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Shifting Cattle Producer Beliefs on Stocking and Invasive Forage: Implications for Grassland Conservation☆

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ABSTRACT

To advance the dialogue to define sustainable working landscapes, it is essential to include the perceptions, knowledge, and factors guiding decision making. We surveyed livestock producers in the Grand River Grasslands region of southern Iowa and northern Missouri, United States, to gain insight into key factors shaping decision making and perspectives on effective management practices in the eastern Great Plains, focusing in particular on demographic and social change and producer willingness to reduce stocking rate as a conservation practice. First, a longitudinal evaluation of livestock producer demographics in 2007 and 2017 revealed individuals were older and were renting grazing land to a greater extent than in 2007. Second, when making land management decisions, producers in 2017 focused on economic concerns more than environmental concerns compared with more balanced views in 2007. For those who prioritized the environment over economics, this prioritization was related to both higher levels of education and a willingness to reduce stocking rate (livestock production) if there is a positive conservation outcome. In contrast, a lower willingness to reduce stocking was associated with increasing rental acreage and prevalence of an invasive cool-season grass that responds favorably to heavy grazing (tall fescue, *Schedonorus arundinaceus* Schreb.). Regardless, about 37% of cattle producers representing ~40% of the land area surveyed were at least moderately willing to reduce stocking rates to achieve a conservation outcome. In conclusion, our findings suggest that producers' need to gain income from livestock may limit the willingness to enact a conservation practice similar to reduced stocking rates. However, there is clearly conservation receptiveness from a segment of the producer community, which indicates potential for improved conservation.

Introduction

The ability of grazing lands to provide forage resources, as well as additional ecosystem services, is dependent on not only the biophysical condition of the grassland (e.g., species composition, topography, soil types, hydrology) but also management decisions that influence these conditions (Hruska et al., 2017). Management decisions are underpinned by a suite of long-term and short-term concerns, and foremost among these decisions is the manipulation of the stocking rate of livestock in the management unit (Scarnecchia, 1990; Ritten et al., 2010). Natural resource professionals and academics typically advocate grazing practices that employ conservative stocking rates as a strategy across years to maintain vigorous and productive forage plants, even in drought years, and to ensure stable livestock production over time (Holechek et al., 1989; Torell et al., 2010; Derner et al., 2017). In contrast, economically focused evaluations of stocking rate indicate high stocking rates are the most profitable in the short term because a higher percentage of the available forage plants are consumed (Hart et al., 1988). In many cases, heavy stocking rates can be supported by non-native forage grasses, such as tall fescue *(Schedonorus arundinaceus),* because they are grazing tolerant (Phillips and Coleman, 1995). However, continued use of heavy stocking rates has implications for the sustainability of productive pastures (Holechek et al., 1999), with potential long-term decreases

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in forage provisioning (Derner et al., 2008), spread of problematic invasive species (Epanchin-Niell et al., 2010), and soil erosion and compaction (Briske et al., 2011; McGranahan et al., 2013b; FAO, 2016). Although the long-term social and ecological cobenefits provided by the conservative stocking rates are known (Torell et al., 2010; Derner et al., 2017), short-term heavy stocking rates are common (Godde et al., 2018). Despite the geographical variation in ecosystem response to grazing and stocking rate (Jones, 2000; Derner et al., 2009; Fuhlendorf et al., 2012), an understanding of how conservation practices can meet both ecological and societal demands is critical to sustainable management of these complex systems (Boyd and Svejcar, 2009).

In addition to long-term effects on cattle production, other ecosystem services are put at risk by long-term heavy stocking rates, which homogenizes grassland. These include reductions in grassland bird, small mammal, and reptile diversity (Briske et al., 2011; Duchardt et al., 2016), degradation of wetlands (Bear et al., 2012; Lambert et al., 2014; Swartz and Miller, 2019), and carbon sequestration (Teague et al., 2016). For instance, in the central Great Plains of North America, the grassland-homogenizing effect of overstocking has been identified as negatively affecting grassland bird populations, including the Greater Prairie-Chicken *(Tympanuchus cupido)* (Fuhlendorf et al., 2006). However, if grazing is completely excluded, grassland can become similarly homogenous and is considered unsuitable as nesting habitat for grassland obligates, including Greater Prairie-Chicken, upland sandpiper *(Bartramia longicauda),* and eastern meadowlark *(Sturnella magna)* (Fuhlendorf et al., 2006). Thus, grazing practices are a key process that mediate the heterogeneity in vegetation structure required to support biological diversity (Derner et al., 2009; Duchardt et al., 2016), as well as livestock production (Allred et al., 2014).

Despite the relevance of moderating stocking rate to multiple ecosystem services, there are few policies or programs available to incentivize this decision on private land. The few programs relating to incentivizing conservation behaviors on grasslands mostly deal with completely excluding grazing by setting aside productive land such as the Conservation Reserve Program (CRP) in the United States (FSA, 2017). Although this can help achieve conservation goals (Dunn et al., 1993), participation and interest in these programs remain modest (Harr et al., 2014). Moreover, recent government programs in the United States like the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Conservation Stewardship Program (CSP) have been developed to integrate conservation efforts into land management plans through incentivizing practices such as adjusting stocking rates to meet both financial and conservation goals (USDA-NRCS, 2018a). Exploring the factors related to willingness to reduce stocking rate at the individual producer level could provide insight into whether managers might be interested in an intermediate approach—reducing stocking on some of their lands without excluding grazing altogether.

Furthermore, because lands are broken up into many parcels with each under individual autonomous ownership (average size: 183 ha; Morton et al., 2010), implementing these practices on grazing lands over large spatial and temporal scales requires engaging a large number of participants (Epanchin-Niell et al., 2010; Wilmer et al., 2019), thus making it difficult to successfully facilitate ecosystem service provisioning and biodiversity conservation (Tscharntke et al., 2005; Batáry et al., 2010). Whether participation in specific federal programs or the application of particular management practices occurs may be contingent on who is making operational decisions. Tenants and landowners may have divergent views toward adopting conservation-based agricultural practices (Petrzelka, 2014; Varble et al., 2016; Floress et al., 2018). Though numerous studies have developed typologies of grazing land operator characteristics and behaviors (Gentner and Tanaka, 2002; Lambert et al., 2014), few have assessed shifts in characteristics and behaviors of managers over time (Huntsinger et al., 2010), something that is needed to assess trends.

