Private Landowners and the Facilitation of an Invasive Species

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Private landowners and the facilitation of an invasive species

By Michael G. Sorice, Kiandra Rajala, and David Toledo

On the Ground

- We explored private landowner perceptions about the invasive Kentucky bluegrass in the US northern Great Plains.
- Landowner responses to a mail survey indicated little to no preventative action.
- We also employed a scenario approach to assess landowner perceptions based on changes to ecosystem services.
- Scenario results indicated that the early stage of invasion was considered slightly acceptable. At the late stage, when negative impacts are most severe for landowner livelihoods, bluegrass was rated as slightly unacceptable.
- Cascading impacts will become more evident and incentivizing early action to prevent further invasion is key to maintaining these working landscapes.

Keywords: ecosystem services, factorial vignette experiment, invasive species, *Poa pratensis*, private lands.

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Introduction

Rangelands in the United States and globally are under constant threat of transformation and degradation from novel and invasive species that negatively impact the ecosystem services supporting agricultural livelihoods.[1] Invasives can outcompete other species for resources, facilitate the spread of pests and diseases, and reduce the biodiversity that supports many ecosystem functions.[2] Effective management of invasives is paramount for sustainable rangeland management, but is particularly complicated in regions where private landowners dominate the landscape. Heterogeneous management goals, risk thresholds, attitudes, and land management preferences among landowners often result in inconsistent cooperation that undermines efforts to achieve desired outcomes at large spatial scales.[3] We explored the prospect that landowners will effectively manage Kentucky bluegrass (*Poa pratensis* L.) on their land in the northern Great Plains of North Dakota; a landscape where over 90% of the land is privately owned and landowners are highly dependent on ranching and farming (Fig. 1).[4,5]

For invasive species like Kentucky bluegrass, ecological research is paramount in tracking its spread, identifying ecological effects, anticipating cascading consequences for livestock operations, and evaluating the effectiveness of interventions. The perennial Kentucky bluegrass can be characterized as an insidious invasive species of the predominantly cool-season grasses of the northern Great Plains. Recent estimates suggest that Kentucky bluegrass is expanding both in terms of the acres on which it is present and its dominance in plant communities where it is found.[6,7] There is scientific agreement that the net ecological impacts of Kentucky bluegrass expansion are negative, yet uncertainty continues to exist regarding the specific impacts to key ecological processes and services, and the implications for agricultural operations and livelihoods.[6–8]

Social science research fundamentally contributes to an understanding of the capacity to respond and adapt to invasive species through formal and informal interventions including policy and outreach. Underlying these interventions are the perceptions of landowners that motivate them to take action against the invader. A key question during the spread of an invasive species is how landowners intend to respond in the midst of active expansion in a region. Because of the dominance of private lands in North Dakota, landowners ostensibly act as gatekeepers of the success of Kentucky bluegrass. Understanding what drives their responses to invasive grasses is key to developing effective interventions.

To understand the social dynamics that relate to the continued spread of Kentucky bluegrass, we draw from and expand on research conducted by Rajala et al.[10] focused on how large-acreage private landowners across nine counties of North Dakota think about and evaluate the acceptability of Kentucky bluegrass. Our goal is to highlight the role of scenario-based social science research as a way to 1) identify key drivers of landowner responses, 2) incorporate scientific uncertainty or system variability, and 3) account for a variety of experiences by providing a richer context that allows

