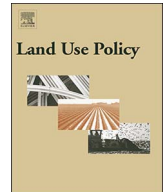




Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Insights into individual and cooperative invasive plant management on family forestlands

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ARTICLE INFO

Keywords:

Invasive species
Human dimensions
Collective action
Cross-boundary cooperation
Private land
Forest management

ABSTRACT

Invasive species are reaching epidemic proportions, greatly altering global biomes. The role of private landowners in controlling invasive plants in forest ecosystems has been well recognized, although limited research has investigated their awareness, actions, needs and concerns. Building upon a broader literature on family forest owner decision making and invasive weed management in non-forested landscapes, we conducted 23 semi-structured interviews with family forest owners and forestry professionals in Indiana, USA. We documented and discussed (1) their knowledge and awareness of invasive plant management, (2) current invasive plant management actions, (3) issues surrounding cooperative invasive plant management, (4) how they understand the responsibility of invasive plant control across the landscape, and (5) an information challenge facing invasive plant management. Our results suggest that future education and outreach efforts should broaden to include urban and suburban residents, as well as forestry professionals who are often assumed to be supportive of and knowledgeable about invasive plant management. Our results also suggest that forestry professionals can help motivate family forest owners toward invasive plant management by providing positive psychological reinforcement such as social approval. Further, our results highlight a gap between the recognized importance of cooperative invasive plant management and a lack of on-the-ground practices mainly due to a family forest owner culture of independence. Overcoming the cultural stigma associated with cooperative management requires forestry professionals' willingness and ability to cultivate a social environment conducive to collective actions by playing the role of community organizers. Together, these insights can be used to inform the development of future invasive plant communication strategies and private forest landowner assistance programs.

1. Introduction

Invasive species are reaching epidemic proportions, greatly altering global biomes, and costing the American public an estimated \$137 billion each year due to productivity loss and management costs such as herbicide application (Pimentel et al., 2005). Currently, 4000 to 5000 nonnative plant species exist in the U.S. as self-sustaining populations in natural ecosystems, among which a significant number are classified as invasive and comprising from 8 to 47 percent of the total flora in most states (Driesche et al., 2002; Runyon et al., 2012). Invasive plants are capable of competitively overrunning an entire ecosystem, diminishing or displacing native plants, resulting in plant hybridization, reducing biodiversity, and increasing the frequency of wild fires (Fei et al., 2014; Rotherham and Lambert, 2011; Simberloff, 2013). In addition, the distribution and impacts of invasive plants are expected to be exacerbated by climate change (Hellmann et al., 2008; Ruiz and Carlton, 2003). Thus, effective control of invasive plants is critical for both the long-term natural ecosystem health and the economic well-

being of human communities (Mack et al., 2000).

Despite the importance of controlling invasive plants, issues surrounding invasive plant management have received limited attention from policy makers and the general public. Many invasive plant species spread via trade, transportation of cargo, vehicle travel, and other human activities. Some invasive plant species also spread due to intentional introduction. For example, in the U.S. the majority of terrestrial invasive plants were in fact introduced for horticultural purposes, while a small proportion were introduced to control soil erosion (Burt et al., 2007; Niemiera and Von Holle, 2009; Reichard and White, 2001). However, policy makers have generally exhibited little interest in imposing restrictions on the sales of invasive plants, as well as the establishment, funding and implementation of invasive plant control programs across the nation (Peters et al., 2006). Beyond the policy arena, public perceptions of invasive plants vary greatly, from those who believe invasive plant management is a futile battle, to those who view invasive plants as harmful to ecosystems that need to be prevented and removed (Davis et al., 2011; Hobbs et al., 2006). Further, the issue

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<https://doi.org/10.1016/j.landusepol.2018.02.010>

Received 18 August 2017; Received in revised form 1 February 2018; Accepted 8 February 2018
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of trust in natural resource professionals is critical to the implementation of invasive plant management strategies (Fischer and Charnley, 2012a; Graham, 2013; Sullivan et al., 2017a, 2017b). For example, in urban areas such as Chicago and San Francisco, the public obstructed and prevented the management of problematic invasive species, because their perception of restoration differed from the forestry professionals, causing misunderstandings and public distrust (Gobster, 2011).

Much of the earlier scholarly literature regarding invasive plant management was focused on the ecological principles that dictate how invasive plants reproduce and disperse, the ecological and economic impacts of invasive plants, and specific physical, chemical and biological control and treatment methods targeting specific plant species. Indeed, Estévez et al. (2015) show that less than 1% of peer-reviewed papers published on invasion biology incorporate social dimensions of invasive management. However, a growing number of researchers have recognized that invasive species is as much a social issue involving various human factors as it is a scientific or technical issue (Bremner and Park, 2007; Epanchin-Niell et al., 2010; Head, 2017; Kueffer, 2010). As such, social science research has documented public perceptions of invasive wildlife species on public lands and the management practices pursued by public resource managers, particularly in Europe and Australia (e.g., Bardsley and Edwards-Jones, 2006; Daab and Flint, 2010; Fraser, 2006; Fischer and van der Wal, 2007; García-Llorente et al., 2008; Selge et al., 2011; Sharp et al., 2011). More recently, researchers have started to address the parallel problems of invasive plant species and management efforts in the U.S. and beyond (e.g., Sullivan et al., 2017a, 2017b; Epanchin-Niell et al., 2010; Ervin and Frisvold, 2016; Hershendorfer et al., 2007; Niemiec et al., 2016; Yung et al., 2015). The success of invasive plant prevention and control relies on not only actions of public resource managers, but thousands of individual landowners taking actions. Failing to engage private landowners will compromise the overall invasive plant management effort.

