EVALUATING TOOLS AND TRADEOFFS FOR SUCCESSFUL GRAZING PARTNERSHIPS ON WISCONSIN PUBLIC GRASSLANDS

By

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Introduction: Collaborative agriculture in a changing climate

As we look into a new decade, it is clearer than ever that agriculture as we know it in the United States *must* change. Corn, soybean, and alfalfa cover nearly 75% of agricultural acres in the 48 contiguous states (LaCanne & Lundgren, 2018) and the confined livestock systems they support contribute to greenhouse gas emissions, to pollution and eutrophication of our waterways, to losses of soil carbon, wildlife habitat, and biodiversity, and to economic consolidation and loss of our rural communities (Dumont et al., 2013; Hatfield et al., 2011; LaCanne & Lundgren, 2018). Our food systems are becoming increasingly vulnerable to climate- and weather-induced instability, pest and pathogen outbreaks, and extreme weather events, all which affects our levels of and access to food across the country and threatens to gut our social and economic resilience (Altieri et al., 2015).

A push toward multifunctionality in our agroecosystems is not new. Many have demonstrated that increasing plant community diversity and perenniality in our agriculture—and thereby contributing to other management goals than food production alone—can have beneficial effects for numerous ecosystem services (Bohman et al., 1999; Jackson et al., 2007; Jordan & Douglass Warner, 2010) As we investigate strategies to increase the multifunctionality in our agriculture, however, historic grasslands and prairies provide an inspiring model to change our cropping systems (Hendrickson et al., 2019). The grasslands and native prairies of the North Central Region of the U.S. have perennial plant cover to hold soil in place and deep root systems to improve water infiltration and store carbon, and are a source of spatial and temporal heterogeneity that supports a wide range of wildlife while making them more resistant and resilient to drought or flood conditions (Koerner & Collins, 2014; Sanderson et al., 2016).

With multifunctionality as a goal and grassland structure and function as a model, it is clear that cooperation and collaboration are also key features of this new generation of agroecosystems. Individual actions, finances, and incremental changes through local incentives or regional policies are not enough to make this shift in the face of a climate crisis. Coordinating our efforts through collaborative and adaptive management necessitates good measurement tools and evaluation to gather information needed for decision-making and iteration.

Using a pilot effort to graze cattle for public habitat management in Wisconsin, this dissertation explores the question: what kinds of tradeoffs and tools do we need to assess, monitor, and evaluate our transition to more perennial, multifunctional agroecosystems? This effort will take careful planning around communication and implementation of new management to adequately address public perception and attitudes (Chapter 1). As we consider the lands around us and their potential for multifunctional agriculture, we will need to get a more complete picture of what those lands look like and their suitability for new management, using traditional grassland survey techniques (Chapter 2) alongside the enhanced spatial monitoring and modeling capabilities of remote sensing (Chapter 3). To address the complexity of implementing new management in a changing climate and unpredictable the biophysical and socio-political shifts that accompany it, we will need new strategies for evaluation to assess progress, change, and learning (Chapter 4).

Ultimately, this work attempts to demonstrate the application of different strategies, approaches, and information types to guide collaboration in agricultural land management, because transitioning our agroecosystems will require enormous collaboration. In the words of Chris Begley, an archeologist and professor of anthropology at Transylvania University:

> [Climate change] will involve billions of survivors. We will find ourselves in large groups, in rapidly changing situations, and we will have to negotiate that. We will not

> escape the messiness of contemporary society [...] The needs will be enormous, and we cannot run away from that. Humans evolved attributes such as generosity, altruism, and cooperation because we need them to survive. Armed with those skills, we will turn towards the problem, not away from it. We will face the need, and we will have to solve it together. (Begley, 2019).

In short, we cannot cultivate food alone in the face of an unstable and uncertain global climate. Cultivating strong relationships across different sectors and working collaboratively toward regenerative, resilient agroecosystems is truly the only way to address varied and complex needs. Careful assessment of the tradeoffs in new management practices and thorough consideration of the tools to monitor and learn from them will help sustain those partnerships for the future.

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Chapter 1. Understanding “the public” in public land management: Perceptions of stakeholders in Wisconsin conservation grazing initiatives

ABSTRACT

Using cattle to manage wildlife habitat offers new opportunities to improve public grassland management, increase conservation in agriculture, and support ecosystem services in the North Central United States, but it faces a number of communication challenges for successful implementation. This paper aims to characterize the perceptions that farmers and state land managers hold about “the public” when it comes to communicating and implementing cattle grazing management on public lands. Using a case study on a new public land grazing program in Wisconsin, we identify some of the challenges land managers, farmers and scientists encounter in communicating public land management, particularly in a landscape where media can drive policy-making for conservation. This case study highlights the ways in which farmers and land managers intend to use managed grazing to change public opinion of state land management and livestock production positively, and it identifies different types of public stakeholders with varying degrees of influence and investment in the outcomes of grazing management. We describe some of the potential problems in communicating about grazing as a conservation management tool, and we explore the role of perceptions in the success of land stewardship.

1. INTRODUCTION

1.1 The importance of public perception in conservation and agriculture

The success of natural resources conservation and management in the United States is closely tied to public perception, or the ways in which individuals observe, evaluate, and interpret their experiences of the environment (Bennett, 2016). Public perception influences the funding, administration, and enforcement of conservation policy, and can be a critical part of decision-making that designates ecosystems or species for protection, restoration, or eradication (Botterill & Mazur, 2004; Brook et al., 2003; Dawson et al., 2017). The beliefs that drive environmental management are rooted in values, whether aesthetic, economic, ethical, or cultural (Streever et al., 1998). Public perception of the individuals or institutions behind conservation management—and the values or motivations of those groups—provides a basis for the public to evaluate the appropriateness, quality, impact, and legitimacy of that management (Bennett, 2016). Increasing interest in bringing conservation practices into agricultural land management has incited new questions about how to navigate public perception while implementing complex public-private partnerships (Bellamy et al., 2001; de Snoo et al., 2013; MacNaeidhe & Culleton, 2000). The general public often focuses on the unknown or significantly negative effects of conservation or agricultural management, regardless of low likelihood (Botterill & Mazur, 2004), which means that understanding the mechanisms of how public perception develops and who is considered a part of "the public" is critical for effective planning, communication, and decision-making.

Much of the historical communication around evidence-based conservation management or agricultural practices relies on the unidirectional "knowledge deficit model," which assumes that a public with more information about a particular issue will understand, accept, and participate in rational decision-making around the issue (Dunwoody & Griffin, 2006; Scheufele, 2007). Farmers, public land managers, and conservation specialists now have more opportunities for public engagement and communication than ever before, but many still view it as a one-way exchange that is difficult or even dangerous to their work (Davies, 2008). Many believe that the primary purpose of science communication is to educate the public on the "big ideas," and worry about the loss of complexity and misuse of information that comes with presenting only the most engaging parts of their work (Bellamy et al., 2001; Besley, 2015; Cash et al., 2003). Though this model of "one-way education to a deficit public" is a widespread strategy of engagement for public conservation agencies and agricultural extension, it has little support in communications literature as an effective strategy or a realistic means of understanding of how the public forms opinions (Besley & Nisbet, 2013; Davies, 2008; Scheufele, 2007). It is clear that public perception has significant power over the success of conservation agriculture initiatives, but the experts implementing that management have limited knowledge about how to inform or manipulate those perceptions.

1.2 Public perception of grazing and grassland management

Grasslands and prairies are viewed as a unique and complex part of the North American landscape, representing a source of essential ecosystem services and deep-rooted conflicts across their historically-estimated 457 million hectares in the United States (Sanderson et al., 2009; Wayland et al., 2018). While cattle ranchers throughout the western United States have grazed public and private grasslands since the early 19^{th} century, the complexity of managing grassland resources with grazing—including wildlife habitat, water and soil reserves, and activities like recreation, education, and agricultural production—continue to challenge public conservation agencies. Mismanagement of grazing has led to wildlife losses, invasive species introduction, soil compaction and erosion, water contamination, contributed to greenhouse gas emissions, conflict between livestock and public users, and even led to violence (Miller, 2016; Wayland et al., 2018). As a result, many farmers and public land managers feel that the general public has a negative perception of grazing as a management tool, one partly based on lack of understanding and assumptions about short-term planning, self-serving farmer interests, and profit (Klyza, 1996; Torell & Doll, 1991). In recent years, a need for grassland management that supplements conservation activities like prescribed fire as well as a struggle for land access among cattle farmers has opened up new possibilities of grazing livestock for habitat and environmental management (Pepper, 2016). Understanding the perceptions that conservation agencies and cattle farmers hold about “the public” is a central issue in building trust and transparency with public stakeholders for effective agricultural management on public lands.