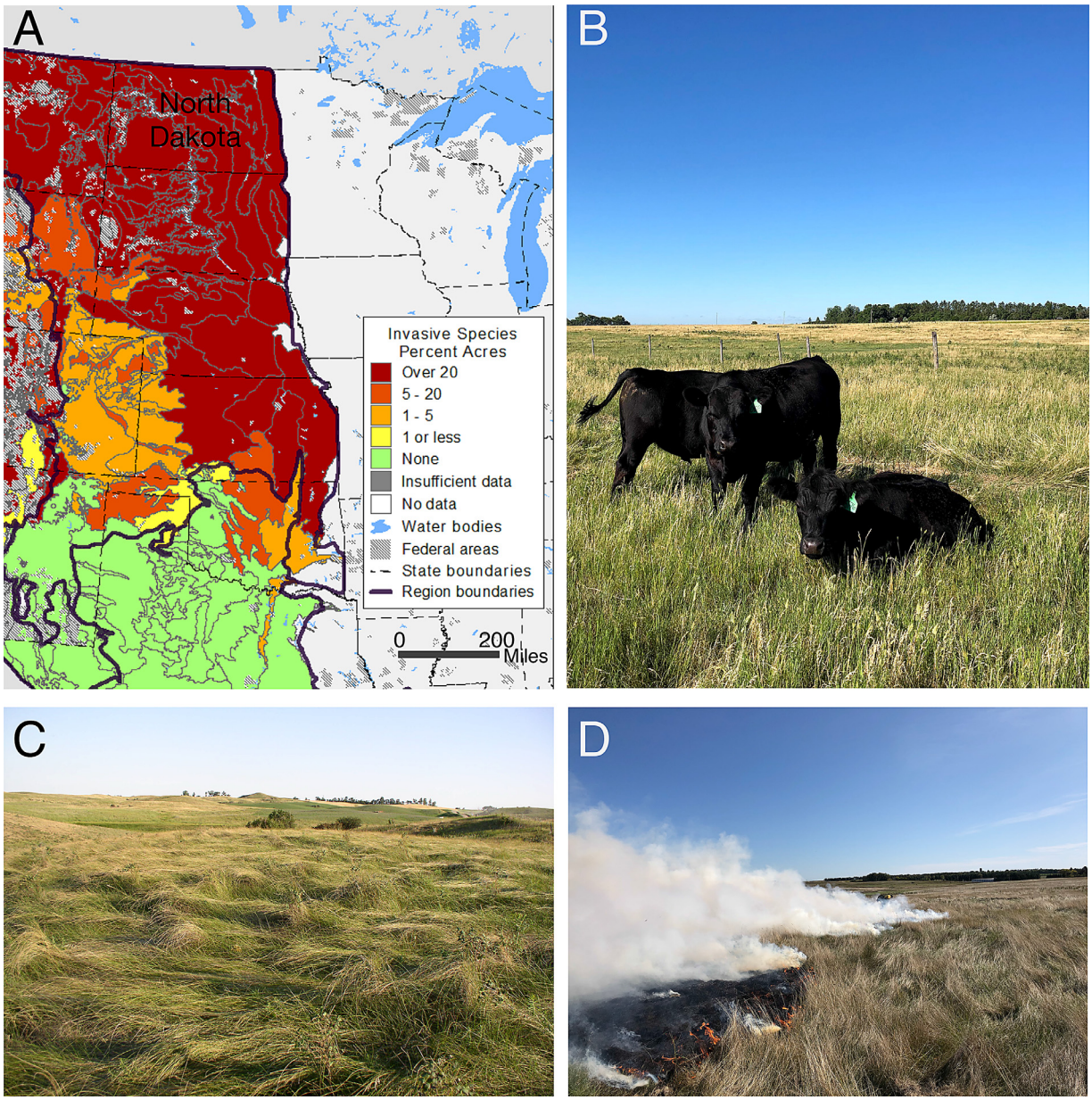

Figure 1. As Kentucky bluegrass continues to spread in North Dakota and the northern Great Plains (A) it threatens rural livelihoods that depend on livestock (B). Bluegrass forms dense mats that displace warm season grasses and native forbs (C). Prescribed fire is an effective but not widely used tool for managing bluegrass (D). Source: 2018 National Resources Inventory Rangeland Resource Assessment Table 27.[9] Photos courtesy of D. Toledo

landowners to have a comparable baseline of understanding of the issue. This can provide a stable foundation for developing and evaluating policy instruments and governance approaches that support both ecological integrity and landowner prosperity.