Therefore, supporting ecosystem services necessitates a thorough understanding of the complex factors that influence producer decision making surrounding stocking. Despite the importance of landowner engagement in these working landscapes, little information is available on the factors that influence livestock producer decision making concerning grazing land management (Roche et al., 2015; Derner et al., 2017). Perceptions of environmental issues are generally known to be drivers of producer beliefs and attitudes (Hall et al., 2003; Greiner, 2015) and, ultimately, can influence the adoption of environmentally friendly behaviors (Morton et al., 2010; Petrzelka et al., 2013; Wilmer et al., 2018) and interest in participating in government programs (Lubell et al., 2013; Roche et al., 2015; Floress et al., 2018; USDA-NRCS, 2018b). Several studies have examined the effects of socioeconomic factors on grazing management decisions and application of prescribed fire (Huntsinger and Sayre, 2007; Briske et al., 2011; Twidwell et al., 2013). However, studies that incorporate both agronomic and socioeconomic factors in an individual-level analysis are uncommon, and assessing the temporal dynamics of such factors through longitudinal surveys is even rarer (Huntsinger et al., 2010; Hruska et al., 2017). Furthermore, factors influencing the stocking rate decision, critical to maintaining the structure and function of productive grazing lands (Briske et al., 2011), are largely unexplored.

To this end, we assess individual-level decision making of cattle producers in the context of shifts in demographics and attitudes in the eastern Great Plains. First, we examine how socioeconomic characteristics and conservation-oriented priorities of livestock producers have changed over a decade (2007 vs. 2017). Second, the socioeconomic and livestock production factors associated with livestock producer willingness to reduce stocking rates for conservation goals are assessed in light of the changes evaluated in our longitudinal comparison.

Methods

Agroecological and Socioeconomic Context

This study was conducted in the Grand River Grasslands (GRG), an agricultural region spanning the Iowa-Missouri border in Ringgold (Iowa) and Harrison (Missouri) Counties, United States (Fig. 1). Due to the abundance of grassland present on the landscape, the GRG has been identified as the best opportunity to restore a productive tallgrass prairie system in the entire Tallgrass Prairie ecoregion (Nature Conservancy, 2008) and serves as a model Great Plains agroecosystem for study. Land use is predominantly used for beef cattle grazing and hay production, as well as mixed row crops and recreation (Morton et al., 2010; Coon et al., 2018). Despite experiencing high rates of conversion to cropland in recent years (Wright and Wimberly, 2013), grassland cover has persisted in the GRG in contrast to other areas of the eastern Great Plains due to a combination of topoedaphic, historical, and climatic factors. Located within the Loess Flats and Till Plains area of the Central Irregular Plains ecoregion (Supplemental **Fig. A.1** https://doi.org/10.1016/j.rama.2019.07.008), the GRG is characterized by rolling hills within fertile loess soils (Chapman et al., 2002). This topographic irregularity results in high soil erosion, limiting the extent to which the fertile soils and relatively high levels of precipitation are effective for row crop production (Chapman et al., 2002). Thus, grass-based livestock production, which is less erosion prone (Compton, 1952), has prevailed as a dominant land use even as landscapes elsewhere in the Central United States have been converted to row crops (Gallant et al., 2011).

Though large areas of grassland remain in the GRG, the biophysical characteristics of these ecosystems have been modified to

