in Indiana were highly correlated with a Cronbach's alpha of 0.8813 (Table 4). Therefore, to measure perceived self-efficacy, we created a composite score (variable name: selfefficacy_specific) by averaging these scores.

In addition to these PMT-related independent variables, we also included in the second empirical model several variables that previous studies have suggested as important factors

influencing invasive plant management behavior and/or forest management behavior in general (Table 2). These include familiarity with invasive plants, past management behaviors, whether a respondent has a written forest management plan, ownership objectives (calculated using a principal component analysis; Table 5), woodland characteristics, and respondent demographics. Finally, we included one additional independent variable (variable name: socialinfluence) to measure the extent to which a respondent is subject to social influence in terms of invasive plant management. The three statements measuring social influence were highly correlated with a Cronbach's alpha of 0.9282; therefore, we created a composite score by averaging scores from these three statements (Table 6).

To estimate our empirical model, we used binary logistic regression where a probability score was assigned to each of two possible outcomes. For a binary response variable Y and a vector of explanatory variables X, these probabilities are:

$$P(Y_i = 1) = P_i = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}}$$
$$P(Y_i = 0) = 1 - P_i = 1 - \frac{e^{\beta X_i}}{1 + e^{\beta X_i}} = \frac{1}{1 + e^{\beta X_i}}$$

where Pi represents the probability of an FFO indicating likely or very likely to manage invasive plants on their forestlands in the next five years, β is a vector of regression coefficients, βXi is a standard notation representing the right-hand side of a regression model. Because the coefficient estimates in a logistic regression do not carry the implication of per unit impact of individual explanatory variables as in an ordinary least squares regression, marginal effect for each explanatory variable was calculated as follows: $dPi/dXi = Pi(1-Pi)\beta$. However, in this paper, the interpretation of the logistic regression results was mainly focused on the identification of significant explanatory variables and their associated signs.

Prior to running the final model, we calculated pairwise correlations to check for potential multicollinearity among independent variables. For the first model, there were strong correlations between perceived severity and perceived vulnerability (Cronbah's alpha = 0.9076; Table 3). We created a combined composite score using all 10 related survey items to measure perceived severity and perceived vulnerability (variable name: severity_impacts_vulnerability). In the second model, several strong correlations were found between variables that measure social influence and perceived severity and vulnerability, past management of invasive plants and perceived self-efficacy, level of familiarity with invasive plants and perceived self-efficacy, past management of

invasive plants and level of familiarity with invasive plants, owning woodlands for family reasons and residence status, owning woodlands for firewood and owning woodlands for family reasons, age and tenure, and age and retirement status. We removed variables measuring residence status, tenure, retirement status, level of familiarity, and owning woodlands for firewood. In addition, we ran a variance inflation factor (VIF) test to check for multicollinearity in both models after removing these variables. The average VIF score for the first model was 1.07, and the average VIF score for the second model was 1.38 – both well below 4, the rule of thumb criterion for multicollinearity.

2.4 Results

Our respondents owned an average of 82 acres of forestlands. Fifty-two percent of woodlands are jointly owned with another individual or their spouse, 36% are individually owned and 12% is jointly owned with two or more individuals. The average woodland owner is 63 years old and 79% of them are male. Thirty-six percent of landowners have a bachelor's or graduate degree and majority reported that only one percent of their annual household income came from their woodlands. Their top five reasons for woodland ownership were: (1) to enjoy scenery or beauty, (2) to protect or improve wildlife habitat, (3) to protect nature and biological diversity, (4) to pass land onto children or other heirs, and (5) to protect water resources.

Respondents owned their woodlands for an average of 25 years and 49% of them were retired. Only a third of the respondents owned their woodlands for extractive reasons such as timber production including logs or pulpwood. Nine percent of respondents were new owners with five years or less experience and 8% were long-term owners with 50 years or more experience. Seventy percent of respondents lived within one mile away of their woodland. Seventy-nine percent of respondents did not have a written forest management plan (21%), 65% had not participated in the Indiana Classified Forest and Wildlands Program, and 87% were not members of an environmental, conservation or woodland owner organization. In addition, over 85% of woodland owners owned 10 acres or more woodland acres on their properties. Seventy-three percent of respondents indicated that their woodland was either currently part of a farm or previously farmed.

FFOs were asked to report their perceived self-efficacy by indicating their level of agreement with seven statements about their ability to manage invasive plants on their wooded lands. Forty-three percent of respondents indicated that they knew what invasive plants to watch for on their wooded lands, and 31% had sufficient knowledge to prevent and remove invasive plants from their wooded land. While 48% of respondents knew how to apply herbicides to kill invasive plants on their wooded land, 15% felt comfortable with using controlled burn or prescribed fire to remove invasive plants from their wooded lands. In terms of reporting invasive plants and getting more information, 55% of respondents knew whom to contact if they have a question about invasive plants on their property, and 43% knew whom to contact if they want to report sightings of invasive plants. Surprisingly, 82% of respondents did not know about county, state or federal programs that assist woodland owners like themselves to remove invasive plants. Respondents were asked to report their likelihood to undertake activities to remove invasive plants from their wooded land in Indiana in the next five years. About one-fifth (23%) of respondents indicated they were unlikely or very unlikely to engage in invasive plant management, 27% were undecided, and 50% were likely or very likely to act.

Both logistic regression models for assessing factors influencing respondents' likelihood of removing invasive plants were significant ($X^2 = 413.76$; $p < 0.01$ and $X^2 = 317.75$; $p < 0.01$, respectively; Table 7). In model 1 with only independent variables informed by the PMT, both perceived severity and vulnerability (i.e., a combined variable) and perceived self-efficacy were statistically significant at the 5% level. In model 2 with additional independent variables informed by the literature, six variables were statistically significant in predicting respondents' likelihood to remove invasive plants: selfefficacy_specific (+), severity_impact_vulnerability (+), past_management (+), socialinfluence (+), own_recreation (+), education (+), and own_heir (-). Specifically, at the 1% level, FFOs who perceived strongly severity and vulnerability associated with invasive plants and who perceived higher self-efficacy in managing invasive plants, were more likely to report a likelihood to remove invasive plants in the next five years. In addition, if respondents had eliminated or reduced invasive plants on their woodlands in Indiana in the past five years, they were more likely to report a plan to remove invasive plants in the next five years. Respondents who were more subject to social influence from their families, friends, neighbors, and other woodland owners were more likely to be interested in removing invasive plants. FFOs who owned their woodlands for recreational purposes were also more likely to report a plan to

remove invasive plants in the next five years. At the 5% level, FFOs who had higher education were more likely to report a plan to remove invasive plants, while FFOs who reported passing land onto their children or other heirs as an important ownership objective were less likely to report a plan to remove invasive plants.

2.5 Discussion

We assessed the role of perceived severity, perceived vulnerability, and perceived self-efficacy on FFOs' intentions to manage invasive plants in the future. The demographic characteristics of woodland owners in our study is mostly similar to other woodland owners in the U.S. (Butler 2016). Also similar to results from previous studies of FFOs, our FFO respondents owned woodlands primarily for amenity reasons. While the percentage of Indiana FFOs with a written management plan is slightly higher than the national average of 13% (Butler 2016), the majority our FFO respondents (79%) did not have a management or stewardship plan. This may be due to the fact that management plans could be perceived by FFOs as being associated with timber production. Based on our results of FFOs' ownership objectives, timber harvesting was one of the least important reasons for woodland ownership.

Managing invasive plants can be very demanding, costly and time consuming. Because the management of already established invasive plants can be expensive, technically challenging and requiring a large time commitment (Courchamp et al. 2017), FFOs may do an assessment of the overall costs and benefits and determine if it is a worthwhile trade-off. Likewise, private landowners in the Sierra Nevada were also influenced by the amount of time and money required for managing invasive plants (Aslan et al. 2009). This large time commitment can be a strong deterrent for some landowners, especially those who are older. Our average respondent is 63 years old and the burdens of invasive plant management may be overwhelming on their physical health. FFOs have shown a preference for incentives in the form of financial assistance, labor, and other resources, which might motivate them to manage invasive plants (Ma et al. 2018).

Perceived self-efficacy has a positive and significant impact on FFOs' intentions to remove invasive plants in the future. Perceived self-efficacy involves FFOs' perceived self-assessment of their own abilities to act. This confirms similar findings in other studies and the theoretical assumption of PMT. For example, whether landowners were knowledgeable about management

strategies was a significant factor in their decision to manage the invasive *Centaurea solstitialis* (yellow star thistle) in California's Sierra Nevada foothills (Aslan et al. 2009). Niemiec et al. (2017) also found that knowledge was a significant factor affecting landowners' decisions to manage *Falcataria moluccana* (albizia) in the Puna District of Hawaii. Self-efficacy includes knowledge about the invasive plants, effective control techniques and how to effectively remove or prevent the species. Perceived self-efficacy is important because if FFOs feel unprepared and incapable of managing invasive plants, they may believe that it is a waste of time and energy. On a related note, it may also be important to ensure that landowners are not only knowledgeable about management strategies but that they develop a sense of confidence in their abilities. This sense of confidence may be achieved by having on-site hands on training for landowners, so they can practice their new-found knowledge in the presence of forestry professionals or other experienced landowners.

Furthermore, landowners may also experience higher perceived self-efficacy through seeing successful reduction in invasive plants. However, this may be difficult to achieve immediately because some invasive plants many take many years of reiteration to be effectively removed. Therefore, we recommend that education, outreach and landowner training also emphasize that invasive plant management is usually a long-term endeavor and their individual abilities to manage should not be based solely on immediate reductions of the invasive plant populations. Although knowledge is known to influence behavior and intentions (Aslan et al. 2009; Fischer and Charnley 2012; Garcıa-Llorente et al. 2011; Niemiec et al. 2016), researchers also argue that the mere transfer of knowledge to landowners is not sufficient to influence behavioral change towards invasive species management (McLeod et al. 2015). FFOs' lack of confidence in their knowledge and control methods could also reflects the fact that there is still a lot of misunderstanding and uncertainty among experts in invasion science. Experts in invasion science have varying and sometimes conflicting perspectives about the definition of invasive plants and their management (Humair et al. 2014). This uncertainty may be communicated to FFOs through newspapers, social media, newsletters and their general interactions with forestry professionals. Family owners expressed hesitations in management because they felt uncertain about whether they were using the most effective treatment, a sentiment that is also common among forestry professionals in Indiana (Ma et al. 2018).