Research indicates that many scientists and conservation practitioners have negative perceptions of the public, and that they question the abilities of the public to make judgments about complex, science-based policies or use that information in their decision-making (Besley & Nisbet, 2013; Nisbet & Huge, 2007). Other literature suggests that media coverage drives public opinion and advocacy around issues in the news, forcing the issues onto the public agenda for elected officials and governmental decision-making (Viggo Jakobsen, 2000). This “CNN effect” has been cited as a force for policy intervention in human rights issues and global conflict crises, but has not been thoroughly explored in contentious environmental or land management scenarios (Gilboa et al., 2016). Both public and private media influence every aspect of the relationship between public perception and policy, framing news stories to meet the competing requirements of policymakers and general audiences (Baum 2008). The assumption that the media drives public perception and outcry further reinforces the idea that general public—nonscientists—and journalists do not fully understand complex issues and events, contributing to the concerns scientists and land managers have about how the public will receive or react to their work (Cobb et al., 2016; Nisbet et al., 2003). While the media environment has become increasingly diverse, the idea that journalism and the media have the ability to direct public outcry and powerful public pressure on elected officials and administrators still persists (Baum & Potter, 2008).

1.3 Grazing management on Wisconsin public lands

This paper will explore the perception of “the public” as a force in decision-making throughout the implementation of grazing management on state wildlife areas in a Wisconsin case study. We assert that these “perceptions of public perceptions” have an important role in the development of grazing partnerships, and as such, the way farmers and land managers interpret public perceptions can determine the success of new grazing initiatives and other public-private, multifunctional land uses. While there is no mainstream tradition or history of grazing public lands in the North Central Region of the United States compared to the large arid rangelands of the West, the Wisconsin Department of Natural Resources (DNR) is testing the use of rotational cattle grazing as a grassland management tool on state habitat conservation and public recreation areas. The Wisconsin DNR maintains over 28,000 hectares of grasslands, and faces a number of financial and political constraints that have decreased the personnel and resources available to improve wildlife habitat with controlled burning, herbicide applications, and mowing (The Wildlife Trusts, 2018). Though Wisconsin wildlife areas differ in vegetation and size from the rangelands of the West, the expansion of grazing management initiatives for grassland conservation from the Minnesota Department of Natural Resources (Hoch, 2013) has increased interest in rotational grazing as a supplemental grassland management approach in the Upper

Midwest. Research has shown potential of using cattle grazing strategically to mechanically damage or defoliate trees, shrubs, and patches of invasive or non-native species, encouraging native forbs and grasses to diversify grassland habitat (Brink et al., 2013; Chamberlain et al., 2012; Euclides et al., 2018; Paine & Ribic, 2002; Ravetto Enri et al., 2017). However, ecosystem responses to rotational grazing management are often highly context-specific, making it difficult to prescribe practices on pastures that vary in size, soil type, terrain, vegetation, and wildlife needs (Briske et al., 2008; Lyon et al., 2011; Teague et al., 2013). Even with the best of intentions and planning, land managers and livestock farmers who use rotational grazing—hereafter referred to as 'graziers'—can spend years struggling with a trial-and-error approach to grazing, increasing the risk of environmental degradation, animal health decline, or financial losses. As such, negative public perceptions, outcry, and backlash are key considerations in the implementation of new public grazing management. This study identifies how land managers and graziers describe 'the public' and the extent to which they weigh public perception as a factor in the development of grazing management, and discusses lessons-learned for other public-private partnerships in conservation agriculture.

2. "THE PUBLIC" OF GRAZED WISCONSIN PUBLIC LANDS

2.1 Study sites

The ongoing grazing research project described here was initiated in 2015 by a partnership between an agroecology research group at the University of Wisconsin-Madison and land managers at the Wisconsin Department of Natural Resources to explore the opportunities and challenges of grazing as a public land management tool. The partnership developed iteratively as the researchers facilitated conversations about the interests and concerns with conservation grazing—the use of rotationally grazed livestock to target conservation goals such habitat recovery or water quality improvement (Pepper, 2016)—among public land management agencies, farmer networks, and grazing specialists. The research team helped select grassland sites for pilot testing and monitor habitat changes with the introduction of managed grazing, while the DNR and grazing specialists developed the grazing contracts, installed infrastructure such as fencing and water, and worked with the research team to develop signage and informational sessions about the grazing project.

The bulk of the findings described in this work came out of a set of group interviews that took place in August 2016 with 4 graziers and 9 land managers representing five pilot grazing project sites. Throughout the interviews, we walked the grazing research sites discussing reflections from the first season of implementing grazing and graduate research monitoring, observations of ecological changes, and goals for future years of grazing.

2.2 Group interviews and facilitated discussion

We conducted semi-structured, open-ended interviews using a conversational guide at each of the five pilot grazing sites. The conversational structure built on the rapport that the research team had developed with land managers and graziers through previous discussions, workshops, and calls (Merriam and Tisdell 2015; Patton 2002). A 60 to 80-minute interview was conducted at each of the five wildlife areas with the available participating graziers and land managers, with a total of five interviews with nine land managers and four graziers. The key interview topics and questions were consistent between interviews but varied according the issues and interests for the group and specific challenges and activities of each pilot grazing site (Patton, 2011). Site visits were planned to create a comfortable environment for participation for both land managers and graziers (Frechtling, 2002). Interview topics were centered around observations on the site and visits incorporated the shared activities of walking the site to checking fences, watering systems, and areas of interest. Interviews were recorded, transcribed, and coded for key themes (Merriam and Tisdell 2015; Mertens and Wilson 2012).

In addition to the five interviews in summer 2016, a facilitated discussion with 30 producers, land managers, and grazing educators in February 2017 helped interpret and contextualize the survey findings. The discussion group was a scheduled roundtable session at the *GrassWorks* annual meeting, a three-day conference for grazing practitioners and educators in Wisconsin Dells, WI. The group was composed of participants in the pilot grazing studies as well as producers and agricultural educators from grazing networks, students, and land managers and administrators from both state and federal agencies. The group was given a brief 10-minute summary of the pilot projects and current research activities, and a set of guiding questions about key tradeoffs and areas of potential conflict in grazing partnerships on public lands, including the profitability of grazing for both producers and public agencies, and public perceptions and communication about grazing on public lands. After 25 minutes of small-group break-out discussions, the whole group reconvened to discuss answers to the guiding questions provided. Student note takers present at the discussion recorded comments on flipcharts for the larger group to see and discuss. These notes generated by the group were then photographed, transcribed, organized by major themes and summarized. The summary was shared participants by email two weeks after the conference session.

Iterative grounded theory (Charmaz 2000) and its application in the work of previous agroecology research groups (Lyon et al. 2011) guided our analysis. Themes were generated from initial codes, and then reviewed and consolidated (Braun and Clarke 2006; Patton 2002). The themes discussed here were included because of their frequent repetition across interviews

(Ryan and Berland 2003). Identifying information has been removed and only aggregate, summary data is presented here for participants' privacy.

3. RESULTS

3.1 "The public" of Wisconsin public grazing management is not a homogenous group

When graziers and land managers brought up "the public" throughout the group interviews, it became clear that they were referring to a number of different stakeholder groups. The group most frequently discussed we classify here as 'neighbors'—individuals described with some investment in the grazing projects because they were confronted with them frequently by proximity. Graziers and land managers referred to this group based on specific interactions from local individuals who stopped by the sites or informally voiced their questions, concerns, or opinions to DNR staff and graziers. This group was mentioned most frequently in anecdotes that farmers and land managers referred to during interviews, using comments from neighbors as an informal measurement of public perception of grazing at each site from their conversations about the project.