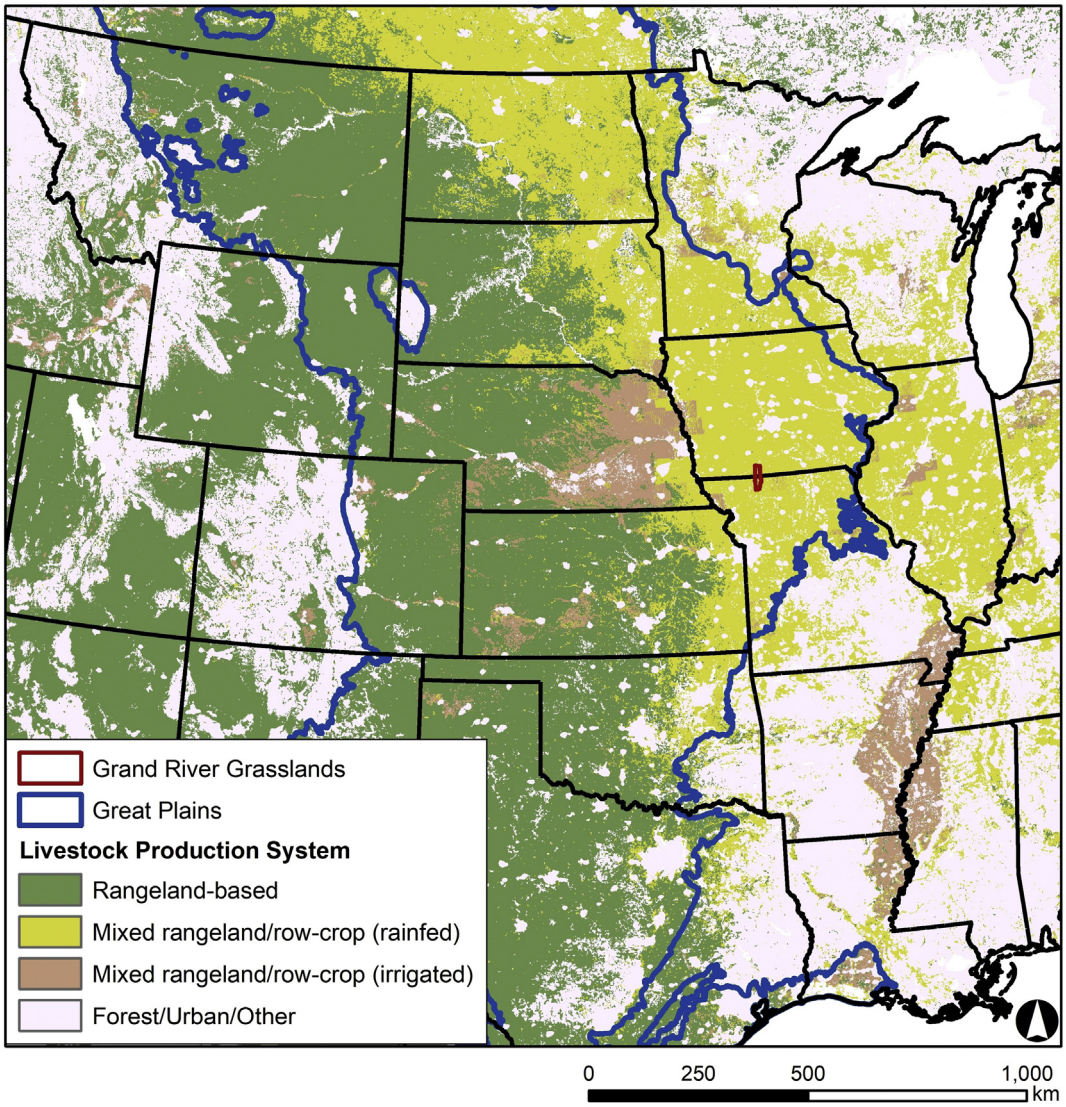

Figure 1. Landscape use based on Digital Map of Global Livestock Production Systems (FAO, 2011). Grand River Grasslands (red) are located in southern Iowa and northern Missouri, United States. The Great Plains Ecoregion (blue) follows delineation by the US Environmental Protection Agency (https://www.epa.gov/eco-research/ecoregions-north-america). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

better support cattle production. High stocking rates and woody encroachment by eastern red cedar *(Juniperus virginiana)* (Miller et al., 2012) have been strong drivers of grassland biodiversity loss through grassland homogenization. In addition to structural changes to the vegetation, the composition of grassland plant communities has been highly altered because of heavy grazing pressure. In the GRG, many exotic forage grasses, most native to Eurasia, are out-competing native tallgrass prairie grasses and forbs (McGranahan et al., 2013a; Raynor et al., 2018). Common non-native species include tall fescue, smooth bromegrass *(Bromus inermis),* timothy *(Phleum pratense),* and Kentucky bluegrass *(Poa pretensis).* These non-native cool-season grasses have been planted by producers to support heavy grazing and to control soil erosion (D'Antonio and Vitousek, 1992; Toledo et al., 2014; Scasta et al., 2015). Notably, traits that make these grasses desirable for cattle production (high stress tolerance) also make them more likely to become invasive (Scasta et al., 2015) . Tall fescue is particularly pernicious in this group (Hoveland, 2000). Prized for its drought tolerance and ability to withstand heavy grazing, tall fescue also can impede efforts to manage pastures with prescribed fire, degrade habitat for wildlife, and cause health and production problems for cattle (Hoveland, 2000; Barnes et al., 2013; Maresh Nelson et al., 2019). The study region lies at the northwest periphery of tall fescue distribution in the southeastern United States (Hoveland, 2000).

This section of the eastern Great Plains has greater and more predictable precipitation and concomitant forage production when compared with more arid environments farther west in North America (Smart et al., 2010; Cunfer et al., 2018; Petrie et al., 2018) and can, therefore, host the highest density of beef cattle to support short-term gains (Derner et al., 2017). Therefore, it is possible that producers in this region could be reticent to adopt a conservative stocking rate strategy due to the reliability of forage production even with heavy stocking.

Survey Methods

The 2007 survey provided the foundational data for this project (Morton et al., 2010). We used selected repeat measures from the original survey to conduct a 2017 population-level longitudinal survey. The development of a 2017 mail survey of landowners with > 8 ha of land in the GRG included replication of prior items and the addition of more detailed questions about forage types and stocking rates and was subsequently pilot tested and revised. Landowners were identified with county plat maps purchased from

Farm and Home Publishers (Belmond, IA). The survey included sections on landowner demographics, management techniques, and landowner perception of grassland management and conservation. The results reported here are from a section that was completed only by cattle producers. Detailed information on each survey question is provided in **Table A.1** (available online at http://hdl.handle.net/2142/99941). The research team obtained approval for our human subject research from the participating universities' Institutional Review Boards (IRB) before the survey mailing commenced. Both the 2007 and 2017 surveys were administered via a multicontact approach with reminders for nonrespondents (Dillman et al., 2014) to obtain the highest response rate possible. Contacts included the use of postcards and mail envelopes with survey and cover letter (Dillman et al., 2014) and contacts occurring at 2-wk intervals. In 2017, mailed surveys were supplemented with an online version (Qualtrics, Provo, UT). Nonrespondents with publicly available phone numbers were contacted by telephone to increase the response rate.

In both 2007 and 2017 surveys, livestock producers were asked about farm characteristics (acres owned, acres rented, number of acres in corn/soy, abundance of tall fescue on land) and demographics (level of education, household income, age, proportion of income derived from their land, length of land ownership in region, and gender). Respondents identified whether they gave economic or environmental considerations a higher priority when making land management decisions using a 10-point Likert scale (1 = economic concerns had the highest priority, 10 = environmental concerns had the highest priority). Producers in both 2007 and 2017 were also asked about priorities relating to wildlife habitat, biodiversity conservation, grassland restoration, invasive species management, crop production, livestock production, income from agriculture, and forage. Due to scale differences for these eight variables between 2007 (which used a 1–4 scale on these items) and 2017 (which used a 1–5 scale), scales were standardized to 1–100 to allow for comparisons between the two surveys (Robinson and Smith, 2002; Hasson and Arnetz, 2005).