Although social influence is not a component of PMT, we included it as a measure in our model because previous studies show that social influence is important to the effective management of invasive plants (Epanchin-Niell et al. 2010; Graham 2013; Graham and Rogers 2017; Hershbdorfer et al. 2007; Ma et al. 2018; Marshall et al. 2016; Niemiec et al. 2016; Niemiec et al. 2017; Yung et al. 2015). Landowners are attentive to community reciprocity and whether their neighbors were also managing invasive plants on their properties (Ma et al. 2018; Niemiec et al. 2017). Yung et al. (2015) found that landowners identified invasive plant seedlings from neighboring properties to be a significant cause of invasion on their own properties. Our results also show that FFOs believe that a part of being a good neighbor involves managing invasive plants on one's property to prevent them from invading neighbors' property. Additionally, FFOs are more likely to manage invasive plants if their neighbors, other woodland owners (not necessarily their neighbors), family and friends are managing them. This is unsurprising because social influence can be a strong incentive for FFOs to act, especially when they are faced with collective action problems such as invasive plant management.

Perceived vulnerability and perceived severity are strong determinants of FFOs' likelihood to manage invasive plants in the future. If FFOs perceive that invasive plants may pose risks to their use of their property, especially to recreation, they are more likely to manage them. This is like other studies, which found that landowners were more likely to remove invasive plants if they perceived that the plant was a threat to biodiversity and other public goods (Niemiec et al. 2017). Interestingly, Niemiec et al. (2017) found that the perceived risk of invasive plants affecting public bads was a strong predictor of intentions to act, whereas perceived risk of invasive plants to personal property was not. However, it also surprising that of the variables testing reasons why FFOs own their wooded land in Indiana, only land investment and recreation objectives were statistically significant in the model. Specifically, it is surprising that our FFO respondents were not more likely to remove invasive plants if they owned woodlands to protect nature or biological diversity, to enjoy the beauty or scenery, to protect wildlife habitat or to pass land onto their children or other heirs. This finding presents a conundrum because FFOs indicated that they are more likely to remove invasive plants if to their recreational use of their property but at the same time, the majority of FFO owned their properties for amenity reasons such as protecting wildlife and natural resources.

Whether landowners managed invasive plants in the past is statistically significant predictor of FFOs' intentions to remove invasive plants in the future. FFOs' past management behavior could boost their confidence in their management abilities, particularly if they have visible results on their properties. Additionally, past management may be associated with an increase in best management practices for invasive plants. The fact that FFOs are who have managed in the past are willing to continue in the future could indicate that they are aware of, and in agreement with the need to control invasive plants on their woodlands. Although FFOs' willingness to continue pursuing management is an overall encouraging sign, we also caution that invasive plant management may increase feeling of defeats if FFOs are not seeing visible reductions in invasive plants.

Our results are similar to other studies which find that landowners with higher education levels are more likely to manage invasive species (Niemiec et al. 2017a; Steele et al. 2006). If FFOs were familiar with invasive plants, they were more likely to express intentions to remove them in the future. Other studies also found that landowners' intentions to control invasive species on their properties is influenced by their knowledge and awareness of the species (Aslan et al. 2009; Fischer and Charnley 2012; Ma et al. 2018; Niemiec et al. 2016). However, other social-demographic variables such as age, sex, household income, and membership in an environmental, conservation or woodland owner organization were not statistically significant. Specifically, income being statistically insignificant is counterintuitive because invasive plant management can be costly, and it would be expected that FFOs with more money would have more financial capacities, access to resources and equipment, forestry professionals to remove them. Our results are unlike those of previous scholars who argue that higher income is associated with increased forest management activity (Joshi and Arano 2009; Straka and Doolittle 1988) and even cooperation to jointly manage forests in the future (Vokoun et al. 2010). For example, a study in Hawaii found that wealthier landowners had lower probabilities of an invasive plant albizia on their subdivisions (Niemiec et al. 2018).

It is also surprising that FFOs with written management plans is statistically insignificant predictor of their likelihood to remove invasive plants in the future. This result is surprisingly because management or stewardship plans are usually written in consultations from a forestry professional. Previous studies also found that FFOs with a written management plan are more likely to engage in other forest management activities (Amacher et al. 2003; Brook et al. 2003; Cai

et al. 2016; Joshi and Arano 2009; Silver et al. 2015). The management or stewardship plan usually includes general advice and a plan for forest management, timber harvesting along with an assessment of invasive plants on the property and a recommended strategy to manage them. Furthermore, it is surprising that most of the landowner demographic variables such as age, gender, acreage, tenure, membership in a conservation/environmental or woodland owners' organization were not statistically significant. This is unlike previous studies which found that these variables are strong predictors of behavior (Butler et al. 2018; Ma et al. 2012).

People's perceptions of invasive plants as having negative or positive benefits also influences whether they will manage them. FFOs who expressed concern or great concern about invasive plants on their woodlands are statistically more likely to express intentions to remove them in the future. While our results also show that a general concern for threat from invasive plants is also a significant determinant, we found that only threat to FFOs' recreation activities such as their use or enjoyment of their property, hunting and other recreation activities. Surprisingly, although FFOs indicated that biodiversity was a primary reason for woodland ownership, the environmental and economic impacts of invasive plants was not statistically significant. Previous research shows that landowners who perceive invasive plants as a threat to their forests are more inclined to manage invasive plants (Robbins 2004; Steele et al. 2006). Furthermore, landowners who identified wildlife protection as important ownership objectives more likely to control invasive species on their properties (Fischer and Charnley 2012).

Our results could indicate that FFOs are unaware or feel uncertain about the environmental impacts of invasive plants on their ownership objectives like protecting wildlife and biodiversity. It might also illustrate that FFOs earn on average such low amounts of income from their forestlands that invasive plant management is does not have enough negative economic impacts to factor into their decisions. Although biodiversity is identified as a primary reason for land ownership, our respondents are more motivated to remove invasive plants of they perceive a threat to the recreational uses of their property. As a result, it may be productive to highlight the impacts that invasive plants can have on recreation such as hunting. For example, some invasive plants such as garlic mustard (*Alliaria petiolata*) are allelopathic and can change the soil composition, making it difficult for other seedlings to grow (Prati and Bossdorf 2004). Consequently, it prevents the growth of native plant species that serve as food source for certain animals like deer and rabbits, thereby having a ripple effect on animal wildlife and hunting. Communicating the effects of

invasive plants in similar narratives that are relevant to FFOs' interests may have increase their motivation to manage invasive plants.

2.6 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. Understanding the role of social psychology theories and using empirical data to assess FFO's willingness to manage invasive plants can provide valuable knowledge about factors that are important to their overall decisions. This paper assessed Protection Motivation Theory and its role in family forest owners' likelihood to remove invasive plants from their properties in the future. We found that all the components of PMT except for response efficacy was not statistically significant. We did an empirical analysis of factors that influence behaviors. We found that FFOs who had at least a bachelor's degree, were familiar with invasive plants, had a written management or stewardship plan, or managed invasive plants in the past were more willing to manage invasive plants in the future. Additionally, FFOs perceived self-efficacy, social influence, perceived response costs and perceived vulnerability were also statistically significant.

We expanded the current knowledge on FFO's behavior by incorporating empirical data and applying theoretical frameworks to their intentions to manage invasive plants. We found that FFOs' perceived threat of invasive plants, especially their impacts on their recreational use of their properties are important motivators for FFOs to manage invasive plants. The results of this study may also be applicable to other natural resource management contexts that recommends collective action among uncoordinated independent FFOs to be successful. Policies that promote collective management of invasive plants should focus on communicating the threats of invasive plants to FFOs' recreational use of their properties, increase training opportunities, provide resources for FFOs to manage invasive plants on their properties and communicate the damaging impacts of invasive plants especially under threat from climate change. Based on our findings, we also recommend that more effort is placed in building community trust and collective capacity to manage invasive plants. While most written management or stewardship plans focus primarily on individual forest management or invasive plant management, many forest management issues go beyond the individual FFO and involve more of a community and landscape level engagement to

be effective. Therefore, we recommend that forestry professionals be trained to coordinate FFOs who are interested in working collectively with their neighbors to manage invasive plants on their properties.

Table 2.1: Definition of independent variables used for model 1, informed by the Protection Motivation Theory.

Variable / Variable name	**Definition**
Perceived severity / severity_impact	Perceived severity is how serious the individual believes the threat will be themselves or their properties (Feng et al. 2017; Gebrehiwot and Van der Veen 2015; Bockarjova and Steg 2014)
Perceived vulnerability / vulnerability	Perceived vulnerability refers to how susceptible someone feels to the incoming threat (Bockarjova and Steg 2014; Zhao et al. 2016; Martin et al. 2007).
Perceived self-efficacy / selfefficacy_specific	Self-efficacy is an individual's perceptions or beliefs about their own abilities to effectively carry out the recommended protective action (Bockarjova and Steg 2014; Dang et al. 2014; Dittrich et al. 2016)

Table 2.2: Independent variables used in the empirical models for estimating respondents' likelihood to remove invasive plants from their woodlands in Indiana in the next five years.