In addition to neighbors generally, we refer to 'users' of public land, people who rely on state wildlife areas for recreation or sporting activities. Of the 'users' group, hunters were largest and the most frequently described source of public opinion. Land managers frequently mentioned their need to prioritize hunter opinion and buy-in to grazing management because of hunting groups' financial investment in agency conservation through their purchase of hunting permits and their numbers—hunting was the most frequent use of all grazing sites. At sites in more densely populated counties, bird watchers, hikers, and dog walkers made up the rest of the 'users' group.

Though they have some overlap with the ‘neighbors’ and ‘users’ categories of the public, the ‘agricultural community’ or ‘farmers’ as a general group also came up frequently throughout interviews. Multiple graziers and land managers brought up their partnership as a means of demonstrating potential private land conservation stewardship practices and as a way to build trust and interest between the state agency and farmers. They described a number of specific questions about grazing costs, labor, and cattle health and wellbeing that farmers brought up with them, and frequently cited the need to increase interest among farmers if grazing were to become a more typical conservation management strategy.

In addition to these three types of stakeholders, the interviewees also described “the public” as a source of potential negative perceptions. In doing so, they frequently spoke in more hypothetical terms about groups that had not interacted directly with the graziers and land managers, but nonetheless impacted their decision-making around how and where grazing should be implemented. The first group that had high influence on decision-making we will refer to as “conservation activists.” This was a group that both farmers and land managers considered a source of potential negative press, outcry, and risk to the future of the project. They described the need to be cautious because of how grazing would be perceived by groups with strong associations between grazing and historical environmental degradation and political tension in the west. This group was closely related to a second hypothetical group we will describe as “policy-makers and administrators.” Land managers and graziers felt that policy makers were bound by their office to respond to any negative public opinion from the conservation activists, and would use top-down governance to stop any new grazing or alternative management options, or use bad press as justification to cut further funding and services from the agency.

During the facilitated group discussion, both land managers and graziers brought up the idea of the different “cultures” among public land users and stakeholders, and the need to find common ground and language to discuss the grazing activities and manage perception.

3.2 Ideas about public perception inform grazing implementation

Throughout the interviews, both graziers and land managers described grazing management and research partnerships as a possible mechanism for both groups to positively change public perception. While the tone of all five interviews was generally positive, most of the graziers and land managers expressed feelings related to caution, apprehension, and awareness of the power of public opinion to influence the success of the new grazing initiatives. A number of interview participants used phrases like, “we’re one bad example away from losing this opportunity” or “we don’t communicate or get our messages out as well as we should.” From the land managers’ standpoint, the new Wisconsin grazing initiative was a way to change public opinion of the DNR as ‘rule-enforcers,’ out-of-touch with the needs and interests of nearby communities near the grazing sites. They explained that grazing demonstrated active management on the landscape, as a way to potentially build trust and interest in conservation with the agricultural community who might otherwise view public-access grasslands as ‘wastelands.’ They described the project with statements like, “we’re trying to show them that we can work with the ag community,” or “we want farmers to see the DNR as a resource instead of an obstacle.”

Graziers explained that the partnership could be a way to increase public knowledge of and support for rotational grazing, moving away from the perception of all grazing as poorly managed and a source of environmental degradation from overgrazing. As graziers talked about using the partnership with the DNR to demonstrate conservation grazing on their farms and to their communities, they explained concepts that had described the agency interests "not in money-making, but money-saving" work on public land, working to reduce inputs and partner with farmers. Some graziers even saw the partnership as a way to add value to production, building the new approach to grassland grazing into their marketing of beef and dairy products, as wildlife-friendly "conservation burgers." This theme of positively changing public perception of each respective group was consistent across all interviews and sites.

During the facilitated discussion, multiple individuals mentioned the need to be explicit about the prioritization of public over private good in grazing on public land, so it was clear that grazing was an important service or benefit to the public, but that wildlife and public resources would be the priority.

3.3 Public perception as a mechanism for cultural change in conservation

A theme of public perception as an important part of broader cultural interest in conservation agriculture also was also consistent across interviews. Land managers explained that they viewed the grazing partnerships as a way to increase overall support for and interest in grassland conservation on a statewide scale, with implications for increased funding, environmental education programs, and new restoration projects. While both graziers and land managers mentioned the opportunity of resting private pasture during periods of grazing on public land, some land managers suggested that these partnerships could be a way to actively encourage stewardship with graziers at home. They expressed hope that taking parcels of private land out of grazing rotation could benefit patch-sensitive wildlife, specifically grassland birds that could use the resting or idling of home pasture as surrogate grassland, ultimately building improved wildlife corridors on a regional scale. One suggested that taking private land out of grazing during nesting season could be a requirement of grazing contracts, while another proposed that the public lands could act as "demonstration sites" for grazing stewardship practices, where other farmers or agricultural educators could learn about best practices for wildlife habitat on private pastures.

Graziers talked about opportunities for land access and learning as part of their long-term goals of grazing on public lands, especially for new graziers. Some suggested that public agencies could contract young graziers who do not have sufficient capital to purchase land or buy their own livestock herds, and give them more experience rotationally gazing cattle for conservation. One joked, "What DNR needs to be recruiting are actually more shepherds." They also talked about the need to select cattle breeds for a particular project based on their physical needs, behavior, and temperament to demonstrate the most successful grazing to the public, minimizing potential conflict with other public land users. One land manager expressed interest in mixed-species grazing to incorporate goats and even pigs in areas with high levels of shrub encroachment to increase the physical damage to woody species from hoof traffic and browsing, but noted the additional fencing and logistical challenges of having multiple livestock types in public areas.

Land managers in particular noted the role of university researchers and graduate students in the projects, and seemed to consider a partnership with the university and private graziers as a step toward more innovative practices by the agency in general. Two suggested that the partnership could be a way to shift institutional momentum away from traditional practices and more toward multifunctional land use in conservation. They hoped to build interest in grasslands enough to justify agency positions for grassland ecologists and grazing specialists, to further build the knowledge and application of new management techniques in the upper Midwest.

4. DISCUSSION

Land managers and graziers working together in the Wisconsin pilot grazing projects demonstrated significant concerns about public perception, and the role of different groups of stakeholders within the general public, in the success of conservation agriculture partnerships. The reoccurring idea that public perception, stories, and images could influence spark media coverage in a viral news era, like others who have studied the "CNN effect", indicated land managers and graziers had felt the potential implications of media coverage to stoke public outcry or support for new regulations or policy (Gilboa et al., 2016). Throughout the interviews and their discussion about "the public," land managers and graziers expressed multiple possible outcomes of changes in public perception, and described ways that they were managing their implementation and messaging about the grazing projects according to their perceptions of groups' influence and stake in the project (**Fig. 1**) (Cash et al., 2003; Mitchell et al., 1997; Reed, 2008).

Land managers and graziers most frequently acknowledged the stake of hunters, neighbors, and other farmers in grazing management because of their direct use of or direct learning opportunities from the grazing projects. Both graziers and land managers expressed feelings of accountability to these groups and their perceptions because of their proximity to the grassland pilot sites. They discussed the wildlife habitat types that hunters and bird watchers would be most concerned about, how to modify grazing infrastructure like fencing and water systems so users could still easily access lands for recreation, and which areas of the sites would provide "good examples" of grazing management that other farmers learn from. They also frequently discussed to what extent grazing was cost-effective compared to other management options, and how to balance potential questions about private cattle farmers benefiting from public grassland resources. They brought up ways that these groups might share attributes such as rural backgrounds or politically conservative public opinion (Cramer, 2006; Ranglack et al., 2015), and how to reassure them that grazing was an appropriate land use that still maintained conservation and use goals for each site.

Land managers and graziers had fewer direct interactions with the ‘conservation activists’ and ‘policy-makers’ groups compared to the ‘users’ group, but these seemed to represent a public with high influence over the future of the project. They talked about conservation activists and policy-makers as more likely to have negative perceptions of grazing based on examples from the political and environmental conflicts on the rangelands of the West, and more likely to have power and influence in preventing grazing initiatives from going forward because of urban locations, connections to government, or access to the media. Graziers speculated that these urban-located, conservation-motivated activists might see grazing on public lands as destructive and serving narrow economic interests, while land managers suggested these groups would perceive livestock farming as unfairly subsidized through low grazing fees and government supplied fencing or forage. To appeal to positive public opinion in these groups, land managers and graziers discussed caution in implementation, under-stocking the grasslands to avoid overgrazing, using high quality fencing to prevent potential risks from escaped cattle, and putting up clear signage to indicate where and why grazing was underway.