Overview of study methods and survey respondents

Our study area consisted of nine adjacent North Dakota counties that create an east-west transect of the state, from Cass County on the Minnesota border to Golden Valley County on the Montana border.[10] We sent a mail survey to 1,219 randomly selected landowners who owned at least 404.7 hectares (1,000 acres) in the study area using five mailing phases to encourage participation.[11] We received a 32% adjusted survey response rate (n = 365) and the landowners who responded to our survey were overwhelmingly focused on agricultural production as their livelihood. Most respondents (76%) said their life is mostly or completely organized around ranching or farming and 75% mentioned ranching or farming as their primary occupation. The majority also expressed that their land completely represents their way of

life (59%), and that they mostly or completely rely on their land as part of their business (87%). In sum, our sample is highly homogeneous in that it represents private landowners reliant on ranching and farming operations for their livelihoods.

Landowner perspectives on Kentucky bluegrass

In one section of our survey, we asked landowners to tell us about their experiences with perceptions of, and land management goals related to, Kentucky bluegrass on their land using a series of Likert-type scales. We found that the species is not at the forefront of many landowners' minds: 50% of respondents said they did not have, or were unsure if they had, bluegrass on their property. Most of these landowners also indicated they were not familiar with (24%) or only had a slight familiarity with bluegrass (45%). With low perceived exposure and low familiarity with Kentucky bluegrass, a large majority (80%) stated they have no goal for managing this species on their rangeland.

Almost all landowners (94%) who reported having bluegrass on their land indicated that they were moderately to extremely familiar with bluegrass. Despite this familiarity, only 32% indicated that their goal was to decrease bluegrass. Instead, a plurality of landowners with bluegrass-invaded grasslands (41%) indicated that they have no goal for bluegrass and 25% indicated they intend to maintain what they currently have. Digging deeper, landowners with a goal to decrease bluegrass self-reported an average of 13% more Kentucky bluegrass on their land than landowners with no goal (95% confidence interval: 2-24%; ANOVA: $F_{(2,119)} = 2.92$, $P = 0.06$, $\eta^2 = 0.05$; Kruskal-Wallis: $X^2_{(2)} = 7.127$, $p = 0.03$, $\varepsilon^2 = 0.03$).

Knowing how a landowner judges the acceptability of an invasive is a useful indicator of their likely management response.[10,12] Overall, landowners were decidedly ambivalent when it comes to Kentucky bluegrass (Fig. 2). Just over half rated it as neither acceptable nor unacceptable (Mean 4.0; SD = 1.3; Median = 4).

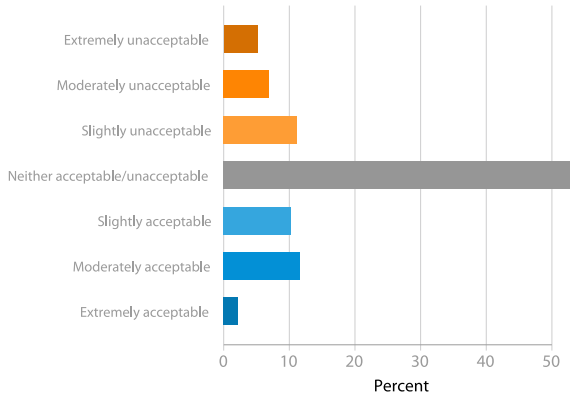

Figure 2. Landowner judgements of acceptability of Kentucky bluegrass on their property (n = 233).

Using scenarios to understand the acceptability of Kentucky bluegrass

With an invasive species that may have substantial negative impacts for the land and a landowner's operation, a key question of interest is how social science can capture landowner responses when landowners differ in their familiarity and exposure to the invasion. Anticipatory research proves difficult in a context where a substantial proportion of the stakeholders are unaware of or currently unaffected by the issue. In cases such as these, scenario-based approaches are useful because they provide the respondent a context in which to make their decisions. Specifically, scenarios provide respondents with a holistic depiction of outcomes associated with an invasive species like Kentucky bluegrass. This description of outcomes is well-suited to a wide range of landowner experiences and knowledge levels because the scenarios orient landowners to the same set of information. Below, we briefly describe the factorial vignette survey experiment employed in the survey detailed in Rajala et al.[10] to gain insights into the drivers of engagement (or lack thereof) in bluegrass control efforts.