Variable name	**Description**
severity_impacts_vulnerability	Composite score calculated by averaging ratings of 10 statements about perceived severity and perceive vulnerability (see Table 3)
selfefficacy_specific	Composite score calculated by averaging ratings of nine statements about perceived self-efficacy (see Table 4)
pastmanage	Binary – 1 if reduced or eliminated invasive plants on their property in the past five years; 0 if otherwise
socialinfluence	Continuous – FFOs being subject to the influence of others (see composite score, see Table 6)
acreage	Continuous – forest acreage owned in the state
age	Continuous (years)
manageplan	Binary – 1 if having a written forest management plan or stewardship plan; 0 if otherwise
own_nature	Continuous – protecting nature as ownership objective (principal component loadings, see Table 5)
own_family	Continuous – family purposes as ownership objective (principal component loadings, see Table 5)
own_recreation	Continuous – recreation as ownership objective (principal component loadings, see Table 5)
own_utilitarian	Continuous – utilitarian reasons as ownership objectives (principal component loadings, see Table 5)
own_invest	Nominal – 1 if owning wooded lands for land investment is not important, 2 if of little importance, 3 if moderately important, 4 if important, 5 if very important
own_heir	Nominal – 1 if owning wooded lands to pass land onto children or other heirs is not important, 2 if of little importance, 3 if moderately important, 4 if important, 5 if very important
own_firewood	Nominal – 1 if owning wooded lands for firewood is not important, 2 if of little importance, 3 if moderately important, 4 if important, 5 if very important
absentee	Binary – 1 if home (primary) residence is more than one mile away from their wooded land in Indiana; 0 otherwise
tenure	Continuous – number of years having owned wooded land in Indiana
farm_history	Nominal – 1 if currently farmed; 2 if previously farmed; 3 if not part of a farm currently or previously
org_membership	Binary – 1 if member of an environmental, conservation or woodland owner organization; 0 if otherwise
sex	Binary – 1 if male; 0 if otherwise

Table 2.2 continued

education	Categorical – 1 if education level was high school or less, 3 if education level is some college or Associate degree and 5 if education level is bachelor's degree or higher
hh_income	Categorical – 1 if income < $50,000, 3 if income is $50,000- $149,999, 5 if income is >=150,000

Table 2.3: Description and summary of survey items measuring perceived severity and perceived vulnerability.

Survey item	**Mean (Std. dev.)[a]**	**Cronbach's Alpha**	**Cronbach's Alpha**
Invasive plants decrease the beauty of my wooded land.	3.74 (.87)	0.8991	0.9076
Invasive plants are bad for wildlife on my wooded land.	3.48 (.85)		
Invasive plants reduce the property value of my wooded land.	3.54 (.83)		
Invasive plants prevent the growth of new trees on my wooded land.	3.76 (.83)		
Invasive plants reduce the value of timber on my wooded land.	3.57 (.86)		
Invasive plants negatively impact my use or enjoyment of my wooded land.	3.46 (.97)		
Invasive plants negatively impact my ability to hunt on my wooded land.	2.97 (.98)		
Invasive plants negatively impact my ability to recreate (other than hunt) on my wooded land.	3.21 (.94)		
Invasive plants from neighboring or nearby wooded lands will eventually spread onto my property.	3.78 (.82)	0.7624	
If I don't remove invasive plants from my wooded land as soon as possible, they will become harder to remove later.	3.92 (.77)		

[a] Survey item scale: 1= strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree.

Table 2.4: Description and summary of survey items measuring perceived self-efficacy beliefs.

Survey item	**Mean (Std. Dev.)[a]**	**Cronbach's Alpha**
I know what invasive plants to watch for on my wooded land.	2.35 (.82)	0.8813
I have sufficient time to inspect my wooded land for invasive plants.	2.48 (.81)	
I have sufficient money to remove invasive plants from my wooded land.	2.20 (.81)	
I have sufficient knowledge to prevent and remove invasive plants from my wooded land.	2.15 (.78)	
I have access to the mechanical equipment needed to remove invasive plants from my wooded land.	2.24 (.91)	
I know how to apply herbicides to kill invasive plants on my wooded land.	2.37 (.91)	
I feel comfortable with using controlled burn/prescribed fire to remove invasive plants from my wooded land.	1.74 (.77)	
I know who to contact if I have a question about invasive plants.	2.51 (.91)	
I know who to contact to report sightings of invasive plants.	2.32 (.89)	
I know about county, state or federal programs that assist woodland owners like me in removing invasive plants.	1.88 (.76)	

[a] Survey item scale: 1= strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.

Table 2.5: Description of survey items measuring family forest ownership objectives and principal component analysis results.

Survey item	**Mean (Std. Dev.)[a]**	**PC_1[bc]**	**PC_2[bd]**	**PC_3[be]**	**PC_4[bf]**	**Cronbach's Alpha**
To enjoy beauty or scenery	4.20 (1.00)	0.7758				0.8828
To protect nature or biological diversity	3.94 (1.06)	0.9136				
To protect or improve wildlife habitat	4.04 (1.05)	0.8732				
To protect water resources	3.69 (1.15)	0.7960				
Is part of my home site/primary residence	3.39 (1.65)		0.8261			0.7484
For privacy	3.66 (1.42)		0.6515			
To raise my family	3.17 (1.58)		0.7805			
Is part of my cabin or vacation home site	2.00 (1.43)			0.5740		0.6460
For nontimber forest products, such as tree nuts, mushrooms, or berries	2.67 (1.32)			0.5272		
For hunting	3.28 (1.49)			0.7262		
For recreation, other than hunting	3.36 (1.34)			0.6822		
Is part of my farm	3.45 (1.58)				0.6208	0.4445
For timber products, such as logs or pulpwood	2.77 (1.41)				0.7917	
For land investment[g]	3.43 (1.28)					
To pass land onto my children or other heirs[g]	3.83 (1.37)					
For firewood[g]	2.69 (1.37)					

[a] Survey item scale: 1 = not important, 2 = of little importance, 3 = moderately important, 4 = important, 5 = very important.

[b] Rotated principal component loadings smaller than 0.50 are left blank.

[c] PC_1 was named own_nature and defined as protecting nature being an important family forest ownership objective.

[d] PC_2 was named own_family and defined as family purposes being an important family forest ownership objective.

[e] PC_3 was named own_recreation and defined as recreation being an important family forest ownership objective.

[f] PC_4 was named own_utilitarian and defined as utilitarian reasons being an important family forest ownership objective.

[g] Three survey items were not loaded onto the four principal components and were included in the regressions as standalone variables: own_invest, own_heir, own_firewood.

Table 2.6: Description and summary of survey items measuring social influence.

Survey item	**Mean (Std. Dev.)[a]**	**Cronbach Alpha**
If my neighbors are controlling/removing invasive plants from their wooded lands, I will feel the need to do the same.	3.77 (.85)	0.9282
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 (.87)	
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 (.88)	

[a] Survey item scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree.

Table 2.7: Logistic estimates of two empirical models for estimating family forest owners' likelihood to remove invasive plants from their wooded lands in the next five years.

Independent variable	**Model 1 with two independent variables informed by the PMT**		**Model 2 with two independent variables informed by the PMT and additional variables informed by the literature**	
	dy/dx[ab]	**Std. Err.**	**dy/dx[ab]**	**Std. Err.**
severity_impact_vulnerability	0.186**	0.118	0.117**	0.027
selfefficacy_specific	0.375**	0.154	0.228**	0.030
acreage			-0.002	0.014
farm_history			0.012	0.037
manageplan			0.050	0.042
pastmanage			0.182**	0.036
socialinfluence			0.103**	0.023
own_nature			0.024	0.017
own_family			0.030	0.017
own_recreation			0.043**	0.017
own_utilitarian			0.017	0.020
own_heir			-0.032*	0.014
org_membership			-0.050	0.048
age			-0.002	0.0017
sex			0.045	0.040
education			0.021*	0.011
hh_income			-0.011	0.013
# of observations	1240		731	
LR chi-squared	413.76		317.75	
Pseudo R^2	0.2407		0.3161	

[a] dy/dx is marginal effect.
[b] *$p < 0.05$, **$p < 0.01$.

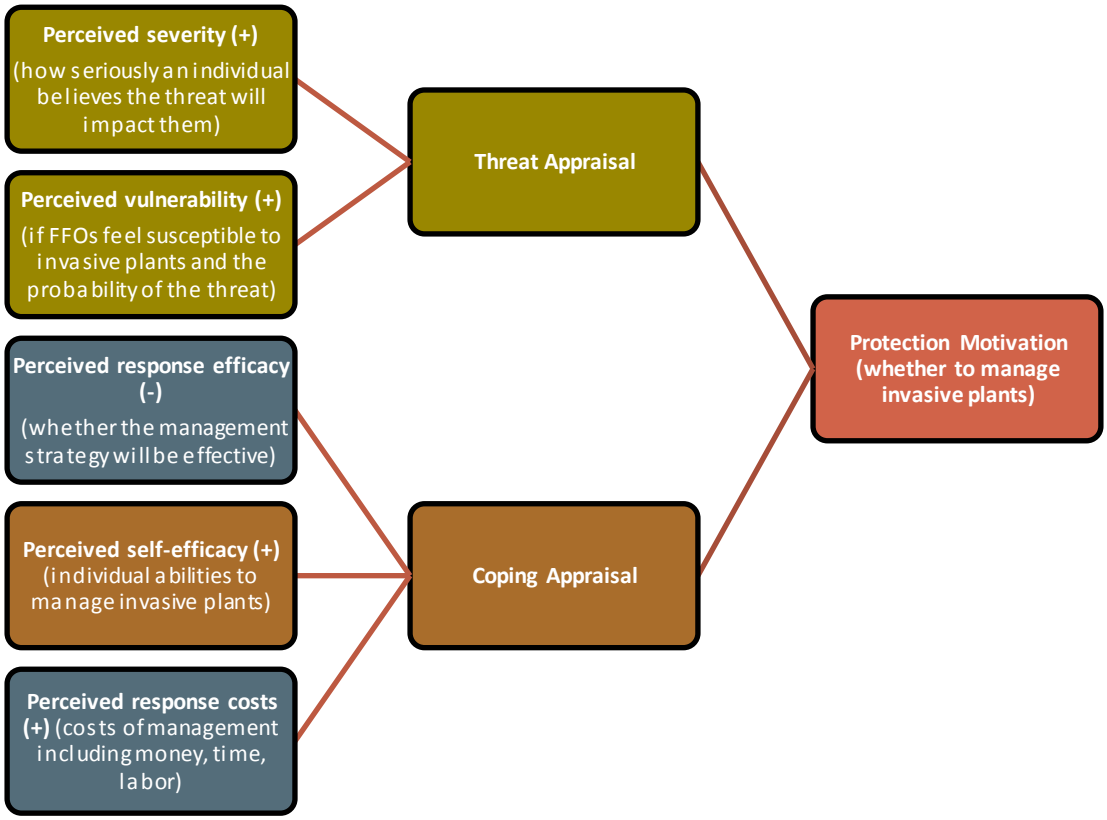


Figure 2.1: Conceptual model of applying the Protection Motivation Theory in the context of family forest owners' decisions to manage invasive plants.