As Wisconsin continues to explore grazing as an opportunity for public land management, the participants and researchers will likely need to take a more active approach to soliciting and documenting public opinion from a heterogeneous “public,” considering different groups in communication about the partnership. Previous work on the Wisconsin grazing case study (Grace, 2018) has suggested that framing grazing management communication in terms of land stewardship or economic benefits may be most effective at improving public perceptions of farmers or the Department of Natural Resources. Because the Wisconsin case study is a relatively small project, and has not undertaken any active efforts to solicit public opinion or measure response, we cannot currently look to evidence to assess the accuracy of land managers' and graziers' perceptions of the public, or look to how perceptions of grazing are changing in the state. Several studies in the west have shown that public perception of grazing and livestock in state and federal wildlife areas is not as negative as previously believed, using social media and photography as metrics for the cultural and aesthetic value in cattle on the landscape (S. Barry et al., 2007; S. J. Barry, 2014; Clay & Daniel, 2000). Others have shown neutral or limited public perceptions of grazing at all (Ranglack et al., 2015; Wayland et al., 2018), which may mean that the effort to plan around public perception of conservation grazing in Wisconsin will not require as much strategy around communication and optics as land managers and graziers anticipated.

However, policy, conservation-focused or otherwise, can be driven by vivid coverage and the assumption that it will influence audiences, so that any vocal minorities that get news coverage might drive land management decisions based on the "CNN effect" (Jakobsen, 2000). Graziers and land managers within our case study are already being proactive about the images and messages they use related to the project, holding public pasture walks to invite public land users, neighbors, and other farmers to ask questions and voice their ideas about the partnership, and have used a few strategic press releases to get successful grazing stories and images in the media (Wisconsin Department of Natural Resources, 2016). In the time since the interviews discussed in this case study, the DNR has hired a full-time grazing and conservation agriculture specialist and expanded funding for grazing management initiatives in the state. Land managers and researchers may also need to be visible to engage in discussion with potential stakeholders and listen to concerns and ideas, instead of using public engagement and communication as a one-way exchange (Dudo, 2015). Being proactive about framing grazing communication, actively soliciting public opinion through dialogue at informal events and at grazing sites, and building relationships with conservation groups and elected officials may be needed for the grazing partnership to understand and positively reinforce public perception.

5. CONCLUSIONS

Consideration of how farmers, scientists, and state land managers perceive “the public” in public land management is a critical part of successful implementation of new grazing management in the North Central Region. Land managers and farmers engaged in grazing management are aware of the tension of agricultural use of public lands and the challenges of communicating the goals of grazing effectively in a viral news era. The threat of miscommunication and potential policy shifts resulting from media-coverage is arguably linked to scientists’ and land managers’ mistrust of a non-scientific audience, and heavily influences their implementation of new agricultural land management. Using a new grazing initiative and research partnership in Wisconsin as a case study, we have documented farmers’ and land managers’ goal of using grazing on public land to positively change public perception of agencies like the Department of Natural Resources and graziers or grazing practices more generally. We characterized the different categories of stakeholder groups that graziers and land managers describe when they refer to “the public,” and how they describe the impact of public perception in terms of relative levels of influence and stake in the outcomes of grazing management. Understanding how practitioners of new public lands management perceive their stakeholders could help guide the messaging, communication, and outreach efforts of future multifunctional partnerships in conservation agriculture.

6. FIGURES

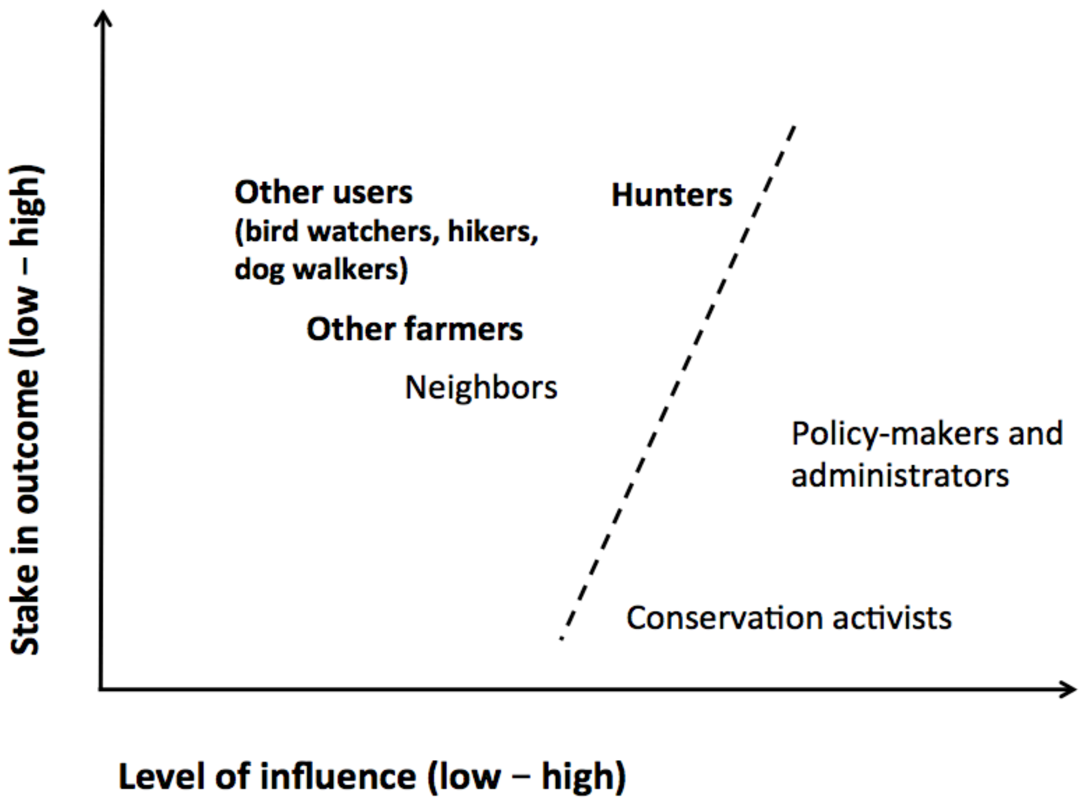

Figure 1: Conceptual model of perceived influence and stake in the outcomes of the grazing projects for different groups of public stakeholders. The dotted line represents a potential urban-rural divide, with high-influence urban-based groups on the right, and high-interest or stake rural groups on the left.

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Chapter 2. Characterizing the suitability of public grasslands for conservation grazing in Wisconsin

ABSTRACT

Partnerships between public land managers and private livestock producers offer the potential to maintain grassland habitat while improving the profitability of grassfed beef and dairy. Though grazing and rangeland management have been extensively studied in western North America, changing climate and increased interest in public-private agricultural partnerships are stimulating new questions about grazing as a land management and conservation tool in the North Central Region of the United States. As adaptive and collaborative management of grassland resources expands on state and federal lands, we argue that there is a critical gap in knowledge about how to assess the suitability of semi-natural grasslands for public-private grazing contracts. Grazing plans and monitoring of such partnerships should be tailored to grassland conservation goals as well as animal nutrition, behavior, and performance for successful, mutually beneficial partnerships between livestock producers and public land managers. This paper illustrates the importance and challenges of grassland management in the North Central Region using a subset of state grassland areas selected for a rotational grazing management initiative in Wisconsin. We identify key vegetation and management considerations for low diversity, low input grasslands, and describe some key considerations for effective, collaborative partnerships in livestock production and conservation.