Factorial vignette survey experiments have respondents evaluate a series of potential outcomes presented as a narrative called a vignette.[13,14] In our survey, we provided landowners with vignettes describing how a new grass species expanding on native rangeland would affect multiple ecosystem services. It is notable that, although we modeled it after Kentucky blue-

A new grass species is expanding onto your native rangelands. Based on current research and the best available information from other landowners, you know that once established this grass:

- **Doesn't change** the variety of grassland birds.
- **Doesn't change** the amount of floral resources that provide pollen and nectar for pollinator species.
- **Moderately increases (20% more)** water infiltration into the soil and the amount of water available to other plants.
- Provides **higher than average (25% more crude protein)** quality forage for livestock during the primary growing period of this species.
- Provides palatable forage for livestock **only early in the grazing season (April & May)**.
- **Greatly decreases (loss of 50% or more)** the diversity of other grasses.
- Produces **an average** yield in terms of lbs/acre.

Figure 3. An example scenario presented to landowners in vignette experiment.

grass, we labeled it as a new, unnamed species. Doing so prevents landowners from judging the species based on preconceived notions about bluegrass and provides the researchers with appropriate latitude in defining the range species impacts.

Vignette experiments provide a number of advantages compared with single-item or lists of direct questions commonly used in surveys.[13] Because vignettes are based on a multidimensional experimental design, the underlying effect of each variable can be identified with greater precision. The experimental design enables researchers to identify the unique effects of individual dimensions that may be highly correlated in reality.[14] Vignette experiments can incorporate scientific uncertainty by asking respondents to evaluate a variety of potential outcomes. Deploying a vignette experiment within a survey combines the strengths of experimental and observational research by enabling causal inference for participants in the study and generalization to the population sampled, respectively, facilitating internal and external validity.

In vignette experiments, each vignette is comprised of multiple attributes (e.g., forage quantity) with fixed levels that randomly vary across vignettes (e.g., forage can decrease, remain the same, or increase). This process forces respondents to make tradeoffs between the attributes presented in each vignette and integrate these tradeoff considerations into a single judgement. For instance, if forage quantity increases while water availability decreases, landowners must consider the relative importance of each change in their overall judgment.

The vignette experiment we deployed in the survey focused on the effects that an unnamed grass with impacts that mirror Kentucky bluegrass may have on ecosystem services salient to agricultural producers. To identify the ecosystem services we conducted a literature review, gathered insight from rangeland specialists in the region, and interviewed landowners in North Dakota. We then refined the ecosystem services and their levels through pretesting with experts and landowners. During the same consultation process we relied on rangeland experts to identify the degree to which each attribute could change as a result of the new grass species. This resulted in seven ecosystem services including impacts to forage availability, quality, and yield as key provisioning services (Table 1). We also identified floral resources for pollinators and water infiltration and availability as regulating services. Finally, we considered grass diversity and bird diversity as supporting services.

We employed an incomplete block experimental design to reduce the 2,187 possible vignettes to 28. Each landowner was randomly assigned to respond to four vignettes (Fig. 3).[10] For each vignette, we asked landowners to indicate the acceptability of the grass on their rangelands using a 7-point Likert-type scale (1 = extremely unacceptable, 4 = neither acceptable or unacceptable, and 7 = extremely acceptable). We also asked landowners to indicate their management intentions for the grass (1 = definitely reduce/control, 4 = would not change current management, and 7 = definitely promote/maintain). Because each respondent evaluated multiple vignettes, we used mixed regression models to analyze the data.[13] We modeled forage quality, forage quantity, and water infiltration as continuous variables, and treated forage availability and grass diversity as ordinal categorical variables. We modeled floral resources and bird diversity as nonlinear continuous variables.[10]