In the 2017 survey, livestock producers were asked more detailed questions about their stocking-rate decisions. First, producers were asked to identify their satisfaction with their growing-season forage as rated on a 5-point Likert scale, from not satisfied to extremely satisfied. Second, they were asked would they adopt a land management practice that reduced stocking rate and beef production if it also resulted in any of the following conservation actions: reducing soil erosion, protecting wildlife habitat, restoring grasslands, controlling invasive plants, reducing tall fescue, increasing native plants, and increasing gamebirds (e.g., northern bobwhite, *Colinus virginianus*). To assess whether perceptions of each of the seven actions were similar and could be used to create a single scale variable, which averages responses over questions with multiple similar answers, the dimensionality of these outcomes was tested using exploratory factor analysis. A single factor was extracted in this analysis, and a single scale variable was constructed. This single factor was supported by a Cronbach's alpha score for internal validity of 0.95 (**Table A.2**, available online at http://hdl.handle.net/2142/99941). This scale represents the overall willingness of producer respondents to reduce stocking rates. The high level of internal consistency (i.e., a score > 0.70 is considered a good level of fit; Nunnally, 1978) suggests that individuals generally had a similar response to all the questions about conservation-based livestock management actions. Hereafter, we refer to this factor as willingness to reduce stocking for a conservation outcome.

Data Analysis

The analysis comprised two stages, both completed in SPSS Statistics (IBM Corp., Armonk, NY, 2017). First, we performed a longitudinal comparison between the two surveys, 2007 versus 2017. The comparisons included the producer characteristics, producer demographics, and producer attitudes previously mentioned but also compared eight additional items concerning conservation-oriented priorities. Because we did not follow up with specific individuals surveyed in 2007, this longitudinal comparison is based on the survey population's response. Due to the different sample sizes for 2007 versus 2017, nonparametric Mann-Whitney U tests were used to determine if there was a difference between variable means between the years, and chi-square tests for independence were used for categorical variables and/or variables with uneven intervals. Exact *P* values are reported to allow readers to distinguish between significant effects ($P < 0.05$) and marginally significant effects that may still warrant attention ($0.05 < P < 0.1$). Next, producer characteristics, demographics, and attitudes that influenced willingness to reduce stocking rate to benefit conservation were assessed. Analysis of variance (ANOVA) was used to test differences in producer willingness to reduce stocking rates between producers with > 50% of their land covered in tall fescue versus low fescue cover and producers who lived on their land versus absentee producers. Pearson's correlation analysis was used to determine if producer willingness to reduce stocking rate was associated with landscape characteristics and socioeconomic factors. Although cattle producers were not asked about their willingness to reduce stocking rate in 2007, comparisons over the decade can inform how the region has changed over time and how this could influence willingness to reduce stocking rate. The ranch characteristics, demographics, and attitudes had identical Likert scales in both years.

Results

Survey Samples

Survey response rate was 51% in 2007 and 33% in 2017, mirroring a national trend in lower response rates in agricultural surveys (Johansson et al., 2017). Because of this lower response rate in 2017, we assessed whether nonresponse bias might be a concern. We compared the demographic composition of our total 2017 sample with a small sample of nonrespondents who answered questions over the phone ($N = 14$) and with published studies conducted in the same region, including the 2007 survey (Morton et al., 2010) and USDA Census of Agriculture (USDA-NASS). In these comparisons, we found no major differences in racial identities, percent of income derived from grazing' properties, or average size of enterprise. The percentage of landowners grazing cattle was the same between 2007 and 2017, and respondents were slightly older when compared with 2007. In addition, more women answered our survey than the Census of Agriculture, a survey that targets farm operators. On the basis of these comparisons, we feel that there is little evidence of nonresponse bias. Of the 98 responses in 2007, 46 individuals were cattle producers (missing values 0–20%), while there were 87 cattle producers of the total 149 responses in 2017 (missing values 0–10%).

Longitudinal Comparison

Livestock producer demographics changed over the decade with mean age in 2017 being greater than in 2007 (Table 1). The age of respondents ranged from 40 to 90 yr old, with an average age of 66 yr. Ten years earlier, the average age of producers was 62 yr with a range of 39–92 yr. In 2017, cattle producers were predominantly men (79%), with 17% identifying as women and 3% as neither men nor women. In 2007, the sample was comprised of 78% men and 22% women. Since 2007, there was a marginal decrease in respondents who placed environmental concerns over economic concerns regarding use of natural resources on their grazing enterprise (see Table 1). Tall fescue was perceived as more abundant on a producer's

Table 1
Descriptive statistics (means and percentages) from the longitudinal comparison, 2007 vs. 2017, of cattle producers at Grand River Grasslands, southern Iowa and northern Missouri, United States. $N = 46$ for 2007, $N = 87$ for 2017

Factors	2007	2017	Mann-Whitney U	Wilcoxon W	*Z*	(2-tailed) *P*
Age	61.2	66.1	1 423.5	2 504.5	−2.298	0.022
Owned acreage (ha)	181.6	225.4	1 303.5	4 306.5	−1.360	0.318
Rented acreage (ha)	27.8	106.4	1 478	2513	−2.333	0.020
Grazed acreage (ha)	319.3	294.1	1 303.5	4306.5	−1.359	0.174
Fescue abundance[1]	3.5	3.9	1 335	2196	−1.539	0.124
Natural resource scale[2]	6.4	5.6	1 238.5	4241.5	−1.951	0.051

[1] Measured on the following 1-5 scale: Extremely abundant (1), moderately abundant (2), found occasionally (3), rare (4), not present (5).
[2] Measured on a 1-10 scale with economic concerns at bottom (0) and environmental concerns at the top (10).

land in 2017 than 2007. There have been significant changes in grazing land ownership in the GRG since 2007. Mean ownership hectares increased by 24% (182 – 225 ha) and area of land rented increased by nearly three times (28 – 106 ha).