CHAPTER 3. FACTORS INFLUENCING FAMILY FOREST OWNERS' INTEREST IN COLLECTIVE INVASIVE PLANT MANAGEMENT

3.1 Abstract

Collective action to manage forest resources is becoming increasingly important. Environmental risks such as nonnative plant invasion, can be considered a public-goods problem that needs individual landowners to engage in collective actions. We conducted a mail survey of 2,600 family forest owners in Indiana, USA. By analyzing this survey data, we examined private landowners' perceptions of and interests in collective invasive plant management. Our results show that family forest owners are motivated by concerns about invasive plants on their neighbors' properties. Perceived self-efficacy in removing invasive plants also contributes to their interest in working with others. Additionally, previous experience talking to others about invasive plants or working with their neighbors to remove invasive plants from both of their woodlands are important predictors of future intentions to work with neighboring landowners. Whether landowners perceive that there is a need for collective action to manage invasive plants, can also be significant for shaping their interest in working with their neighbors to remove invasive plants. However, none of the demographic chracteristics (e.g., age, sex, education, household income) or ownership characteristics except for woodland holding size, were statistically significant predictors of family forest owners' likelihood to collectively manage invasive plants in our study. Our results suggest that future invasive plant management policies and programs should focus on building individual competency and confidence, a shared concern about invasive plants, and trust to facilitate collective actions. Our results also contribute to building knowledge about applying the concept of collective efficacy beliefs and social influence to better understand forest management challenges in general.

3.2 Introduction

Approximately one-fifth of the world's ecosystems are vulnerable to invasive species, and the spread and impacts of terrestrial invasive plants, in particular, are expected to exacerbate due to ongoing climate change (Early et al. 2016). If untreated, invasive plants can outcompete native plants, displace native species, and homogenize landscapes (Simberloff 2013). Furthermore,

invasive plants can take several years to establish in an ecosystem (Webster et al. 2008) and may not exhibit immediate ecological impacts but will be detrimental in the long run. Efforts on invasive plant-related research has been focusing on the ecological principles underlying the reproduction and dispersal of invasive plants, and the control strategies targeting specific species. However, more scholars and practitioners are starting to recognize that invasive plant management is a social problem because people not only play an important role in the introduction and distribution of invasive plants across landscapes but are also key to developing and adopting strategies for invasive plant control and prevention (Head et al. 2015; Perrings et al. 2002).

Previous research on people's attitudes towards invasive plants and related management programs shows that people's cultural, psychological, social, and environmental values are important factors (Gobster 2012). Differing values among stakeholders may create conflicting views on invasive plant management (Estevez et al. 2015). Several studies of the public, master gardeners, agricultural producers, private forest landowners, and horticultural professionals have shown that many people perceive invasive plants to be problematic and a cause for concern (e.g., Daab and Flint 2010; Graham 2013; Kapler et al. 2012; Ma et al. 2018). However, other studies also show that people can sometimes be indifferent to the socio-ecological impacts of invasive plants and some may even think they provide valuable services such as food to wildlife (Fischer and Charnley 2012; Yung et al. 2015). Despite some of these perceptions, landowners who prioritize wildlife habitat and biodiversity are more likely to control invasive plants on their properties (Estevez et al. 2015). Place attachment is also significant in landowners' perceptions of invasive plants. While individuals who feel a stronger connection to, and dependence on nature generally view invasive plants as ecologically destructive (Kapler et al. 2012), other landowners with stronger place attachment may also become attached to the invasive plants associated with specific places and accept them as part of the natural community, consequently unwilling to remove them (Niemeic et al. 2017b.) Additional studies focusing on individual landowners have shown that invasive plant management is also influenced by landowner knowledge and awareness of various species (Fischer and Charnley 2012; Steele at al. 2006; Daab and Flint 2010; Ma et al. 2018; Bremner and Park 2007; Novoa et al. 2017), their past experience of managing invasive plants, and their general land stewardship practices.

More recently, scholars have increasingly recognized that beyond individual landowners taking actions to remove invasive plants from their properties, it requires community engagement

to be effective (Epanchin-Niell and Wilen 2014; Yung et al. 2015). In fact, studies show that collective, coordinated management is necessary for invasive plant control across landscapes and tends to be more effective than individual, uncoordinated management (Epanchin-Niell and Wilen 2015; Graham 2013; Hershdorfer et al. 2007; McKiernan 2017; Niemiec et al. 2017a; Yung et al. 2015). This is because invasive plant management poses a public goods problem (i.e., non-excludable and non-rivalrous) at the individual, community, national, and international scales (Perrings et al. 2002; Costello et al. 2017; Graham and Rogers 2017; Ravnborg 2004). Problems of invasive plants on private lands are non-excludable because invasive plants on one landowner's property can easily spread to another landowner's property through water, wind, human activity, animals or other seed dispersal mechanisms. As such, landowners who introduce invasive plants on their property or those who do not manage them can create negative externalities to other landowners by allowing their lands to act as sources of invader propagule, thus increasing the risk of invasive plant spread to their neighbors' properties (Epanchin-Niell et al. 2010; Simberloff et al. 2005; Ma et al. 2018). The benefits of invasive plant management are non-rivalrous because invasive plants can encompass a free rider problem as landowners who choose not to manage invasive plants on their properties may be able to free ride on the invasive plant control efforts of others that reduce invasion risk for all.

As a public-goods problem, managing invasive plants requires collective actions. Collective invasive plant management requires landowners in a certain geographic region to work together on control and prevention measures (Hershdorfer et al. 2007). Specifically, Epanchin-Niell and Wilen (2015) argue that bioinvasions including nonnative plant invasions are generally under managed in systems of independent landowners because landowners tend to consider the costs and benefits of invasion control to themselves rather than to society as a whole. Perrings et al. (2002) classifies invasive species as a "weakest link" public goods problem - the benefits of invasive species management depend on how much the "weakest links" would be willing to engage in management actions. This collection action problem associated with invasive plant management is particularly challenging to address because private landowner cultures and social norms have not adapted sufficiently to address invasive plant problems at the landscape scale (Perrings et al. 2002).

So far, research on family forest owners' (FFOs) interests in collective action mostly focused on cross-boundary cooperation among FFOs in the contexts of timber harvesting, wildfire

management, and ecosystem management (e.g., Blinn et al. 2007; Brunson et al. 1996; Canadas et al. 2016; Fischer et al. 2018; Kittredge 2003; Kittredge 2005; Mendes 1998; Pavelgio et al. 2015; Rickenbach et al. 2005; Rickenbach et al. 2011; Rickenbach and Jahnke 2006; Stallman and James 2015). Family forest owners are "families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land" (Butler 2008). In the United States, 10.7 million FFOs collectively own 290 million acres (36%) of forestland (Butler et al. 2016). Several studies have pointed out that FFO cooperatives can help increase the efficiency and effectiveness of forest management (Fischer et al. 2018; Kittredge 2005). For example, Rickenbach et al. (2005) found that FFOs were interested in pursuing collective action by joining Sustainable Woods Cooperatives because they wanted to create an economy of scale to replace the typical timber sale arrangements that often disadvantage individual and smaller FFOs. Generally speaking, collective actions among FFOs are more likely when (1) FFOs understand that collective management is more effective than working individually, (2) FFOs believe that the benefits of collective actions outweigh the costs, (3) when FFOs can contribute to collective actions, and (4) when there is a strong sense of reciprocity and trust among group members (Gass et al. 2009; Rickenbach and Reed 2002; Bergmann and Bliss 2004; Wolf et al. 2007). Peer-to-peer learning can also contribute to FFOs' interest in collective learning and cooperative forest management (e.g., Kueper et al. 2013). Although previous research on forest management studied collective action related to cross-boundary cooperation among individual private landowners in other contexts, collective action is still one of the major challenges to invasive plant management (Marshall et al. 2016).

Collective invasive plant management is difficult partly because of the large number of private landowners involved and their diverse interests and ownership objectives (Butler et al. 2016). Within the context of invasive plants, previous studies on collective actions have mainly focused on agricultural producers, ranchers and the public. These studies have revealed the complexity of factors influencing landowner management decisions (Epanchin-Niell and Wilen 2015; Epanchin-Niell et al. 2010; Graham 2013; Graham and Rogers 2017; Marshall et al. 2016; McKiernan 2017; Niemiec et al. 2016; Yung et al. 2015). For example, landowners may decide to participate in invasive plant management if they perceive that their neighbors are also actively controlling invasive plants on their properties (Epanchin-Neill and Wilen 2015; McKiernan 2017; Niemiec et al. 2017a Yung et al. 2015). A study in western Montana shows that landowners

identified invasive plant seedlings from neighboring properties to be a significant cause of invasion on their own properties, and those who were managing invasive plants on their properties stated that they were doing so to be a good neighbor (Yung et al. 2015). Furthermore, landowners who perceive invasive plants as more threatening to the health and production of their forests tend to be more motivated to control invasive plants so they can be a good neighbor by preventing the spread of invasive plants (Fischer and Charnley 2012; Yaffee 1998). In contrast, if landowners perceive that their neighbor are s not controlling invasive plants on their properties, they may mirror their neighbors' behaviors and not actively manage invasive plants because they perceive their efforts as futile (Hershdorfer et al. 2007). Additionally, landowners' risk perceptions (Colton and Alpert 1998; Sharp et al. 2011; Norgaard 2007; Van Wilgen 2012; Flint and Luloff 2007) and environmental attitudes (Sharp et al. 2011) also impact their decisions to work collectively.