Acceptability of impacts

Landowners' judgements about the acceptability of the Kentucky bluegrass analog were strongly related to their intention to control it, do nothing, or promote it ($n = 209$, Wald $X^2_{(1)} =$, $P < 0.001$, $R^2 = 0.75$). For every one-level decrease in the acceptability (e.g., moving from neutral to slightly unacceptable), a landowner's intention to reduce/control the species increases by 13% on average ($b = -0.77$, $SE = 0.02$, $z = -46.54$, $P < 0.001$). Following attitude theory that such judgements mediate the relationship between outcomes and behavior, we focus on the relationship between ecological impacts and judgements of acceptability.[12]

Overall, landowners considered all ecosystem services in their evaluation of the Kentucky bluegrass analog (Wald $X^2_{(11)} = 349$, $P <= 0.01$, $R^2 = 0.25$). Landowners preferred grasses that increased forage quality and quantity, as well as the hydrologic function of their rangeland (Fig. 4A). Summer or fall (late season) forage was preferred to spring only (early) (Fig. 4B). Landowners preferred that bird diversity and pollinator resources did not decrease, but there were no differences between the no change and increase conditions (Fig. 4A). Finally, landowners' acceptance of the species decreased as the diversity of other grass species was reduced (Fig. 4C).

The stages of Kentucky bluegrass invasion

Using the results of the model, we can explore scenarios that reflect landowner acceptability of Kentucky bluegrass at early, moderate, and late stages of invasion (Fig. 5). Early invasion of bluegrass is characterized by enhanced forage quality and yield that is only available in the spring, and no change to other ecosystem services. Under these conditions, bluegrass is expected to be considered slightly acceptable. Moderate stage invasion includes a moderate loss in grass diversity along with increased forage quality, quantity, and spring availability. Landowners are expected to view these impacts as neutral to slightly acceptable. Late-stage invasion is characterized by enhanced forage quality and quantity in the spring, but a large reduction in the diversity of other grasses as well as reductions of floral resources and grassland bird diversity. Our model indicates that landowners would be expected to judge the advanced bluegrass analog as slightly unacceptable.

These results include all landowners in the sample, but it is possible that concern about the bluegrass analog may be higher or lower for specific subgroups of landowners. We considered that landowners with a livestock operation may be more sensitive (i.e., less accepting) than other landowners to the bluegrass analog, while so-called absentee landowners may be less sensitive. We found that differentiating landown-

Table 1
Ecosystem services examined in vignette experiment

Ecosystem service	Levels	Vignette text
Provisioning services: Forage		
Availability	Early	Provides palatable forage for livestock only early in the grazing season (April & May).
	Summer*	Provides palatable forage for livestock only during the summer grazing season (June, July, August).
	Late	Provides palatable forage for livestock only late in the grazing season (September, October, November).
Quality	Decrease	Provides lower than average (25% less crude protein) quality forage for livestock during the primary growing period of this species.
	No change*	Provides average (in terms of crude protein) quality forage for livestock during the primary growing period of this species.
	Increase	Provides higher than average (25% more crude protein) quality forage for livestock during the primary growing period of this species.
Quantity	Decrease	Produces a lower than average (25% less) yield in terms of lb/acre.
	No change*	Produces an average yield in terms of lb/acre.
	Increase	Produces a higher than average (25% more) yield in terms of lb/acre.
Regulating services		
Pollinator resources	Decrease	Leads to a considerable decrease (loss of 15%) in the amount of floral resources that provide pollen and nectar for pollinator species.
	No change*	Doesn't change the amount of floral resources that provide pollen and nectar for pollinator species.
	Increase	Leads to a considerable increase (gain of 15%) in the amount of floral resources that provide pollen and nectar for pollinator species.
Water infiltration & availability	Decrease	Considerably decreases (loss of 20%) water infiltration into the soil and the amount of water available to other plants.
	No change*	Doesn't change water infiltration into the soil and the amount of water available to other plants.
	Increase	Considerably increases (gain of 20%) water infiltration into the soil and the amount of water available to other plants.
Supporting services: diversity		
Grassland birds	Decrease	Leads to a considerable decrease (loss of 3-5 species) in the variety of grassland birds.
	No change*	Doesn't change the variety of grassland birds.
	Increase	Leads to a considerable increase (gain of 3-5 species) in the variety of grassland birds.
Grasses	Large decrease	Greatly decreases (loss of 50% or more) the diversity of other grasses.
	Moderate decrease	Moderately decreases (loss of 20%) the diversity of other grasses.
	No change*	Has no effect on the diversity of other grasses.