At the same time that more land area was rented (see Table 1), more landowners reported living on land they owned: 81% in 2017 compared with 54% in 2007 (Table 2). Over the decade, there was a decrease in the percentage of individuals reporting that they had experimented with new land management techniques that they had not previously used, from 67% to 42%. No significant change was found in household income, level of education, length of land ownership, or distance of place of residence from grazing land (see Table 2). In 2017, 61% of respondents had annual household incomes at $50,000 or above, compared to 68% 10-years earlier. The percentage of cattle producers relying on their land for more than half of their income was relatively stable over the decade (39.5% to 41%). The number of cattle producers having college degrees increased slightly, from 24% to 29%. There are indications that land turnover rates were low, with more producers owning land in the GRG for > 25 yr in 2017 (75%) versus 2007 (44%). Level of education was not associated with income categories ($X^2_{54} = 47.7$, $P = 0.76$) or acres owned ($F_{6,74} = 1.03$, $P = 0.42$).

Changes from 2007 to 2017 in how a cattle producer prioritized various goals when making land management decisions occurred for only three of nine survey items (Table 3). Prioritization of restoration of native grassland properties and promoting biodiversity were lower in 2017 than in 2007 (see Table 3). In contrast, more value was placed on land management decisions that prioritized the reduction of soil erosion, and soil erosion was already a high priority in 2007. Priorities when making management decisions that did not change over the period included the use of livestock, income from land, controlling invasive plants, managing land for forage availability, use of crops, and protecting wildlife habitat.

Table 3
Average ranking for 2007 and 2017 and Mann-Whitney U-test statistics for question: "How important are each of the following when deciding how to manage your land?" $N = 46$ for 2007, $N = 87$ for 2017. All variables are ranked on a scale of 1 – 100 with high values indicating high importance and low values indicating low importance.

Item	2007	2017	Mann-Whitney U	Wilcoxon W	*Z*	(2-tailed) *P*
Forage	67.5	73.1	1 231.5	1 972.5	−1.522	0.128
Agribased income	79.4	75	1 621.0	5 107.0	−0.678	0.498
Livestock	73.5	78.5	1 638.5	2 628.5	−1.228	0.219
Crops	47.2	39.7	1 401.5	5 056.5	−0.751	0.452
Soil erosion	78	84	1 389.0	2 379.0	−2.639	0.008
Biodiversity	64.1	51.6	817.0	4 057.0	−1.666	0.096
Wildlife habitat	62.8	56.5	1 682.5	5 252.5	−0.640	0.522
Restoration	58.8	41.8	1 021.0	4 676.0	−3.301	0.001
Invasive plants	77	74.1	1 638.5	2 541.5	−0.887	0.375

Willingness to Reduce Stocking Rate if It Resulted in Conservation Outcomes

In this section, we cite the percentage of producers that were moderately, very, or extremely likely to reduce stocking rate. Cattle producers as a group were most likely to reduce stocking rate when the conservation outcomes related to production goals (Fig. 2), including reducing soil erosion (65%), controlling invasive plants (63%), or reducing tall fescue (50%). However, most producers were also likely to reduce stocking rate to benefit game birds (55%). Cattle producers were less likely to be willing to reduce stocking for other outcomes not related to production, such as restoring prairies/grasslands (34%) and increasing wildflowers/native plants (33%). When asked to what extent they were satisfied with their growing season forage, most respondents (54%) were moderately satisfied, and another 42% percent were very or extremely satisfied.

Table 2
Chi-square analyses from the longitudinal comparison, 2007 versus 2017, of cattle producers at Grand River Grasslands, southern Iowa and northern Missouri, United States. $N = 46$ for 2007, $N = 87$ for 2017

Factors	X^2	DF	(2-tailed) *P*
Percent household income from enterprise[1]	0.73	5	0.983
Ownership length[2]	17.7	4	0.001
Experimented with new management	6.9	1	0.008
Living on their enterprise	10.6	1	0.001
Household income[3]	5.6	8	0.72
Education level[4]	7.8	6	0.25
Enterprise distance to residence[5]	5.8	3	0.12

[1] Measured on the following 1 – 6 scale: None (1), Under 10% (2), 11 – 25% (3), 26 – 50% (4), 51 – 75% (5), 76 – 100% (6)
[2] Measured on the following 15 scale: < 5 yr (1), 6 – 10 yr (2), 11 – 25 yr (3), 25 – 75 (4), > 75 yr (5)
[3] Measured on the following 1 – 9 scale: < $15 000 (1), $15 000 – 24 999 (2), $25 000 – 34 999 (3), $35 000 – 49 999 (4), $50 000 – 74 999 (5), $75 000 – 99 999 (6), $100 000 – 149 999 (7), $150 000 – 19 999 (8), > $200 000 (9)
[4] Measured on the following 1 – 7 scale: Some high school (1), high school graduate (2), technical/vocational school (3), some college (4), bachelor's degree (5), some graduate school (6), graduate or professional degree (7)
[5] Measured on the following 1 – 3 scale: < 50 miles (1), 50 – 100 miles (2), > 100 miles (3)