Several studies have investigated private landowner awareness of invasive plants, their control practices, and factors that influence their management decisions. For example, Steele et al. (2006, 2008) have suggested that although invasive plant problems are moderately salient among some landowners who are actively engaged in land management activities, the majority of landowners have little knowledge about invasive plants. Further, private landowners have widely different perceptions of invasion risks, ranging from a lack of concern, to the belief that nonnative plant invasions have discrete causes and controllable consequences, to the view that invasions have gone out of control (Fischer and Charnley, 2012a; Yung et al., 2015). Together, these studies suggest a need for communicating invasive plant information in a way that resonates with landowners and that is consistent with landowners' management objectives. A few additional studies have attempted to identify factors that influence private landowner invasive plant management decision making. Steele et al. (2006), as well as Fischer and Charnley (2012a), posit that if landowners are unaware of, or perceive invasive plants as nonthreatening, they might be uninterested in invasive plant management and unlikely to participate in related government programs. Invasive plant management can be also costly and labor intensive (Larson et al., 2011). Landowners tend to be less likely to engage in invasive species management if they believe the monetary and time investment needed is unjustified (Howle and Straka, 2010), but they might respond favorably if provided with financial or technical assistance through a locally adapted program (e.g., Epanchin-Niell et al., 2010; Graham, 2013; Hershendorfer et al., 2007).

There is also growing research to assess cooperative invasive plant management on private lands (e.g., Epanchin-Niell et al., 2010; Graham, 2013; Graham and Rogers, 2017; Marshall et al., 2016; Niemiec et al., 2016, 2017; Sullivan et al., 2017a, 2017b). This growing research area addresses the fact that individual landowners may assume responsibility for only a small portion of the total risk imposed by invasive plants, but their individual actions or inactions over time and across the landscapes collectively affect society's ability to control

invasions. By allowing their land to act as invader propagule sources, those who opt not to take action will increase control costs for neighboring private and public landowners (Epanchin-Niell et al., 2010; Simberloff et al., 2005). As such, cooperative invasive plant management, or collective actions to invasive plant management, are critical to effectively control invasions over time. Previous studies highlight that collective action to cooperatively manage invasive plants is influenced by social norms and community reciprocity (Graham, 2013; Marshall et al., 2016; Niemiec et al., 2016), neighbors' attitudes and previous management (Epanchin-Niell and Wilen, 2015; Hershendorfer et al., 2007; Klepeis et al., 2009), sense of community (Graham and Rogers, 2017), and shared goals and coordinated institutional partnerships (Graham and Rogers, 2017; Hershendorfer et al., 2007; Higgins et al., 2007).

Although there is an increase in research about individual and collective invasive plant management, there has been less research on this topic specific to forestlands, particularly the challenges and potential of managing invasive plants on family forestlands in the U.S. In the U.S., 36% of forestlands are owned by 10.4 million private individuals and families (i.e., family forest owners¹; Butler et al., 2016). The attitudes and behaviors of family forest owners are pivotal to curbing the spread of invasive plants and reducing the consequential economic and ecological losses. Their perceptions, motivations and the resulting management decisions regarding invasive plant management directly determine the function and health of forest ecosystems (Howle and Straka, 2010).

In contrast to the limited research on the human dimensions of invasive plant management on family forestlands, a significant body of literature has been developed over the past 20 years about the behaviors of family forest owners (or non-industrial private forest owners) in other contexts, such as timber harvesting, wildlife habitat management, and participation in government-sponsored landowner assistance programs. These studies have identified various individual and household factors that influence family forest owner behaviors that may be important for understanding how they make decisions to individually or collectively control invasive plants. Such factors include landowner age (e.g., Ma et al., 2012a), landowner affluence and education level (e.g., McDonald et al., 2006), landowner occupation (e.g., Tian et al., 2015), forest holding size (e.g., Mehmood and Zhang, 2005), landownership tenure (e.g., Vokoun et al., 2006), absentee ownership (e.g., Fischer, 2011), landowner environmental values and attitudes (e.g., Butler and Leatherberry, 2004), and landowner past forest management experience (e.g., Ma et al., 2012a).

In particular, several studies have examined factors enticing family forest owners to engage in cross-boundary cooperation. Such factors include landowner age, affluence, personal values and attitudes, and the values and actions of neighboring landowners (e.g., Finley et al., 2006; Rickenbach et al., 2011; Yung et al., 2015). More recently, Ferranto et al. (2013) show that forest and range landowners in California exhibited willingness to cooperate for pest and disease control, fire hazard reduction, and wildlife conservation, but their degree of willingness differed based on their ownership motivations, which were categorized into rural lifestyle, working landscape, natural amenity, and financial investment. In addition, family forest owner decision making is influenced by external factors related to larger economic, policy and landscape contexts, such as stumpage price and market demand for desirable tree species (Kittredge et al., 2003), property taxes (Butler et al., 2012), regulatory uncertainty (Zhang and Flick, 2001), population density (Wear et al., 1999), household density (Liu et al., 2003), extent of urbanization (Munn et al., 2002), and road density (McDonald et al., 2006).

¹ Family forest owners are "families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land. This group is a subset of nonindustrial private forest owners" (Butler, 2008, p. 3).

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