1. INTRODUCTION

1.1 Managing grassland resources in the North Central Region

Grasslands provide essential ecosystem services across the United States, including wildlife habitat, soil and water protection, and biofuel and livestock production (M. A Sanderson et al., 2009; Wayland et al., 2018; Wilmer et al., 2018). We define grasslands by their cover—lands dominated by grasses (family Poaceae)—and they include prairies, rangeland, savannas, steppes, and pastures (Bengtsson et al., 2019; Ohwaki, 2018; Scurlock & Hall, 1998; Werling et al., 2014) Natural and semi-natural grasslands, where vegetation is historically maintained by climatic and disturbance factors, make up the majority of grassland cover in the Western United States, while pastures, often managed with inputs such as fertilizers and herbicides as well as grazing, make up the majority of grassland acreage east of the W 98˚meridian (M. A Sanderson et al., 2009).

The North Central U.S. typically has warm summers (>27˚C) and cold winters (air and soil temperatures at their coldest monthly average near -3˚C) (Schaeffer et al., 2009) and is comprised of North Dakota, South Dakota, Nebraska, Kansas, Missouri, Iowa, Minnesota, Wisconsin, Illinois, Indiana, Michigan, and Ohio. This region is notable for sustaining a mix of grasslands that include remnant prairie and sown pasture. The prairies are comprised of a mix of both cool-season (C_3) and warm-season (C_4) grasses, broadleaf species including legumes (family Fabaceae) and other forbs, and woody and non-native shrub species (Sanderson et al., 2009), while pastures are predominantly sown with C3 grasses and clovers. Warm-season grasses thrive in warm, dry climates (where optimum growth temperatures are ~21 to 32˚C) (Undersander et al., 2014) and are differentiated from cool-season grasses by their photosynthetic pathway, which uses a combination of anatomical and physiological adaptations to concentrate carbon dioxide within the leaf. This adaptation reduces competition between CO_2 and O_2 for the enzyme Rubisco, which provides a competitive advantage to plants using this pathway in low-resource, high temperature conditions (Sanderson et al., 2009). Conversely, when soil resources like water and nutrients are not limiting and conditions are relatively cool, plants using C_3 photosynthesis are competitively superior.

Over the last half century, grasslands have shifted from 60% of land cover in the 48 contiguous states to less than 44% of land cover (844 million acres or 342 million ha), and 13 endangered grassland ecosystem types have lost 98% of their original distribution (Herrero et al., 2015; Wang et al., 2016). As grasslands are fragmented and their diversity is diminished by urban development, row-crop agriculture, and invasive plant species, the need to collaboratively manage grasslands and preserve the connectivity of the unique habitat they offer is becoming increasingly urgent. Today's grasslands and pastures in the North Central Region require regular grazing or other management such as mowing or prescribed burning to maintain an open, light-rich environment and prevent the encroachment of woody shrubs and trees (Hendrickson et al., 2019).

While there has been extensive research conducted on grassland plant communities and their responses to grazing, the results are highly variable. Approaches to grazing range widely across different regions and conditions, and the degree of "success" in grazing as a management tool is highly dependent on soil type and structure, seasonal temperature and precipitation, land management history, and the timing and intensity of grazing (Briske et al., 2008; Sanderson et al., 2004; Sollenberger et al., 2019; Woodis & Jackson, 2009; Zegler et al., 2018) Practitioners of management intensive grazing—a system of livestock grazing in which pastures are subdivided into paddocks and animals are rotated between them on a daily or weekly basis—advocate that restricting animal access to one area at a time improves vegetation productivity, habitat structure, and forage quality of their pastures, but research results are inconsistent (Lyon et al., 2011; Teague et al., 2011). Management intensive grazing has been shown to increase plant community diversity by promoting persistence of warm season grasses in cool season grass-dominated pastures (Alber et al., 2014; Chamberlain et al., 2012) and reduce large woody or invasive shrubs that shade and outcompete grassland forb species in the North Central Region (Bailey et al., 2016; Naeth et al., 1991). Without management intensive approaches, however, some studies have found detrimental effects from grazing, including increased soil compaction, accelerated shrub encroachment (Asner et al., 2004; Briggs et al., 2002; Pinchak et al., 2010), reduced community diversity from invasive plant species, and in some cases, degradation from overgrazing (Lyseng et al., 2018). Overgrazing occurs when plants are subjected to multiple defoliations without sufficient regrowth and recovery time, which leads to a decline in the plant's productivity, root biomass and vigor (Asner et al., 2004; Paine et al., 1999; Roche et al., 2015). Grasslands are both spatially and temporally dynamic, and wildlife are sensitive to the precise habitat conditions created through burning or grazing in addition to the composition and density of vegetation (Walk & Warner, 2000), which means monitoring and planning are central to effective conservation grazing.

1.2 Evaluating grasslands for grazing management

Despite the potential of grazing as a management tool to improve plant community diversity and structure, few guidelines exist to assess the suitability of grasslands for conservation grazing in the North Central Region. Most literature on addressing the evaluation and selection of areas for grazing management focuses on the expansive, arid rangelands of the western United States in guidebooks from the Bureau of Land Management, or in international development manuals from agencies like the Food and Agriculture Organization (United Nations, 1988; Oberlie & Bishop, 2009). While there are some resources specific to the small parcels of semi-natural humid grasslands of the North Central Region, many are directed either at private livestock producers or at public land managers and wildlife biologists, with little direction for developing public-private relationships that address both conservation and agricultural production (Missouri Forage and Grassland Council, 2016). Historically, the public rangelands of the west were assessed with the primary goal of promoting livestock production, typically specifying animal type, number, and the timing of their distribution on the landscape (Briske et al., 2011). Considerations for grazing include the both composition and condition of vegetation, allowing a grazier to predict the forage quality and mix of plant species available throughout the growing season.

Water sources and their locations factor heavily into grazing planning—cattle need anywhere between 38 and 115 L d^{-1} of water a day, depending on their age, growth rate, and type. Cattle tend to congregate in flat areas near water, such as stream bottoms, riparian zones and avoid grazing on steeper slopes, which means that appropriate fencing to divide the pasture into paddocks and an electricity source for temporary fencing are all important in enabling effective rotation and preventing excessive trampling (Midwest Perennial Forage and Grazing Working Group, 2013). Animal behavior, nutrition, and the infrastructure needed to manage them are all key for effective grazing management with cattle.

In addition to considerations for animal health and welfare, wildlife biologists and land managers need to identify management goals for habitat and land use when considering grazing as a conservation tool. Characteristics like vegetation composition and structure and desired outcomes for native plants, fish, and terrestrial wildlife such as birds and invertebrates all factor into assessment of grasslands for grazing (Bureau of Land Management, 2005; Oberlie & Bishop, 2009). Other considerations include soil type, terrain, and watershed characteristics that could heighten risk of erosion or nutrient runoff, or the presence of undesirable vegetation such as invasive weeds or resources that require special management or protection (Greiner et al., 2009).

By definition, management intensive grazing does not rely on recipes or formulas for application of practices (Lyon et al., 2010). Managing for conservation outcomes adds additional complexity and we argue that more research is needed to address holistic evaluation of grasslands for conservation grazing in the North Central Region. Recent studies have explored grassland plant diversity as a source of ecosystem stability and resilience in a changing climate, and have reinforced the importance of that monitoring changes in grassland plant community composition to assess wildlife habitat, soil protection, and water quality improvement in addition to livestock production (D'Ottavio et al., 2018; Tilman et al., 2012; Vogel et al., 2012). We examine seven sites selected for a new conservation grazing management initiative in Wisconsin, identify the biophysical and management characteristics used to determine where grazing was implemented, and propose a set of lessons-learned and more holistic criteria for evaluating the suitability of grazing on public grasslands managed for wildlife.

2. SELECTING PUBLIC GRASSLANDS FOR GRAZING IN WISCONSIN

The Wisconsin Department of Natural Resources (WDNR) coordinates management of 2.4 million hectares of public-access lands, working with federal, state, and local government agencies to protect wildlife habitat and promote outdoor recreation and education (Wisconsin

Department of Natural Resources, 2018). To address increasing financial and political constraints, the agency began a new effort to use pilot grazing as a habitat management tool in Wisconsin in 2015, the WDNR entered into a collaboration with our interdisciplinary research group from the University of Wisconsin-Madison, cattle producers, nonprofits, and other state agencies. In Wisconsin, management intensive grazing has shown potential to increase grassland carbon storage, promote plant community diversity, and support wildlife habitat (Alber et al., 2014; Chamberlain et al., 2012; Harrington & Kathol, 2009; Oates & Jackson, 2015; Oates et al., 2011) but research specifically on public grasslands to assess grazing as a management tool is lacking. The WDNR hired a full-time conservation agriculture specialist after two years of pilot grazing projects to support grazing development and allotted over $250,000 to fund grazing planning and infrastructure, including fencing, water, and signage. The Wallace Center's *Pasture Project* and *Wisconsin Grassfed Beef Coop* contributed grazing expertise and planning to this effort and coordinated pasture walks and educational events about public lands grazing. Graduate students and researchers monitored the implementation of grazing at several sites to understand the environmental and wildlife responses to grazing. Beyond a general farm agreement policy created for arable public lands (Wisconsin Department of Natural Resources, 2012), no clear guidelines exist to help land managers and graziers document their goals, concerns, and methods to assess successful grazing for habitat management at each new site.