Social norms, specifically norms of reciprocity, are also important factors shaping landowners' decisions to engage in collective invasive plant management (Niemiec et al. 2016; McKiernan 2017; Howard et al. 2018). For example, Graham and Rogers (2017) suggest that within already established community groups, successful collective actions require: (1) shared common goals, (2) strong internal and external relationships including a strong sense of community or a culture of social learning, (3) institutional partnerships, and (4) recognized leadership. For example, Graham (2013) conducted a qualitative study in Australia to examine how serrated tussock (*Nassella trichotoma*), a common invasive weed species, is managed collectively. The author identified three important strategies that helped communities become effective in organizing collective invasive plant management actions: (1) sharing information about the importance, identification, and treatment of the species, (2) providing support like financial and social incentives (e.g., encouragement) to landowners, and (3) providing formal and informal pressure via government regulations and peer pressure.

Previous research also discussed barriers to collective action. In terms of institutional capacity, few government agencies have a clear understanding of what collective action is, how it works, and how to facilitate it (Graham and Rogers 2017). Government agencies could play a potentially important role in facilitating collective management of invasive plants among various landowners by incentivizing those who are unwilling to participate directly. These agencies could also build trust and leadership by managing weeds on their government-owned properties (Graham and Roger 2017; Perrings et al. 2002). At the individual level, fluctuating landowner demographics

is also a barrier to collective action (Howard et al. 2018). As newer and often amenity-focused landowners move into an area, it is challenging to build a sense of community and to engage both recent and older owners in active land management activities (Graham 2013; McKiernan 2017). In several studies, landowners were reluctant to talk with their neighbors about invasive plant management because of a culture of private property rights and social norms related to privacy and independence (Graham 2013; Ma et al. 2018; Ravnborg and Westermann 2002). Furthermore, even if landowners have strong social bonds to other members of their community, and interest in managing invasive plants, they might still be unwilling to engage with their neighbors because they do not want to intrude on their neighbors' privacy and private property rights (Niemiec et al. 2017b).

Despite the growing body of literature, a lot remains unknown regarding how private forest landowners, another important group of landowners in the United States and many other parts of the world, collectively manage invasive plants (Marshall et al. 2016). Particularly interesting is the lack of understanding about the knowledge, perceptions, and interests of family forest owners to collective invasive plant management (Fischer and Charnley 2012; Ma et al. 2018). As family forestlands continue to be subdivided and fragmented due to development pressure and intergenerational transfer (Kittredge 2009; Markowski-Lindsay et al. 2016), engaging FFOs in invasive plant management will become increasingly challenging but necessary (Vokoun et al. 2010).

3.2.1 Insights into Collective Efficacy Beliefs

In many cases, addressing large-scale environmental problems is beyond the ability of a single individual (Chen 2015) and requires collective actions of many individuals (Bandura 1997). Collective efficacy is the belief that people can work together to achieve collective benefits (Bandura 1997). It can include individuals' perceptions of their collective ability to address an issue affecting their communities. Collective efficacy beliefs can influence an individual's perceptions, motivations to act, and the amount of effort they will contribute to a specified action. Several studies even suggest that collective efficacy is a more significant predictor of pro-environmental behavior than self-efficacy (Chen 2015; Homburg and Stolberg 2006). Self-efficacy refers to whether the individual perceives that can they successfully do a certain act based on a self-assessment of own abilities (Bockarjova and Steg 2014). Other scholars have shown

strong interactions between self-efficacy, collective efficacy and the resulting associated perceptions. Specifically, people's collective efficacy can indirectly affect their perceived self-efficacy. Experimental studies have shown that as people's perceived collective efficacy increases with manipulations, their perceived self-efficacy also grows (Jugert et al. 2016). Similarly, perceived collective efficacy is affected by perceived self-efficacy (Bandura 2000); people with higher perceived self-efficacy are more likely to contribute to problems involving collective efficacy (Bandura 2000; Doran et al. 2015; Hanss and Böhm 2010).

As society becomes increasingly interdependent, the need for collective efficacy also increases, which in turn suggests the importance to understand the negative impact of perceived collective powerlessness (Bandura 1998). According to Bandura (1998), people's perceived collective powerlessness can be a stronger hindrance to socially-desirable behavior than external factors. Collective efficacy can be thwarted by (1) long gaps between collective efforts and visible results, (2) bureaucratic structures, (3) differing self-interests in values and goals, and (4) perceptions of other societal problems and the application of collective action (Bandura 1997). For collective action to be successful, recognized leadership and opportunities for members to formally interact are important (Fischer et al. 2018; Watkins et al. 2013), especially when there is new information, new members, when participants are divided about an issue, and when there are different groups engaged in the collective action process (Watkins et al. 2013).

Previous research on collective efficacy beliefs primarily focused on neighborhood crime rates (Browning et al. 2004; Hipp 2016; Wickes et al. 2013), sports and team cohesion (Bruton et al. 2016), and physical health (Browning and Cagney 2002). In the environmental context, collective efficacy beliefs were examined in the context of people's acceptance of electric vehicles in Germany (Barth et al. 2016), willingness to pay for environmental goods and services (Doran et al. 2015), and sustainable behavior of reducing plastic use (Reese and Junge 2017). In one recent study, Niemiec et al. (2017a) examined perceived collective efficacy in the context of the Cape-to-City (C2C) invasive predator control program in New Zealand. The authors defined perceived collective efficacy as program participants' perceived likelihood that the program would be successful. Generally speaking, perceived collective efficacy can be measured in two ways: (1) combining individuals' perceptions of their own ability (i.e., self-efficacy) to act or (2) combining individuals' perceptions of their group's ability to act (Bandura 2000). For this paper, we used the latter measurement of perceived collective efficacy.

In sum, previous studies of collective invasive plant management has done little to incorporate the concept of collective efficacy, which is important to better understand people's decision making about engaging in collective actions. Furthermore, few studies about cooperative management of private forestlands have used quantitative, empirical data (Fischer et al. 2018; Vokoun et al. 2010). Previous research on collective or coordinated invasive plant management has been primarily qualitative (Graham 2013; Sullivan et al. 2017), case studies of specific geographic areas (Klepeis and Gill 2016; Lubell et al. 2017; Marshall et al. 2016), studied agricultural producers, ranchers or rural residents (Graham 2013; Graham and Rogers 2017), or focused on cooperatives facilitated by formal organizations or programs (Hershdorfer et al. 2007; Lubell et al. 2017; McKiernan 2017; Niemiec et al. 2017a; Ravnborg et al. 2004). Building upon various bodies of literature, this paper will examine private landowners' perceptions of, and interests in collective invasive plant management on family forestlands and identify factors that influence their perceptions and interests with a specific focus on the role of perceived collective efficacy beliefs. The results of the study will also contribute to building knowledge about applying the concept of collective efficacy to understanding forest management challenges.

3.3 Methods

3.3.1 Data Collection

The data used in this study was collected from a random sample of FFOs in Indiana using a mail survey. To develop the survey questionnaire, we first conducted in-person, face-to-face interviews with 11 forestry professionals and 14 FFOs in Indiana. Informed by the interview data, the survey questionnaire includes the following topics: (1) general questions about FFOs' forested properties (referred to as "wooded lands" in the survey), (2) FFO's familiarity with invasive plants on their lands, (3) past invasive plant management activities and future plan for managing invasive plants, (4) FFO's concerns about invasive plants and various management options, and (5) socio-demographic information. For consistency reason, we provided a definition[2] of invasive plants on the front cover of the survey questionnaire.

[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."

To create a sampling frame of all FFOs in Indiana, we first identified forestlands in the state 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 own at least one acre of forested property categorized as "woodland" or "classified forest" in the state of Indiana as of 2014. We then selected a random sample of 2,600 FFOs and administered a mail survey following the Tailored Design Method (Dillman et al. 2014).

By following the Tailored Design Method, we sent a total of five mail to each FFO: (1) a pre-notification postcard, (2) the first survey questionnaire with 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 including a questionnaire, a cover letter, and a pre-stamped return envelope, and (5) the final survey packet. We included a $2 bill in the first survey packet because previous research shows that having pre-paid token of appreciation can help improve response rates (Dillman et al. 2014; Simmons and Wilmot 2004). Our study was approved by Purdue University Institutional Review Board (IRB) and administered from November to December 2015. Of the 2,600 FFOs, 1,422 completed and returned the survey questionnaire, while 112 had inaccurate or unreachable addresses and 64 were deceased or no longer owning woodland. Therefore, our response rate was 58.7%. We analyzed the survey data using STATA 12.0 statistical software.

3.3.2 Empirical Model

We constructed an empirical model to evaluate factors that influence FFOs' intentions to engage in collective invasive plant management. The response variable for the model is "collective_action," measured by respondents' self-reported likelihood to work together with their neighbors to remove invasive plants on both of their woodlands in the next five years using a five-point Likert scale from 5 (very likely) to 1 (very unlikely). We recoded this variable to 1 if respondents indicated that they were likely or very likely to work together with their neighbors in the next five years and 0 if they indicated otherwise.