* Levels reflect the status quo or no change outcomes.

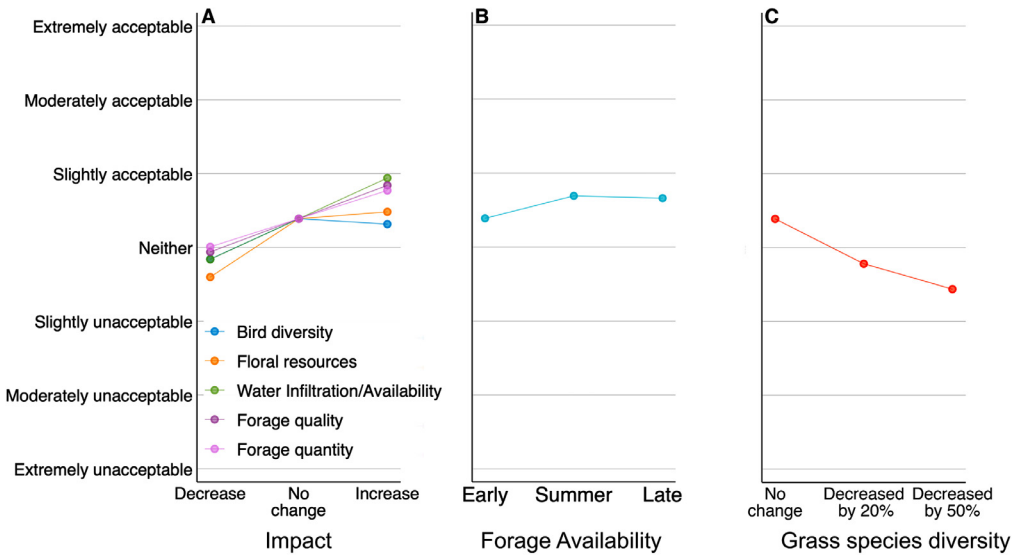

Figure 4. All ecosystem services were significantly related to landowner judgements of acceptability. Several ecosystem services were treated as continuous (A), and others were modeled as nominal (B) or ordinal (C).

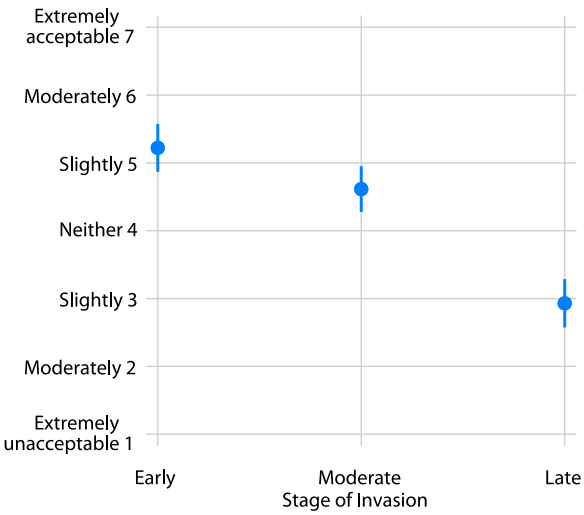

Figure 5. The expected acceptability of a grass like Kentucky bluegrass at early, moderate, and late stages of invasion based on expected ecological impacts of bluegrass to ecosystem services.