2.1 Study site selection

The seven grassland sites described here implemented rotational grazing management between 2015 and 2019. Sites were selected for baseline characterization, research, and monitoring because of their geographic distribution across Wisconsin, their range of vegetation and habitat characteristics, and in cooperation with the land managers supervising the implementation of grazing management (**Table 1**). All sites selected were identified by DNR land managers because of their relatively low use for public recreation—the most common visitors to the sites were hunters, bird watchers, and dog walkers—and their challenges with implementation of other kinds of grassland management. The habitat management goals were focused on increasing utilization by grassland bird species, including passerines or grassland songbirds such as bobolinks (*Dolichonyx oryzivorus*), savannah sparrows (*Passerculus sandwichensis*), dickcissels (*Spiza americana*), and grasshopper sparrows (*Ammodramus savannarum*) and upland game birds such as pheasant and grouse species, and at Buena Vista Wildlife area, greater prairie-chickens (*Tympanuchus cupido*).

The grassland sites had relatively low plant community diversity for grasslands in the North Central region and were dominated by non-native cool-season grasses including Kentucky bluegrass (*Poa pratensis*), smooth brome grass (*Bromus inermus*), reed canary grass (*Phalaris arundinacea*), and quack grass (*Elytrigia repens*). Common broadleaf species included Canada goldenrod (*Solidago canadensis*), stinging nettle (*Urtica dioica*), yarrow (*Achillea millefolium*), and yellow toadflax (*Linaria vulgaris*), and common legumes included red clover (Trifolium pratense), white clover (Trifolium repens), and yellow sweet clover (*Trifolium melilotus-officinalis*). The patches of woody vegetation types varied between sites, but common species observed included prickly ash (*Zanthoxylum americanum*), aspen (*Populus tremuloides*), willow (*Salix* spp.), *Spiraea alba*, bush honeysuckle (*Lonicera x bella*), and dogwood (*Cornus* spp.).

2.2 Plant community composition and quality measurements

The sampling design at three sites (Buena Vista, Western Prairie, and Hook Lake) was developed to complement other research on managed grazing in combination with pre-grazing mowing or foliar herbicide application (Grace, 2018), and in conjunction with baseline sampling for hyperspectral data collection at two sites (Kickapoo River and Peter Helland) (Mittra et al., forthcoming manuscript), and as part of a planned Before-After-Control-Impact (BACI) design at the remaining two sites (Glacial Habitat and Leola Marsh). We worked within 20 x 20-m plots established in representative areas of each site, selected after walking the site with land managers to identify area of management interest that would not interfere with grazing rotation or other activities (Elzinga et al., 1998). To estimate species cover within each plot, we used point-intercept transects where measurements were taken at points along a line or tape, at 25 (2016 season) or 50 points (2017 and 2018 seasons) per plot (Cook and Stubbendieck 1986). Vegetation was measured where it intercepted with a stake or point along the transect, identified to the species or genus level. The point-intercept transect is most easily used in sparse vegetation in which the limits of plants are distinct (Brown 1954), but in areas with dense vegetation we counted every species with leaf parts touching the point (Heady et al., 1959).

We harvested plant biomass from 4 randomly placed 0.5-m^2 quadrats in each plot at a 10-cm residual height and then dried, ground, and analyzed it with Near Infrared Spectroscopy to calculate forage quality attributes such as lignin, nitrogen, mineral content, and total digestible nutrients (Moore et al., 2010; Paine et al., 1999) to match the work completed by other on-site research (discussed more extensively in Grace, 2018). This baseline plant community data was collected between 15 May and 15 July, depending on land manager constraints and plans to initiate grazing.

2.3 Documentation of management goals

In order to document management goals, we used a conversational interview guide during site visits to potential grazing locations, discussing management goals, site history, and wildlife of interest (M.Q. Patton, 2003; Michael Quinn Patton, 2002). Interviews with land managers lasted 45-75 minutes and coincided with walking the grassland areas before grazing to identify areas of interest, challenges and strengths of current management practices, and opportunities or concerns with implementing grazing. All land managers had previously expressed interest in grazing management and monitoring, and most knew a cattle producer in the area who had expressed interest or who they felt would be a good fit for a grazing agreement. Interview data is reported only in aggregate and identifying information has been removed. We took detailed notes after these site visits and summarized them for key themes (Braun & Clarke, 2006; Reed, 2008) and used document analysis of site master plans and public-facing information about state wildlife areas (websites and popular press articles) to contextualize themes (Bowen, 2009).

3. RESULTS

3.1 Plant community composition and quality

Plant community surveys confirmed that the sites had relatively low diversity and were dominated by cool-season grasses. Nearly 80% of living vegetation cover across all sites was composed of 8 plant species, and the remaining 20% was made up of 52 species (**Table 2**). The most diverse sites were Hook Lake wildlife area and Glacial Habitat Restoration Area at 26 and 24 species observed, and the least diverse was Peter Helland at 10 species (**Table 3**). Kickapoo River and Glacial Habitat had the highest proportion of native warm-season grasses, predominantly big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium)*. Reed canary grass had the majority of cool-season grass cover at Peter Helland and Kickapoo River, and by a small margin at Glacial Habitat Restoration Area. Smooth brome grass dominated at Buena Vista and Leola Marsh, and Kentucky bluegrass formed a pervasive understory of vegetation cover at Hook Lake and Western Prairie (**Table 4**). At Kickapoo River and Glacial Habitat, sampling was split between riparian areas of the sites that were dominated by reed canary grass (*Phalaris arundinacea*), and upland areas with sandier soils with patches of more native species (**Fig. 1**). Rank abundance showed a skewed distribution of species at all sites, with many 'rarer' species observed with low frequency and a few common grass species observed with high frequency (**Fig. 2**) (Eriksson & Jakobsson, 1998; Polasky et al., 2011).

Mean forage quality attributes across sites were low compared to managed pastures (**Table 5**) and were likely influenced by seasonality as well as plant community composition (Moore et al., 2010; M. A Sanderson et al., 2009; Matt A. Sanderson, 2014). Sites with higher proportions of weedy broadleaf species such as goldenrod may have had reduced quality for livestock, and sites with higher percent cover of warm season grasses—which were also sampled later into the growing season during the "summer slump" of vegetation growth for cool season grasses—had higher estimated fiber and lower levels of protein. Peter Helland, which was sampled earliest in the year and was nearly a monoculture of reed canary grass, had the highest estimated digestibility and protein content, while Glacial Habitat Restoration Area, sampled latest in the year, had some of the lowest estimated quality, likely driven by the high levels of undigestible fiber from woody and broadleaf species despite the cool season grasses present at the site.

3.2 Management goals

All sites were selected for grazing because of a combination of challenges in current management practices and opportunities to improve habitat for grassland songbirds, game birds such as pheasants and waterfowl, and invertebrates or pollinator species. Several land managers described specific impediments to controlled burning or mowing, such as lack of personnel to operate machinery for brush clearing or lack of training to implement prescribed burning. Others noted that they had proposed the grassland sites for grazing because of their high potential for improvement, citing a need to reduce woody shrub encroachment, increase structural or compositional diversity in grassland vegetation, and a lack of success with other management tools because of wet areas or competing land uses.