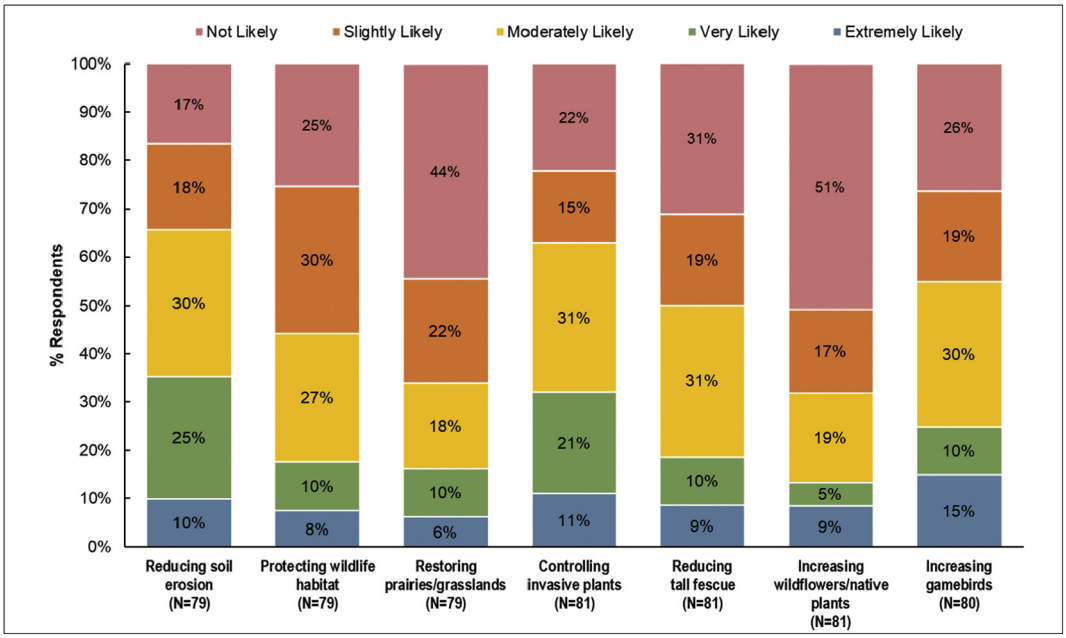

Figure 2. Responses to the 2017 survey question: "How likely is it that you would adopt a management practice that would reduce stocking rate and beef production per acre if it resulted in the following?"

Table 4
Cattle producer landholding characteristics among levels of willingness to reduce stocking rate if it resulted in a positive outcome for conservation in 2017. Rankings are on a scale of 1–5 with low values indicating low willingness to high values indicating high willingness.

Willingness to reduce stocking	Avg. hectares (acres) per landowner	Total hectares (acres)	Hectares (%)	Number of landowners	Landowners (%)
1	215 (530)	5 793 (14 315)	31	27	33
2	216 (535)	5 195 (12 837)	28	24	30
3	252 (622)	5 037 (12 446)	27	20	25
4	327 (808)	2 614 (6 460)	14	8	10
5	97 (240)	194 (480)	1	2	2

Only 5% were less than moderately satisfied. Thirty-seven percent of cattle producers in 2017 were at least moderately willing to reduce stocking rate for a conservation outcome (Table 4), and these respondents owned 42% of the land area represented in the survey (7 845 of 18 833 ha).

Factors Associated with Willingness to Reduce Stocking Rate

Correlation analysis indicated that the perceived abundance of tall fescue and the level of satisfaction with growing season forage on a producer's land were negatively associated with willingness to reduce stocking rate if it resulted in positive outcomes for conservation (Table 5). Estimated abundance of tall fescue and satisfaction with growing season forage were not correlated with each other ($r = 0.01$, $F_{1,75} = 0.01$, $P = 0.94$). If a cattle producer managed a greater area of rented land, he or she was less willing to reduce stocking. The acreage of grazing land on a producer's property was also negatively associated with their willingness to reduce stocking rate. A marginal difference in willingness to reduce stocking rate for positive conservation outcomes occurred between producers with < and > 50% of estimated tall fescue abundance (ANOVA, $F_{1,64} = 2.78$, $P = 0.10$). This implies that producers with less tall fescue on their land are more likely to reduce stocking rate if it results in a conservation outcome. No difference in willingness to reduce stocking rate occurred between producers who lived on their land or lived absentee (ANOVA, $F_{1,78} = 1.7$, $P = 0.20$) or for level of education attained (ANOVA, $F_{9,57} = 0.62$, $P = 0.77$).

Table 5
Directional relationships between a livestock producer demographic characteristics and willingness to reduce livestock stocking rate if it resulted in a positive outcome for conservation in 2017 ($N = 75$).

Item	Correlation coefficient (r)	P (2-tailed)
Acreage owned	0.097	0.397
Acreage rented	−0.218	0.055
Length of land ownership	−0.051	0.661
Grazed grassland acreage	−0.200	0.092
Corn/soy acreage	−0.099	0.395
Satisfaction with growing-season forage	−0.381	0.000
Age	−0.014	0.901
Economic-environmental orientation[1]	0.523	0.000
Tall fescue abundance on land	−0.236	0.045
% income from land	−0.112	0.345

[1] Rankings were on a scale from 1 – 10 with economic orientation at lower end of scale and environmental orientation at upper end.

Producer respondents that made more environmentally oriented decisions than economically based decisions showed greater willingness to reduce stocking rate (see Table 5). A respondent's level of formal education was also positively correlated with their willingness to reduce stocking (ANOVA, $F_{6,71} = 2.81$, $P = 0.016$). An evaluation of whether a cattle producer respondent's level of education was associated with their orientation toward economic- or environmental-based management decisions indicated no relationship (ANOVA, $F_{6,67} = 1.48$, $P = 0.20$).

Discussion

An understanding of the complex suite of drivers and socio-economic characteristics that underlie grazing decisions is required

to comprehend past changes and to project future changes that lead to improvement or deterioration of natural resources (Ostrom, 2009; Godde et al., 2018). Temporal shifts of cattle producer characteristics, attitudes, and decisions in a working grassland landscape in the eastern Great Plains are assessed, providing insight into the socioeconomic contexts that influence grazing management decisions over time. Building on previous work conducted in the region on landowners' perceptions of grassland management practices (see Morton et al., 2010), we examined shifts in these perceptions and socioeconomic characteristics of cattle producers from 2007 to 2017. To better pinpoint factors leading to positive conservation outcomes for grazing lands, demographic characteristics associated with producer willingness to reduce stocking rate, a critical conservation practice, are highlighted.