Our independent variables are described in Table 1, measuring respondents' level of concerns about invasive plants on neighboring or nearby woodlands, past invasive plant

management experience, perceived self-efficacy, perceived collective efficacy, the extent to which they are subject to social influence, experience of talking to others about invasive plants, various land characteristics, and respondents' socio-demographic characteristics. Speficially, we measured perceived self-efficacy by asking respondents to indicate their level of confidence in their own ability to remove invasive plants from their woodlands in Indiana if needed (Table 1). Similarly, we measured perceived collective efficacy by asking respondents to indicate how much they agree with three statements (Table 2). Each statement was rated on a five-point Likert scale from 5 (strongly agree) to 1 (strongly disagree). Ratings of these statements were not highly correlated and were used as three separated variables in the model (variable names: need_work_together, know_how_cooperate, cooperate_hard). We created composite scores to measure the extent to which respondents are subject to social influence and their experience of talking to others about invasive plants. We used composite scores because responses to several survey items measuring the same construct were highly correlated with a Cronbach's alpha of 0.70 or higher. To measure past experience related to talking with others about invasive plants, we asked respondents to indicate their levels of agreement with three statements (Table 3). Average ratings of the three statements were used as a single measure of past experience talking to others about invasive plants (variable name: past_talk; Cronbah's alpha = 0.6119). Similarly, we measured social influence by asking respondents to indicate their levels of agreement to three statements. Each statement was rated on a five-point Likert scale from 5 being strongly agree to 1 being strongly disagree. Ratings of the three statements were averaged into a single score (variable name: social_influence; Cronbah's alpha = 0.9282) to measure the extent to which a respondent is subject to social influence in terms of invasive plant management (Table 4).

To estimate our empirical model, we used binary logistic regression where a probability score was assigned to each of two possible outcomes. For a binary response variable Y and a vector of explanatory variables X, these probabilities are:

$$P(Y_i = 1) = P_i = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}}$$
$$P(Y_i = 0) = 1 - P_i = 1 - \frac{e^{\beta X_i}}{1 + e^{\beta X_i}} = \frac{1}{1 + e^{\beta X_i}}$$

where Pi represents the probability of an FFO indicating likely or very likely to engage in collective invasive plant management, β is a vector of regression coefficients, βXi is a standard notation representing the right-hand side of a regression model. Because the coefficient estimates

in a logistic regression do not carry the implication of per unit impact of individual explanatory variables as in an ordinary least squares regression, marginal effect for each explanatory variable was calculated as follows: $dPi/dXi = Pi(1-Pi)\,\beta$. However, in this paper, the interpretation of the logistic regression results was mainly focused on the identification of significant explanatory variables and their associated signs. Prior to running the final model, we calculated pairwise correlations of variables to check for multicollinearity. We also ran a Variance Inflation factor (VIF) test to check for multicollinearity. The average VIF score for the final model was 1.24, well below 4, the rule of thumb for detecting multicollinearity.

3.4 Results

Our survey responses came from all 92 counties in Indiana. The average forest acreage is 82 acres with a standard deviation of 135.44. The primary woodland ownership objectives were to: (1) enjoy scenery or beauty, (2) protect or improve wildlife habitat, (3) protect nature and biological diversity, (4) pass land onto children or other heirs, and (5) protect water resources. Only a third of the respondents owned their woodland to produce timber products, including logs or pulpwood. Seventy percent of FFOs had their home or primary residence on or within a mile of their forestlands. Majority of FFOs were older with an average age of 63 years old. Twenty-one percent of FFOs had a written forest management or stewardship plan. In addition, 13% of respondents were members of an environmental, conservation or woodland owner organization. Eighty-six percent of FFOs acquired their wooded land in Indiana through purchase, 24% inherited it, and 2% received it as a gift. Ninety-two percent of FFOs were the primary decision-maker about their wooded land in Indiana, while 25% had joint decision-making authority with their spouse and 11% with another family member.

When asked about collective action in the past five years, 98% of respondents had not worked with their neighbor to remove invasive plants from their wooded lands. In addition, most respondents had not talked to, or shared information about invasive plants with their family and friends (86%), neighbors (92%), or other woodland owners (90%). Notably, 38% of respondents did not undertake invasive plant management activities in the past five years, while 62% had done it. When asked about their level of concern about invasive plants on their own wooded land in Indiana, 42% of respondents were concerned or greatly concerned with an additional 35%

moderately concerned. When asked about their level of concern about invasive plants on their neighboring or nearby wooded land, 35% of respondents were concerned or greatly concerned with an additional 33% moderately concerned. Ninety-six percent of respondents believed that their neighbors were not preventing or removing invasive plants or indicated that they did not know about what their neighbors were doing. Similarly, 89% of respondents believed that other woodland owners in their county were not doing anything to prevent or remove invasive plants or indicated that they did not know.

In terms of future actions, 43% of respondents were likely or very likely to talk to their family and friends about invasive plant management, 26% were likely or very likely to talk to their neighboring landowners about it, and 27% indicated likely or very likely to talk to other non-neighboring landowners about it. In addition, 43% of respondents agreed or strongly agreed that Indiana needs some sort of coordinated effort to control/remove invasive plants from privately-owned wooded land, while 42% of them were undecided or did not know. On the other hand, 57% of respondents agreed or strongly agreed that Indiana needs some sort of coordinated effort to control/removed invasive plants from publicly-owned wooded land.

In terms of respondents' perceived collective efficacy to address invasive plant problems (Table 2), 66% of respondents agreed or strongly agreed with the statement that "Effective control and removal of invasive plants require woodland owners to work together." However, only 12% of respondents agreed or strongly agreed that "Woodland owners know how to self-organize and cooperate with one another to control or remove invasive plants." Interestingly, 49% of landowners were undecided or did not know while 38% believed that "Woodland owners did not know how to self-organize and cooperate with one another to control/remove invasive plants." Additionally, 69% of respondents agreed or strongly agreed that "the idea of woodland owners working together to control/remove invasive plants is great but hard to implement," and 62% also agreed or strongly agreed that "it is difficult for woodland owners to self-organize and cooperate with one another on their own."

Respondents also reported their preferences for potential collaborators or collaborating organizations that they can work with to manage invasive plants (Table 5; Figure 1). Specifically, nearly half of respondents found it appealing or very appealing to work with their neighbors to prevent invasive plants from invading both of their wooded lands (48%) or to remove invasive plants from both of their wooded lands (47%). Similarly, close to half of respondents

found it appealing or very appealing to work with other woodland owners in their town/city/county to prevent (47%) or remove invasive plants (43%). In terms of working with government units to remove/control invasive plants on privately-owned wooded lands, 42% of respondents found it appealing or very appealing to work with a state agency, while 38% found it appealing or very appealing to work with their town/city/county government. Somewhat surprising, 49% of respondents found it appealing or very appealing to work with a non-profit organization such as a land conservation organization or woodland owner association, to remove/control invasive plants on privately-owned wooded lands.

Respondents were asked to report their likelihood to work with their neighbors to remove invasive plants on both of their wooded land in the next five years. Thirteen percent indicated they were likely or very likely to do so, while 22% were undecided and 65% indicated they were unlikely or very unlikely to do so. The logistic regression model for estimating FFOs' likelihood to engage in collective invasive plant management in the next five years was statistically significant (X^2 =138.81; $p < 0.001$; Table 6). At the 1% level, five variables were statistically significant in predicting FFO's likelihood to engage in collective invasive plant management: concern_neighbor (+), confidence_removal (+), past_talk (+), past_work_together (+), and social_influence (+) (Table 6). Specifically, respondents who were concerned about invasive plants on neighboring or nearby properties were more likely to be interested in collective action. In addition, landowners who expressed confidence in their own abilities to remove invasive plants from their properties—a measure of perceived self-efficacy, had a higher likelihood of engaging in collective action. If landowners worked with their neighbors in the past to manage invasive plants or had talked to family and friends, neighboring landowners or other non-neighboring landowners about invasive plants, they were more likely to indicate an interest in collective action in the future. Finally, those who were more subjective to social influence were more likely to indicate a plan to engage in collective action. At the 5% level, two additional variables were statistically significant: need_work_together (+) and acreage (+) (Table 6). Specifically, FFOs who agreed or strongly agreed that effective control and removal of invasive require woodland owners to work together were more likely to be interested in collective action in the future. FFOs who had larger woodland holdings were more likely to be interested in collective action as well.

3.5 Discussion

Collective action to manage invasive plants is becoming increasingly important as invasive plants continue to spread with globalization and climate change. Our empirical analysis found that family forest owners were more likely to work collectively with their neighbors if they had talked to their family, friends, neighbors and other woodland owners about invasive plants in the past five years. In fact, sharing information was also classified as a form of cooperative management in previous studies (Fischer et al. 2018; Kittredge 2005; Yaffe 1998). If landowners talked to others about invasive plants in the past, it could indicate that they have established trust and expanded their social network about invasive plants with others. This is like previous studies which found that trust and strong social networks are strong determinants of landowners' decision to work cooperatively (Fischer et al. 2018; McKiernan 2017; Niemiec et al. 2016; Ostrom 2010). For example, McKiernan (2017) detailed how social capital, particularly trust and social norms are developed and then used among rural-amenity landowners to effectively manage invasive plants.

As emphasized in other studies, it is important to develop a sense of trust and reciprocity among neighbors concerning invasive plant management (Marshall et al. 2016; Howard et al. 2018; Niemiec et al. 2016). One way to achieve this could be through facilitating repeated social interactions (Ostrom 2010). Repeated social interactions can enhance trust among landowners by providing various opportunities for them to socialize, share information, resources and/or plan activities together. In the case of FFOs, this may be challenging because landowners might not know their neighbors and in some cases, FFOs properties may be geographically isolated from each other. Therefore, we suggest that programs are strategic about building social bonds among landowners by making effort to keep landowners aware of what is happening in their communities. A relatively accessible way to do achieve this may involve a posting a section in the newspapers on a regular basis that is specifically for forest landowners to feature other activities of landowners in the community. This could be a first step in increasing a sense of community and social bond among landowners even before initiating in-person social gatherings.