In addition to the potential biophysical changes they hoped to see under grazing management, land managers discussed the advantages and disadvantages each site had to offer to livestock producers, including distance from the producer's farm for rotating and checking on animals, the length and flexibility of grazing contracts (which ranged from 1- to 10- year contracts, with to 3 years being the most typical options), and options for distributing labor, liability, and maintenance of infrastructure like fencing and water systems. Several noted the need to match the cattle producer and herd to the project, working with producers with specific animal breeds and temperaments to match to quality of forage, available acreage, and typical public land uses (**Fig. 3**). The combination of biophysical grassland attributes, wildlife management history and constraints, and their process-related concerns about coordination with a producer all contributed to their selection of sites for grazing management and were documented using a prototype worksheet for describing site characteristics (**Fig. 4**).

4. DISCUSSION

While the seven grassland sites selected for grazing varied in their plant community composition and forage quality, some similarities in their management goals and challenges may provide insight into the value of relatively low-diversity and low-input grasslands as a habitat and agricultural resource. The multifunctionality of these grasslands as a resource for preserving habitat and raising livestock offers a unique opportunity for conservation and agricultural production, particularly when considered at a landscape scale. Grassland management literature for the North Central Region frequently recommends a “coarse-grained mosaic” to accommodate diverse habitat needs of multiple species of interest (Walk & Warner, 2000). Grassland birds seem to select territory using multiple scales of information, so that the vegetation composition of the surrounding landscape may be just as important for utilization and nesting (Byers et al., 2017; Ribic & Sample, 2001). While burning can effectively control woody shrubs and increase native diversity, evidence has shown it decrease presence of some passerine or songbird species like the Henslow’s sparrow (Asper, 2017; Walk & Warner, 2000) that prefer a deeper litter layer. Generalist species like savannah sparrows will often seek out habitat of medium or short vegetation, while grasshopper sparrows typically prefer relatively short and sparse vegetation and seem to respond more to vegetation density and height than composition (R.B. Renfrew & Ribic, 2016; Rosalind B. Renfrew & Ribic, 2008). Even if grazing alone cannot consistently reduce, for example, homogenous stands of reed canary grass, to significantly increase plant community diversity, increasing heterogeneity of vegetation height and density may have some benefits.

Grazing agreements offer additional potential for landscape-level management because of their public-private structure. Several land managers discussed the potential of grazing contracts that would recommend a producer rest or renovate their home pasture with additional native vegetation while they graze public land, creating a refuge within the broader landscape for grassland bird species (Temple et al., 1999). Land managers are always balancing tradeoffs between multiple habitat types on the landscape, so areas where livestock can add structural diversity without reducing habitat composition may be more suitable for conservation grazing.

Clearly addressing cattle and producer needs alongside conservation management is critical to reduce risk and improve communication in assessing suitability for grazing management. Briske et al. (2011) note that conservation planning should use a more adaptive, holistic approach to promote environmental quality of grasslands for both habitat and cattle health and nutrition compared to single-resource management. Considerations for matching livestock class to grazing management include the availability of shade and water, animal social behavior and training with electric fencing, vulnerability to drought and soil erosion, and caution with animals that could be territorial with public hikers or bird watchers. Forage inventory is important for effective planning, and while our results did not show very high forage quality across public lands, the proportion of cool season grasses may indicate potential for higher quality and palatability—animal preference—earlier in season grazing season (Oates et al., 2011). This forage availability provides a producer with an opportunity to stockpile forage at home until the summer growth slump. In some ways, relatively low-diversity, low-quality grasslands provide an easier model to balance conservation needs and livestock health. The abundance of non-native cool season grasses may lower the likelihood that any rare or listed plant species are present on a given site. Cattle may be more likely to improve habitat by increasing structural heterogeneity, and emphasis on rotational grazing practices may help increase diversity of forbs and legumes additional light to reach slow-growing or shorter species, so that livestock have a role in increasing both composition and quality. In short, low-diversity and relatively low forage quality grasslands could be a low-risk option of both cattle producers and land managers.

Managers should assess other considerations for cattle health and wellbeing, however, such as the adequacy of water sources to last through hot weather, water hauling distances, and whether terrain allows cattle to easily access the water from any spot while minimizing excessive hoof traffic (Midwest Perennial Forage and Grazing Working Group, 2013). All of our sites were relatively flat in topography, but barriers to cattle movement such as steep terrain and dense stands of woody vegetation are also important considerations in evaluating suitability (Bartlett et al., 2007; Oberlie & Bishop, 2009). On wetter wildlife areas or grasslands with more finely textured soils, the public agencies may need to be cautious with stocking density, potentially grazing smaller breeds of cattle to minimize trampling and compaction of soils (Mapfumo et al., 1999). Highland cattle or meat goats could be a management option for grazing areas with high shrub cover because of their tolerance for woody species in their diet and smaller size (Newman et al., 2006) where appropriate.

Though there are a number of guidelines and tools among conservation practitioners and producers that assist with evaluation of grasslands for different management approaches, more work is needed to understand the key factors that contribute to success in grazing for habitat management in the North Central Region. Our study provides a brief look into the types of grasslands and management priorities under consideration by the state of Wisconsin, but a more detailed evaluation of soil attributes, seasonal change in plant community composition and structure, and surveys of wildlife species of conservation interest would enhance our understanding of grazing as a potential conservation tool.

5. CONCLUSIONS

Selecting public grassland habitat for rotational grazing in the North Central Region should take a systematic approach that accounts for a range of habitat objectives that require careful planning and observation to account for changes in plant community and wildlife needs.

Public lands support a variety of recreational and educational activities such as hiking, hunting, and bird watching, and need to maintain a heterogeneous habitat to support a variety of wildlife including grassland birds, small mammals, and invertebrates in the North Central Region. Land managers and producers bring different goals and experiences to grazing management; thus, developing strategies to assess grassland sites that serve mutual needs record keeping, cost calculations, and vegetation growth projections for those grassland sites could help establish common terminology and identify potential costs and intended activities in a way that improves transparency and trust. Habitat goals need to be incorporated alongside public land uses and safety concerns for successful implementation of grazing as a management tool. Though wildlife management and livestock production have different metrics of success, studies like ours indicate that assessing the habitat and animal health considerations of different grassland sites may increase understanding of the different goals, risks, and considerations needed to establish more effective collaborative management of grassland resources in a changing global climate.

6. TABLES AND FIGURES

Table 1. Locations of baseline data collection over a three-year period at seven state wildlife area managed by the Wisconsin Department of Natural Resources before the start of the first grazing season. Soil type comes from the Natural Resources Conservation Service's Web Soil Survey. The unbalanced sampling design was dependent on the needs or interests at a particular site, ranging from 8 to 25 plots.

	Sampling time		Site characteristics				
Site name	Month	Year	Region	Latitude	Longitude	Soil Type	Plots
Peter Helland	May	2016	Cent.	43.52721	-89.18289	Adrian muck	25
Western Prairie	June	2017	NW	45.20598	-92.41965	Santiago silt loam	12
Hook Lake	June	2016	S	42.93905	-89.31844	Dodge and Kidder	8
Buena Vista	June	2016	Cent.	44.36485	-89.58359	Newson mucky loamy sand	8
Kickapoo River	July	2016	SW	43.29387	-90.83322	Ettrick silt loam; Windward loamy sand	8
Glacial Habitat	July	2018	NE	43.66813	-88.6249	Pella silty clay loam	12
Leola Marsh	July	2018	Cent.	44.20995	-89.6668	Meehan loamy sand; Adrian muck	12
Totals: 7 sites, 85 plots							

Table 2. Most commonly observed 20 species across all 7 sites (from 6798 observations).

Species	Common name	Individuals observed	Percent of total observations
Poa pratensis	Kentucky bluegrass	1343	19.8%
Phalaris arundinacea	Reed canary grass	1125	16.5%
Bromus inermis	Smooth bromegrass	1016	14.9%
Solidago canadensis	Canada goldenrod	746	11.0%
Urtica dioica	Stinging nettle	364	5.4%
Andropogon gerardi	Big bluestem	318	4.7%
Schizachyrium scoparium	Little bluestem	272	4.0%
Elymus repens	Quack grass	202	3.0%
Salix spp.	Willow	102	1.5%
Trifolium repens	White clover	78	1.1%
Melilotus officinalis	Sweet clover	74	1.1%
Trifolium pratense	Red Clover	72	1.1%
Sorghastrum nutans	Indiangrass	66	1.0%
Solidago rigida	Stiff goldenrod	66	1.0%
Linaria vulgaris	Toadflax	64	0.9%
Achillea millefolium	Yarrow	58	0.9%
Elaeagnus umbellata	Autumn Olive	50	0.7%
Cornus spp.	Dogwood	46	0.7%
Potentilla recta	Sulfur cinquefoil	44	0.6%
Daucus carota	Wild carrot	44	0.6%

Table 3. Total species observed at each site, divided by cover type. Hook Lake was the most diverse plant community sampled, followed by Glacial Habitat and Western Prairie. A total of 60 plant species were observed across all 7 grasslands. Spp. refers to plant species, CS grasses refers to cool season grasses and WS grasses refers to warm season grasses.