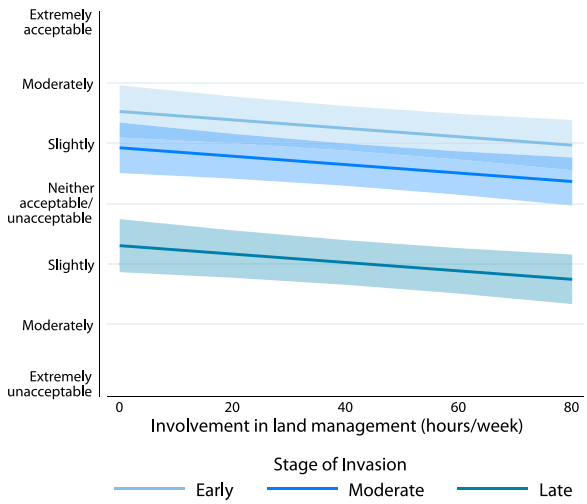

Figure 6. Of the models tested only the number of hours landowners typically spend managing, operating, or working on their land was related to the acceptability of Kentucky bluegrass. Acceptability decreases at each progressive stage of invasion.

ers who use their land primarily for crop production from those who use their land primarily for livestock production or as a mixed crop and livestock operation did not help explain acceptability judgements ($b = -0.11$, $z = -0.62$, $P = 0.54$). Similarly, focusing in on landowners who use their land primarily for livestock did not improve understanding of acceptability ($b = 0.12$, $z = 0.70$, $P = 0.49$). When we considered absentee landownership using the distance of the landowner's primary residence from their land in miles (0 miles if living on the land), we found no relationship ($b < 0.01$, $z = -0.83$, $P = 0.40$). Finally, we considered the degree to which landowners were directly involved in land management based on the number of hours landowners typically spent managing, operating, or working on their land per week.[15] Landowners' involvement with their land was high (Mean = 44.5 hours/week, SD = 29, Median = 50) and inversely related to acceptability, with greater involvement in management related to lower acceptability of the bluegrass analog (Fig. 6; $b = -0.007$, $z = -2.61$, $P < 0.01$).

In sum, landowners preferred increases to ecosystem services that have a more direct impact on their operation (e.g., forage and water) with less focus on increasing indirect services such as biodiversity and pollination. The vignette experiment showed that landowners focused primarily on livestock production judged the acceptability of the bluegrass analog similarly to those focused primarily on crop production. Only the degree to which a landowner is actively engaged in management was related to increased sensitivity of invasion (i.e., lower acceptability ratings). Based on the strong relationship between acceptability and management intention, landowners are likely to attempt to control bluegrass only once the invasion is advanced.

Incorporating uncertainty into social science research

When trying to understand an uncertain phenomenon that threatens both social and ecological systems but unequally affects them, scenario approaches can be useful tools to assess landowner reactions and inform potential policy responses. A number of different scenario approaches exist. For instance, economics valuation studies use scenarios to estimate economic values of environmental goods,[16] and approaches that employ cognitive mapping integrate insight from multiple stakeholders to compare the outcomes of scenarios or evaluate the effectiveness of different management interventions.[17] These and other methods can inform a structured decision-making process for invasive species management to social and ecological outcomes of rangeland management.[18]

As a whole, respondents were overwhelmingly ambivalent when asked directly about the acceptability of Kentucky bluegrass. Familiarity with bluegrass varied and although only 50% of landowners reported having Kentucky bluegrass on their land, recent ecological estimates suggest that most nonfederal rangelands in our study have been invaded by Kentucky bluegrass.[6] Providing landowners with scenarios that reflect different ecological outcomes in the vignette experiment creates a context that can adjust for variation in knowledge and personal experiences evident in the landowner sample (i.e., familiarity with and self-reported presence of Kentucky bluegrass on their land). Although bluegrass attitudes are not polarized in the vignette results, respondents viewed the initial impacts of Kentucky bluegrass positively but evaluated outcomes associated with increased expansion as increasingly unacceptable. The experimental design of the vignettes enables further insight into how landowners' preferences for ecosystem services, such as for-

age, influence their final judgements of tradeoffs in real-world situations.