Surprisingly, perceived collective efficacy among landowners was only a marginally significant determinant of their intentions to work with their neighbors in the future. This result is unusual because collective efficacy beliefs can increase people's decisions to engage in collective action (van Zomeren et al. 2008) and was a more significant predicator of pro-

environmental behavior than personal efficacy in some cases (Homburg and Stolberg 2006; Jugert et al. 2016). Perceived collective efficacy also impacts how much effort individuals will devote to the tasks. It is therefore surprising that if landowners perceived that collective efficacy would be difficult, this was not as significant a variable as others in the model. People's perceived collective efficacy also affects how much effort they will put in the collective action, staying power when group effort fails and the future they will aspire to collectively (Bandura 2000). Assessing landowners' perceptions of their collective abilities is important and should be considered when designing landowner outreach programs. It is not enough to recommend collective action, we should also consider the factors that impact their perceptions of collective efficacy to create effective landowner outreach.

Concern about invasive plants on neighboring wooded land is also a strong predictor of willingness to manage invasive plants collectively with their neighbors. Landowners' concern about invasive plants on their neighbors' wooded lands is an important consideration since most landowners indicated that their neighbors or other woodland owners in their county were not managing invasive plants on their properties or they did not know if they were. If landowners are concerned about invasive plants, it could indicate that they have enough familiarity about invasive plants to understand the negative impacts they might have on their forest ecosystems or overall use and enjoyment of their properties. Shared concern is expected because both individual and collective concerns are important factors that people consider when deciding about environmental risks (Bockarjova and Steg 2014; Fischer et al. 2018). Therefore, if landowners do not perceive invasive plants as a threat to their livelihoods, collective action might be difficult (McKiernan 2017). Fischer et al. (2018) did a comparative case study of private landowners in the Pacific Northwest and Upper Midwest of the U.S. and found that landowners engaged in cooperative management because of high concerns about invasive plants. If landowners are concerned about invasive plants, it could indicate that they perceive them as a threat and may react to reduce the perceived threat. Their threat perception may lead to community action. Community action can be influenced by the social construction of risks, the residents' proximity to the risk and collective experience with previous environmental issues (Flint and Luloff 2007). Invasive plants problem is a particularly interesting environmental threat because it requires FFOs to assess the susceptibility of their properties to invasive plants while simultaneously assessing the likelihood that invasive plants might spread from their neighbor's

property to theirs. This complex calculation can involve many variables such as visible invasive plant infestation or amount of management on their neighbor's property. One of the challenges to collaborative management is how to create social ties among members who are uninterested in collaborative management, how to ensure that diverse interests are considered and how to create a flexible and adaptable collaborative environment (Bodin 2017). Therefore, it is important to understand the factors that might make collective management more appealing between neighboring landowners.

It is important for FFOs to observe other landowners actively managing invasive plants on their properties. In our model, social influence is a strong indicator of willingness to work collectively. The impacts of social proof on collective action has been well-documented in other studies (Ostrom 2010) such as wildfire risk (Martin et al. 2007); climate change adaptation (Feng et al. 2017) and pro-environmental behavior (Chen 2015). Other studies on invasive plant management found that landowners are less likely to manage invasive plants if their neighbors are not managing them on their properties (Marshall et al. 2016; Epanchin-Neill et al. 2010; McKiernan 2017; Howard et al. 2018). In fact, landowners are dissuaded from further invasive plant control if their neighbors are not controlling on their properties because it is not cost-effective to keep controlling if there the neighbors' property is serving as a seed source for invasive plants (Ma et al. 2018). Furthermore, laboratory experiments about the role of information in governing the commons, found that the availability of information about what others are doing can affect cooperation (Janssen 2013). When there was a lack of information about other participants' behavior, cooperation levels declined (Janssen 2013). Although social proof can be a powerful motivator, it is also important to note that many landowners also own their properties for independence and privacy. While social proof can be helpful, we also acknowledge that social norms may not support landowners sharing information directly with each other because of culture of independence and not disrupting their neighbors (Graham 2013; Ma et al. 2018; Ravnborg and Westermann 2002). Nonetheless, we suggest that subtle forms of social proof including visible signs or posters placed in FFOs yards announcing that they are actively managing invasive plants on their properties may also be an effective and indirect way of encouraging their neighbors to also do likewise.

While previous studies show that landowner demographics are significant factors in their likelihood to work collectively (Howard et al. 2018; Graham 2013; Niemiec et al. 2018), it is

unexpected that none of the demographic variables (education, gender, age, annual household income, primary residence/absentee, membership in an environmental, conservation or woodland owner organization or retirement status) were statistically significant in our model. It is surprising that whether landowners were members of an environmental, conservation or woodland owner organization was not a statistically significant factor in their behavior. Previous studies show that higher perceived social bonds lead to higher perceived collective efficacy at the neighborhood level (Collins et al. 2014). Participation in community organizations provides the opportunity for residents to build trust among each other – thereby leading to an increase in perceived collective efficacy (Colling et al. 2014; Flint and Luloff 2007). Furthermore, several studies on cooperative management of invasive plants found that income was a strong predictor of behavior (Niemiec et al. 2018). It particularly surprising that whether landowners had a written management plan or had managed invasive plants in the past five years was not statistically significant. Our result is unlike several previous studies which suggest that written management plans are significant factors in collective management (Kittredge 2005; Schulte et al. 2008; McKiernan 2017).

Like previous studies, whether landowners managed invasive plants in the past can also be a significant predictor of their likelihood to manage invasive plants. If landowners managed invasive plants in the past, it can indicate that they are aware of the best strategies to manage invasive plants and they are more likely to do so in the future. Furthermore, past management of invasive plants can also indicate that landowners may have more self-confidence in their abilities to remove invasive plants. Perceived self-efficacy is a significant predictor of likelihood to manage invasive plants. This is like previous studies which show that collective efficacy has increased people's pro-environmental behaviors when their self-efficacy beliefs were also increased (Jugert et al. 2016). Other studies also reiterate this finding that higher perceived self-efficacy also results in higher collective efficacy beliefs—thereby increasing the likelihood that individuals will contribute to collective efforts (Bandura 2000; Doran et al. 2015; Hanss and Böhm 2010). Therefore, we believe that landowners may be more inclined to collectively manage invasive plants if they feel enough confidence in their own individual abilities. Furthermore, when individuals develop strong social identity with others in a group, they also get certain benefits like a sense of self-efficacy, responsibility and increased capacity to take certain actions (Jugert et al. 2016). In the future, there needs to be more studies about how landowners

identify themselves within groups and how their social identity directly or indirectly impacts their perceived self-efficacy, perceived collective efficacy and the resulting amount of invasive plant management.

Surprisingly, we found that age was not statistically significant in our model and it was not statistically significant how long landowners and whether they are more willing to work collectively with their neighbors to remove invasive plants in the future. Landowners' perception of collective efficacy is influenced by the amount of time they have lived on their property (Niemiec et al. 2017a). Specifically, landowners who have been living on their properties for longer, have lower perceived collective efficacy (Niemiec et al. 2017a). Other studies found that landowners in the Puna District of Hawaii who have been living on their properties for longer, had lower perceived collective efficacy to control invasive predators Niemiec et al. (2017a). In our study, we believe that tenure might not be statistically significant in our model for several reasons. First, they may already be socialized to not interfere with their neighbors' property management and have adapted the culture of independence and privacy. Second, they may feel ill-equipped to collectively manage invasive plants because majority of them have never collectively managed invasive plants with their neighbors or talked to their neighbors about invasive plants. Third, there are few institutions and structures in place to help them facilitate this process of collective management.

We recommend that (1) landowners are contacted earlier in the process as they move to their forest properties to prevent them from being entrapped in the culture of individually managing their forest properties, and (2) institutions and programs be set in place to help landowners navigate the process of working collectively. For example, a case study done in New South Wales, Australia found that new amenity landowners are more likely to manage invasive plants if they are educated about the negative impacts of invasive plants early rather than later when they are already settled and develop specific forest management styles, which may not be the best approaches (McKiernan et al. 2017). The relationship between government organizations and landowners is important when trying to encourage landowners to collectively manage invasive plants (Graham 2013). There are several programs in place to help landowners manage invasive plants individually. We recommend that these programs such as the Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP) be re-evaluated to include and encourage forestry professionals to work with a group of landowners

rather than individual households. By serving as a facilitator, such programs could help breakdown the cultural barrier around privacy and individual management while promoting trust and opportunities for FFOs to interact with each other. Overall, we suggest that while landowners are being encouraged to work collectively, programs and policies that promote invasive plant management on private forests such as be redesigned to encourage this management style.

3.6 Conclusion

Collective action is pivotal to the successful management of invasive plants on the individual and landscape level. We did an empirical analysis to examine FFOs collective efficacy beliefs and the factors that contribute to their willingness to collectively manage invasive plants in the future. While previous studies assessed the factors that encourage or hinder collective or coordinated management of invasive species, no study has assessed uncoordinated landowners' perceptions of their collective abilities to effectively manage invasive plants. Therefore, this paper provides important insight into the ways that FFOs can be dissuaded or motivated to manage invasive plants collectively and their overall assessment of their abilities to work collectively. Further research could focus on the factors that encourage the emergence, longevity and effectiveness of collective management among uncoordinated landowners. While previous studies evaluated the effectiveness of invasive species management programs, it would also be beneficial to understand the underlying factors that would prompt uncoordinated landowners to work with each other without a formal mechanism or program in place. These studies could also investigate how effective collective management of invasive plants is on the ground, and if the amount of effectiveness varies based on perceived threat and other external factors.