Socioeconomic Characteristics Influencing Perceptions and Decisions

To achieve management goals, policy makers or resource managers need to identify variables that drive management decisions on private lands because social processes and ecosystems are tightly interlinked (Ostrom, 2009), and these variables need to be measured over time for any effort to detect system changes (Allen and Holling, 2010; Hruska et al., 2017). Such information allows some level of prediction for the success of policy changes. Like elsewhere in the Great Plains, our study population of cattle producers aged and increasingly rented more land for their grazing operations (Varble et al., 2016; Derner et al., 2018a; Zhang et al., 2018). This result suggests future policy creation incorporating land ownership and resource user demographics in our study system may move forward like other rural communities, where land-holdings are under agricultural crop cultivation (Cromartie et al., 2015; Varble et al., 2016). From a conservation perspective, the longitudinal comparison of socioeconomic characteristics revealed mixed results, with cattle producers reporting marginally higher levels of invasive tall fescue cover on their operation in 2017 than in 2007; whereas, in contrast, fewer respondents implemented alternative grazing practices in 2017 than in 2007. Such results suggest 1) a potentially increasing awareness of vegetation cover type on grazing enterprises, albeit of an invasive species, and 2) increasing reticence for adoption of nontraditional grazing practices. Increased reticence to adopt nontraditional practices is associated with strong place and livelihood attachment, particularly among aging, independent managers (Marshall, 2010; Marshall and Smajgl, 2013). Such reluctance to employ alternative grazing practices on a livestock enterprise has been suggested as a major factor driving an operation's vulnerability to climatic change in the Great Plains (Wilmer and Fernández-Giménez, 2015; Derner et al., 2018a). Further, socioeconomic characteristics of livestock producers were not the only component of this socioecological system that changed. How cattle producers prioritized land management decisions that impact the environment also shifted over the decade.

Results from the 2007 and 2017 surveys revealed that cattle producers highly value preventing soil erosion, which was more of a priority in 2017, indicating growing support for an ecosystem service with landscape-level implications for biodiversity conservation and ecosystem function (Bear et al., 2012; Lambert et al., 2014; Derner et al., 2018b). Furthermore, controlling invasive plants and protecting wildlife habitat remained important practices among cattle producers. Producers in the GRG are therefore concerned about the maintenance of ecosystem services that include food provisioning and biodiversity conservation and are not resistant to implementing all types of conservation practices, which is the conceptual underpinning of "working landscapes" as a conservation goal and opportunity (Huntsinger et al., 2007; Huntsinger and Sayre, 2007).

This analysis offers a new perspective on the factors that influence willingness to reduce stocking rate in North American grasslands, a practice with significant agricultural and ecological implications (Hart and Ashby, 1998; Irisarri et al., 2016). We found notable heterogeneity in the drivers of cattle producer willingness to enact this conservation practice. Although the average acreage for the most willing respondents was also the lowest across the spectrum (see Table 4), the average acreage per respondent was not linearly related to willingness to reduce stocking if it resulted in a conservation outcome. Further investigation will be necessary to establish the full reason behind this variety in producer perceptions. Our data provide evidence that environmental concerns are taken into account by livestock producers in this region, and this relationship is nonlinear and not fully dependent on a single factor such as land-holding size.

Economic And Environmental Priorities

This study suggests that the capability to enact a conservation practice may be limited by the financial needs of cattle producers in the eastern Great Plains and implies that financial incentives may be necessary to realize the implementation of sustainable grazing practices on private lands. Economically motivated individuals composed a greater proportion of the study population in 2017 compared with 10 yr earlier, and agricultural priorities increased markedly. External perturbations that potentially influenced the shift from environmental to economic prioritization include commodity prices spiking, high rates of cropland conversion, the economic downturn in 2008, and the 2012 Great Plains drought, all of which occurred between 2007 and 2017 (National Agricultural Statistics Service, 2013; Wright and Wimberly, 2013; Knapp et al., 2015).

Regardless of the indications that economic concerns may limit long-term sustainability of the region, some findings point toward opportunities for landscape-scale conservation. For instance, a policy initiative to incentivize stocking rate reductions could target cattle producers (who own ~40% of the acreage) who were at least moderately willing to reduce stocking rate. Comparable findings in productive pasture lands in eastern Tennessee demonstrated that once producers participated in sustainability-based grazing practices, they were more likely to adopt similar pasture improvement measures in the future (Lambert et al., 2014). Despite the overall importance of economics to cattle producers in the region, efforts to engage the most willing operators may benefit from environmentally focused messaging. Programs such as the Environmental Quality Incentives Program (USDA-NRCS, 2018b) and the CSP (CSP; USDA-NRCS, 2018a) advocate environmentally responsible behaviors by providing cattle producers cost-share opportunities to manage cattle movement and improve pasture productivity.

Invasive Species

Willingness to reduce stocking rate for conservation purposes was also correlated with pasture conditions. In particular, abundance of tall fescue and perception of forage conditions on respondents' land were both negatively related to producer willingness to enact stocking rate reduction. Because tall fescue is widely reported to be a reliable forage in many pasture types and during drought (Burns et al. 1984; Hoveland, 2000), cattle producers with pastures with high tall fescue cover are apparently reticent to reduce stocking rates or adopt alternative land management practices for economic reasons, as high tall fescue cover may indicate good pasture condition. However, such views are not consistent across all producers in the GRG; some individuals

perceived tall fescue negatively because of its detrimental effects on cattle health and performance when infected with a fungal endophyte (Coon et al., 2018). Therefore, our results on the perception of pasture-level tall fescue cover and adoption of conservation action point toward heterogeneity in producer opinions on this invasive grass in our study system.

Reliance on tall fescue for livestock production in the southeastern United States has been questioned (e.g., Monroe et al., 2016; Monroe et al., 2017), as native, warm-season grass-dominated pastures have been shown to offer greater cattle weight gains with lower fertilizer inputs compared with fescue-dominated pastures (Harper et al., 2015). Costs (i.e., loss of revenue during pasture deferment for native plant species cultivation/establishment) and risks (i.e., establishment failure, variation in market conditions, or weather) of converting tall fescue pasture to native, warm-season grass pasture remain a significant barrier to adoption. However, positive outcomes of converting forage plant composition to native species for nonforage provisioning ecosystem services, such as supporting diversity and abundance of grassland birds, are coming to light in this historically tall fescue–dominated agriecosystem (e.g., Monroe et al., 2016; Monroe et al., 2017; Maresh Nelson et al., 2018). For instance, nest survival of the grasshopper sparrow *(Ammodramus savannarum)* and dickcissel *(Spiza americana)* benefits from decreased cover of tall fescue (Lyons et al., 2015; Maresh Nelson et al., 2018). Thus, our finding that producers perceive an increase in the abundance of tall fescue over the past decade is a potential cause for conservation concern.