Anticipating and planning for invasive species

We found that private landowners are likely ineffective gatekeepers against an invasive grass that behaves analogous to Kentucky bluegrass. The more involved a landowner is with the land, the more responsive they are regardless of distance they live from the land.[15] Although landowners respond to decreased ecosystem services triggered by the invasive, late-stage bluegrass invasion was only slightly unacceptable. This estimate signals a relatively small chance that private landowners will independently combat the invasion of Kentucky bluegrass, especially in its early stages. The idea that landowners may delay the control of bluegrass until it has severe negative impacts is supported by additional analyses in Rajala et al.[10] The paradox is that the failure of preventative and early management of invasive species often results in more expensive and less effective management options at later stages of invasion, along with greater social and ecological impacts of the invasion.[19]

This lack of preventative action is not uncommon in invasive species management or human decision-making under conditions of risk and uncertainty. Invasive species are wicked problems without simple causes or solutions and the management response from individual landowners may be encumbered by a number of interacting and potentially conflicting scientific, ethical, political, and individual considerations.[20–23] Engaging in protective action is not assured even when they perceive high risks from natural hazards.[24] Consequently, it is not surprising that the landowners did not indicate an intention to take direct decisive action. The next question relates to the kinds of interventions that can motivate control of Kentucky bluegrass given the high threshold for action in this case.

External incentives and collaborative engagement can help generate the cooperation necessary to thwart continued expansion of invasive species like Kentucky bluegrass throughout privately owned, agricultural landscapes like the northern Great Plains. A number of policy solutions have been highlighted for controlling invasive species in complex social-ecological landscapes, stemming from incentive programs to collaborative landscape planning. A well-designed incentive program can employ cost-share, direct payments, and/or technical assistance to induce landowners to engage in particular range management practices at particular times that impact Kentucky bluegrass. In such cases, landowner perceptions of bluegrass are surpassed by other needs and concerns. Regional invasive species control organizations can engage stakeholders to develop coordinated strategies and leverage funding to support invasive species control.[25] However, a combination of top-down (i.e., rules, regulations, and incentives), bottom-up (i.e., self-organization by landowners), and middle-out approaches (e.g., boundary organizations like weed management districts that foster coordination) recognizes the importance of taking action while providing private landowners with the latitude to design and adopt solutions that fit their needs. Invasive species management strategies that incorporate landowner needs and consider ecosystem service tradeoffs can better align policies with specific stages of invasion to promote adaptive governance and achieve improved social and ecological outcomes.[19,26]

Overall, it is not surprising that landowners in our study were not willing to take immediate definitive action against the Kentucky bluegrass analog. Despite broad consensus among scientists about the net negative ecological impacts of the species, uncertainty remains about specific ecological impacts. Further, many landowners may be largely unaware of or unaffected by the species, and little is known about the cascading impacts on a landowner's operation. This is compounded with the fact that rangelands in general are perpetually threatened by invasive species and that landowners do not always judge invasives as bad using the same parameters as ecologists.[27] Efforts to deal with invasives must continue to consider the complex interacting dynamics that influence individual decisions to control invasives.[18]

A major challenge to stemming the negative social and ecological consequences of the Kentucky bluegrass invasion is reconciling scientific information with landowners' local knowledge and experiences. The specific attributes of this invasive grass and its patterns of invasion can be deceptively attractive to the livestock industry—it is a palatable, productive, cool season species growing in a geographic area well suited to cool season grasses. However, as Kentucky bluegrass invasion progresses, the inevitable loss of warm season grasses and reductions in native forb abundance results in the reduction of ecological as well as livestock enterprise resilience, as grazers no longer have access to warm season forage during drier, hotter parts of the year. As Kentucky bluegrass continues to transform northern Great Plains rangelands, cascading impacts will become more evident and the problem will likely become more salient. Adopting ways of productively managing invaded rangelands to account for ecosystem services landowners value as well as incentivizing early action to prevent further invasion of Kentucky bluegrass are keys to maintaining these working landscapes.

Declaration of competing interest

DT was a member of the Society for Range Management's Board of Directors from 2019-2021 and was involved with the development of this Special Issue, but was not involved in the handling, review, or decision process for this manuscript.

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