Our study provides new insight into the factors that landowners perceive to be important to their decisions to collectively manage invasive plants. While previous studies recommend that incentives like increased funding could encourage landowners to work collectively, we add to this literature by going a step further. Overall, family forest owners are highly motivated by intrinsic factors such as perceived self-efficacy, perceived collective efficacy and concern about invasive plants. Therefore, we recommend that greater emphasis be placed on building community capacity, community cohesion, trust and a shared concern about invasive plants. Although landowners are

concerned about invasive plants on their properties, messages should also focus on the landscape scale and how invasive plants could affect communities rather than just at the individual or large-scale ecosystem scale. External factors such as social proof and visibility of invasive plant management on neighbors' property can be capitalized to encourage collective action. Invasive plant management can borrow successful strategies that have been used in other environmental contexts by having posted signs, increased social bonding through frequent communication and social interactions, and incentivizing invasive management plans among groups of landowners. In sum, as forest ecosystems are further subdivided in the future, it is important to continue research on best approaches to environmental threats such as invasive plants or provisioning of ecosystem services that require collective action.

Table 3.1: Independent variables used in the empirical model for estimating respondents' likelihood to work with their neighbors to remove invasive plants from both their woodlands in the next five years.

Explanatory variable	**Description**
concern_neighbor	Nominal – Respondents' self-reported level of concern about invasive plants on their wooded land on a five-point Likert scale: 1 = no concern, 2 = little concern, 3 = moderate concern, 4 = concern, 5 = great concern
confidence_removal	Nominal – Respondents' perceived self-efficacy, measured as self-reported level of confidence in their own ability to remove invasive plants from their woodlands in Indiana if needed on a five-point Likert scale: 1 = not confident, 2 = low confidence, 3 = moderately confident, 4 = confident, 5 = very confident
past_talk	Composite score calculated by averaging ratings of three statements about past experience talking to others about invasive plants (see Table 3)
past_work_together	Binary – 1 if reduced or eliminated invasive plants on their property in the past five years; 0 if otherwise
need_work_together	Nominal – Respondents' level of agreement with the statement "Effective control and removal of invasive plants require woodland owners to work together" on a five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree
know_how_cooperate	Nominal – Respondents' level of agreement with the statement "Woodland owners know how to self-organize and cooperate with one another to control / removal invasive plants" on a five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree
cooperate_hard	Nominal – Respondents' level of agreement with the statement "It is difficult for woodland owners to self-organize and cooperate with one another on their own" on a five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree
social_influence	Continuous – FFOs being subject to the influence of others (principal component loadings, see Table 4)
acreage	Continuous
absentee	Binary – 1 if home (primary) residence is more than one mile away from their wooded land in Indiana; 0 otherwise
farm_history	Nominal – 1 if currently farmed; 2 if previously farmed; 3 if not part of a farm currently or previously
management_plan	Binary – 1 if having a written forest management plan or stewardship plan; 0 if otherwise
org_membership	Binary – 1 if member of an environmental, conservation or woodland owner organization; 0 if otherwise
age	Continuous (years)

Table 3.1 continued

Sex	Binary – 1 if male; 0 if otherwise
education	Nominal – 1 = high school or less, 2 = some college or associate's degree, 3 = Bachelor or graduate degree
hh_income	Nominal – 1 = less than $50,000, 2 = $50,000 to $149,999, 3 = $150,000 or more

Table 3.2: Description and summary of survey items measuring perceived collective efficacy.

Survey item	**Variable name**	**Mean (Std. Dev.)[a]**
Effective control and removal of invasive plants require woodland owners to work together.	need_work_together	3.73 (.80)
Woodland owners know how to self-organize and cooperate with one another to control/remove invasive plants.	know_how_cooperate	2.67 (.86)
It is difficult for woodland owners to self-organize and cooperate with one another on their own.	cooperate_hard	3.66 (.81)

[a] Survey item scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree.

Table 3.3: Description and summary of survey items measuring past experience of talking about invasive plants in the past five years.

Survey item	**Mean (Std. Dev.)[a]**	**Cronbach's Alpha**
I talked to my family about invasive plants.	0.14 (.35)	0.6119
I talked to my neighboring woodland owner about invasive plants.	0.08 (.27)	
I talked to other woodland owners who is not my neighbor about invasive plants.	0.10 (.30)	

[a] Survey item scale: 1= yes, 2 = no.

Table 3.4: Description and summary of survey items measuring social influence.

Survey item	**Mean (Std. Dev.)[a]**	**Cronbach Alpha**
If my neighbors are controlling/removing invasive plants from their wooded lands, I will feel the need to do the same.	3.77 (.85)	0.9282
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 (.87)	
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 (.88)	

[a] Survey item scale: 1 = strongly disagree, 2 = disagree, 3 = undecided / don't know, 4 = agree, 5 = strongly agree.

Table 3.5: Description and summary of survey items measuring preference for potential collaborators or collaborating units for invasive plant management.

Survey item	**Mean (Std. Dev.)[a]**
Working with my neighbor to prevent invasive plants from invading both of our wooded lands.	3.40 (.99)
Working with my neighbor to remove invasive plans from both of our wooded lands.	3.36 (1.00)
Working with other woodland owners in my town/city/county to prevent invasive plants from invading both of our wooded lands.	3.37 (.95)
Working with other woodland owners in my town/city/county to remove invasive plants from invading both of our wooded lands.	3.30 (.97)
Working with my town/city/county government to remove invasive plants on privately owned wooded lands.	3.14 (1.06)
Working with a state government agency to remove invasive plants on privately owned wooded lands.	3.18 (1.11)
Working with a non-profit organization to remove/control invasive plants on privately owned wooded lands.	3.36 (1.05)

[a] Survey item scale: 1= very unappealing, 2 = somewhat unappealing, 3= undecided / don't know, 4 = somewhat appealing, 5 = very appealing.

Table 3.6: Logistic estimates of the empirical model for estimating family forest owners' likelihood to work together with neighbors to remove invasive plants on both of their woodlands in the next five years.

Independent variable	**dy/dx[ab]**	**Std. Err.**
concern_neighbor	0.033**	0.012
confidence_removal	0.033**	0.011
past_talk	0.101**	0.052
past_work_together	0.326**	0.084
need_work_together	0.035*	0.017
know_how_cooperate	0.007	0.014
cooperate_hard	-0.013	0.015
social_influence	0.060**	0.017
acreage	-0.017*	0.010
absentee	0.003	0.024
farm_history	-0.015	0.025
management_plan	-0.031	0.031
past_management	-0.030	0.029
org_membership	0.007	0.035
age	0.000	0.001
sex	0.003	0.028
education	-0.003	0.008
hh_income	-0.007	0.009
# of observations	843	
LR chi-squared	138.81	
Pseudo R^2	0.2044	

[a] dy/dx is marginal effect.
[b] *p < 0.05, **p < 0.01.

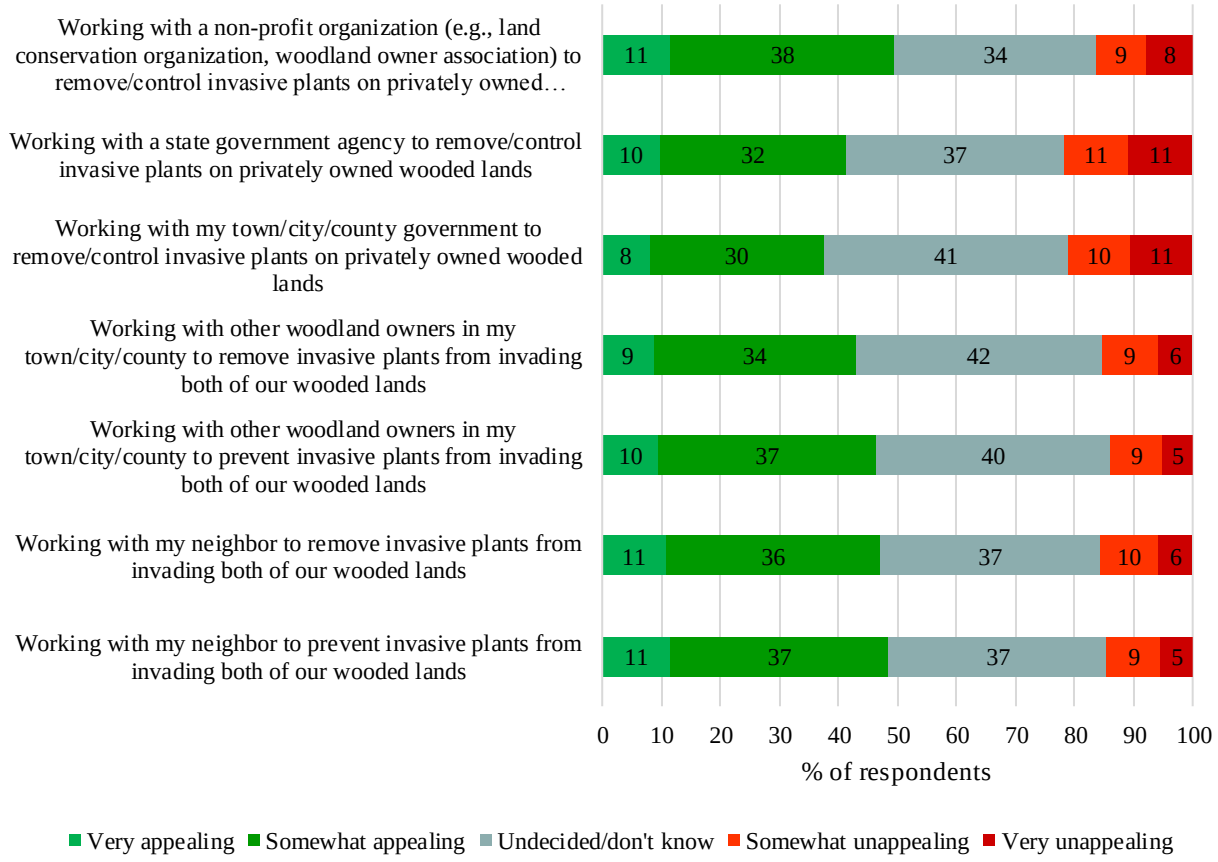


Figure 3.1: FFO respondents' preferences for working with potential collaborators and entities in managing invasive plants.

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