Positive attitudes toward tall fescue cover at the enterprise level exemplify a positive feedback loop that likely amplifies the presence of this invasive grass across the region. The recognition of this cross-scale feedback loop with negative consequences is a crucial step for grassland restoration management of this socioecological system (Gunderson and Holling, 2001). Extra precautions should be taken to prevent such feedback loops from taking further effect. For instance, short-term expenditures to promote communication among community members and community leaders may be justified by long-term benefits (Lubell et al., 2013; Roche et al., 2015). Although the establishment of venues for stakeholder meetings and management collaboration may require investing additional time and money, this effort may result in growing participation that reduces management costs and improves outcomes in the long run.

Ownership

To date, studies have pinpointed city-dwelling absentee landlords that rely on local land managers to make operational decisions as the underlying driver for fewer adoptions of long-term conservation-based practices (Petrzelka et al., 2013; Petrzelka, 2014). Producers that do not live on the grazing land may be less likely to have contact with extension and local natural resource agency program staff who teach conservation practices (e.g., Duffy and Johanns, 2014). In our study region, such absentee ownership from outside the region was minimal; landowners that leased land mostly resided in our study region (Ringgold County, Iowa or Harrison County, Missouri) (Coon et al., 2018).

Instead of absentee landownership influencing willingness to enact a conservation practice, we found that increasing rental land was related to lower willingness to reduce stocking rate. Most operators who rent may not have the long-term sustainability of those parcels in mind as a resident operator-landowner would (Soule et al., 2000). Our finding that the more area of land that was rented was negatively associated with an individual's willingness to reduce stocking rate suggests the individuals making decisions for that parcel were likely to be more focused on short-term gains than conservation practices that provide benefits over the longer term. While several studies have found that renters are less likely to be engaged in conservation practices (Petrzelka et al., 2013), this trend has been found to vary depending on the management practice being studied (Varble et al., 2016).

Our findings agree with trends throughout the central United States showing more farm land is being rented, while fewer acres are farmed by owners (National Agricultural Statistics Service, 2014; Varble et al., 2016). In this study, rented acreage for cattle production substantially grew yet this increase was not limited to land for cattle production. Across all landowner respondents in Coon et al. (2018), average acreage rented increased 83% from 2007 levels. Because land sale prices are increasing in this region (Duffy, 2013), we surmise increasing prices are driving younger family members to rent from older family members instead of purchasing their own holdings; thus, substantial increases in rental acreage are being observed. This likely scenario also follows the aging trend in this community, which feeds back to increased acreage under rent. How such social dynamics interact with ownership attributes to shape adoption of conservation practices on grazing lands is an area in need of study (Fulton and Vanclay, 2011).

Education and Communication

In our study region, respondents with higher levels of formal education tended to report greater willingness to reduce stocking rate than respondents with lower levels of education. However, evidence for the effect of producer education level on the adoption of agrienvironmental schemes is mixed. Although some studies show that educated producers are generally more likely to adopt new agrienvironmental practices (Wilson, 1997a), others have argued that access to knowledge (i.e., the 'information environment' or networking) more so than formal education may drive willingness to participate in conservation practices (Wilson, 1997b). Perhaps producers with more formal education have access to social networks that provide support for a normative environment that encourages more conservation-oriented actions.

Moreover, more educated producers might be less likely to regard organizational requirements of alternative management activities as onerous (Falconer, 2000). Our results in the eastern Great Plains accompany findings from the central Great Plains (Sliwinski et al., 2018) and the western Great Plains (Wilmer and Fernández-Giménez, 2015; Wilmer et al., 2018) to suggest that livestock producers with more knowledge about drivers of grazing enterprise problems may be more willing to adopt conservation practices. Such enterprise-level problems include pasture vegetation homogenization and impact of invasive forage species on performance (DiTomaso et al., 2017). An increasing number of groups, such as the Sustainable Rangelands Roundtable (http://www.sustainablerangelands.org/), are devoted to communicating this type of knowledge to receptive producers.

Conclusion

Looking at the broader implications of this study, changes over the past decade such as the increasing prevalence of rented land and the aging producer population are concerning trends for grazing land conservation. Advancing management goals that underpin long-term sustainable grasslands requires addressing both the constraints around 1) economically oriented decision making that reinforces the presence of an invasive forage species and the use of heavy stocking rates and 2) the shift in ownership from full-owners to renters and the concomitant drop in the adoption of conservation practices. Despite these barriers, conservation perceptions and socio-economic characteristics of the population vary widely and a large portion of the landscape is owned by producers who are interested in the sustainability of their pastures.

Our fine-scale enterprise-level evaluation may help to inform regional policy by providing insight into which type of producer may be most likely to participate in conservation-based grazing land management recommendations. On the basis of 2017 survey results, likely participants include operators owning grazing land (versus renting), managing medium-sized acreage with lower levels of invasive forage grasses, less satisfied with their forage resource, and being more environmentally oriented than economically oriented. Further, we recommend messaging that emphasizes soil conservation as a benefit of moderating stocking rates. The linking of cattle producer perceptions of grassland management to their participation in conservation actions highlights the need for targeted outreach and policy that empowers producers to make informed decisions in the adoption of sustainable management practices. Given that landowners have an important economic stake in pastures, we recommend a balanced approach for understanding this socioecological system that weighs the influence of stocking rate on conservation with the producer's need to optimize vegetation to earn income.

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Appendix A. Supplementary data

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