Site name	Month	Spp. observed	CS grasses	WS grasses	Broadleafs	Legumes	Woody
Peter Helland	May	11	3	1	6	0	1
Western Prairie	June	20	5	0	10	0	5
Hook Lake	June	26	4	2	14	4	3
Buena Vista	June	16	4	1	8	1	2
Kickapoo River	July	20	4	2	13	1	0
Glacial Habitat	July	24	6	3	6	5	4
Leola Marsh	July	14	3	0	8	0	3
Total species observed		**60**	**7**	**4**	**30**	**7**	**12**

Table 4. Ranking of 10 most frequently observed species at each site, listed by common names and ranked in order from most frequent observation (1) to least frequent (10) at each site.

Spp. rank	**Peter Helland**	**Western Prairie**	**Buena Vista**	**Hook Lake**	**Kickapoo River**	**Glacial Habitat**	**Leola Marsh**
1	Reed Canary grass	Kentucky Bluegrass	Smooth Brome	Kentucky Bluegrass	Big Bluestem	Little bluestem	Smooth Brome
2	Stinging Nettle	Canada Goldenrod	Kentucky Bluegrass	Canada Goldenrod	Reed Canary grass	Reed Canary grass	Stinging Nettle
3	Canada Goldenrod	Smooth Brome	Canada Goldenrod	White clover	Canada Goldenrod	Kentucky Bluegrass	Quack grass
4	Elderberry	Quack grass	Warm Season grass	Stiff goldenrod	Kentucky Bluegrass	Canada Goldenrod	Autumn Olive
5	Catchweed bedstraw	Prickly Ash	Toadflax	Yarrow	Showy tick trefoil	Willow	Giant ragweed
6	Wild Parsnip	Virginia Creeper	Trefoil	Red Clover	Bergamot	Sweet clover	Bindweed
7	Smooth Brome	Dogwood	Sulfur cinquefoil	Wild carrot	Smooth Brome	Cup plant	Canada Goldenrod
8	Yellow Nutsedge	Canada thistle	Spirea	Yellow Hawkweed	Sulfur cinquefoil	Black-eyed Susan	Toadflax
9	Canada thistle	Sulfur cinquefoil	Common milkweed	Bush honeysuckle	Catchweed bedstraw	Red Clover	Common milkweed
10	Cup plant	Blackberry	Quack grass	Smooth Brome	Purple Loosetrife	Dogwood	Reed canary grass

Table 5. Mean forage quality parameters by site and month sampled, estimated through Near Infrared Spectroscopy (NIRS). Mean percentage of crude protein, acid detergent fiber (ADF), neutral detergent fiber (aNDF, used if amylase is used during extraction), and in vitro total dry matter digestibility (IVTDMD30) indicates the portion of feed that will be digested by animals, calibrated by incubating ground forage in rumen fluid for 30 hours (R. D. Horrocks & Vallentine, 1999; Marten et al., 1989).

Site name	Month	Crude Protein	ADF	aNDF	IVTDMD30
Peter Helland	May	21.04	31.28	49.01	79.33
Hook Lake	June	14.06	38.03	46.72	63.74
Johnson	June	11.54	34.95	57.40	57.34
Buena Vista	June	11.23	40.83	59.24	65.50
Kickapoo River	July	7.68	49.82	67.65	56.86
Glacial Habitat	July	5.68	42.87	62.85	46.01
Leola Marsh	July	6.64	40.71	59.10	46.51
Totals: 7 sites, 85 plots					

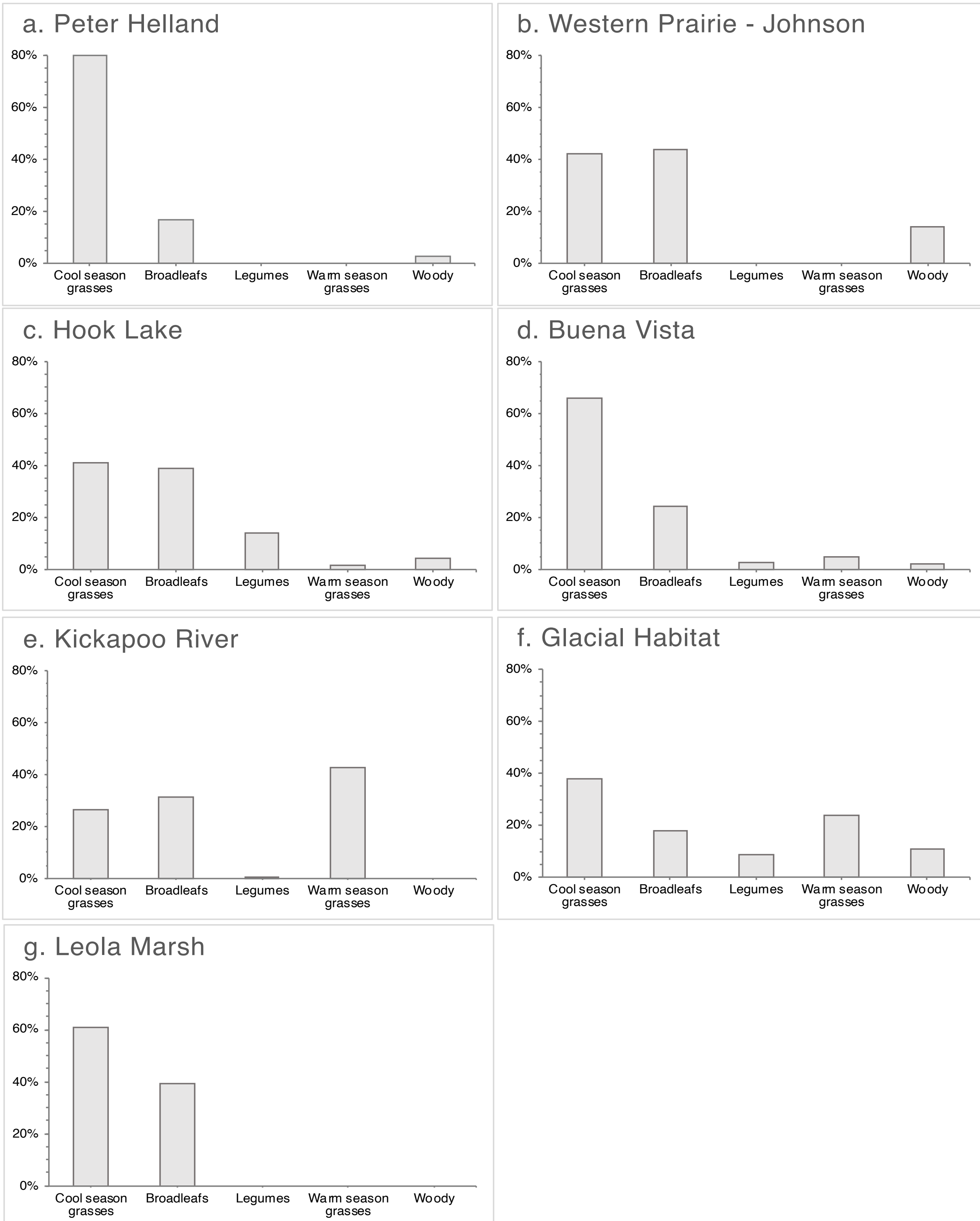

Figure 1. Vegetation cover for each site. Cover was normalized by the total frequency of each species observed divide by the number of observations at each site and grouped by plant functional groups of interest for wildlife and livestock management (Sanderson et al., 2009).

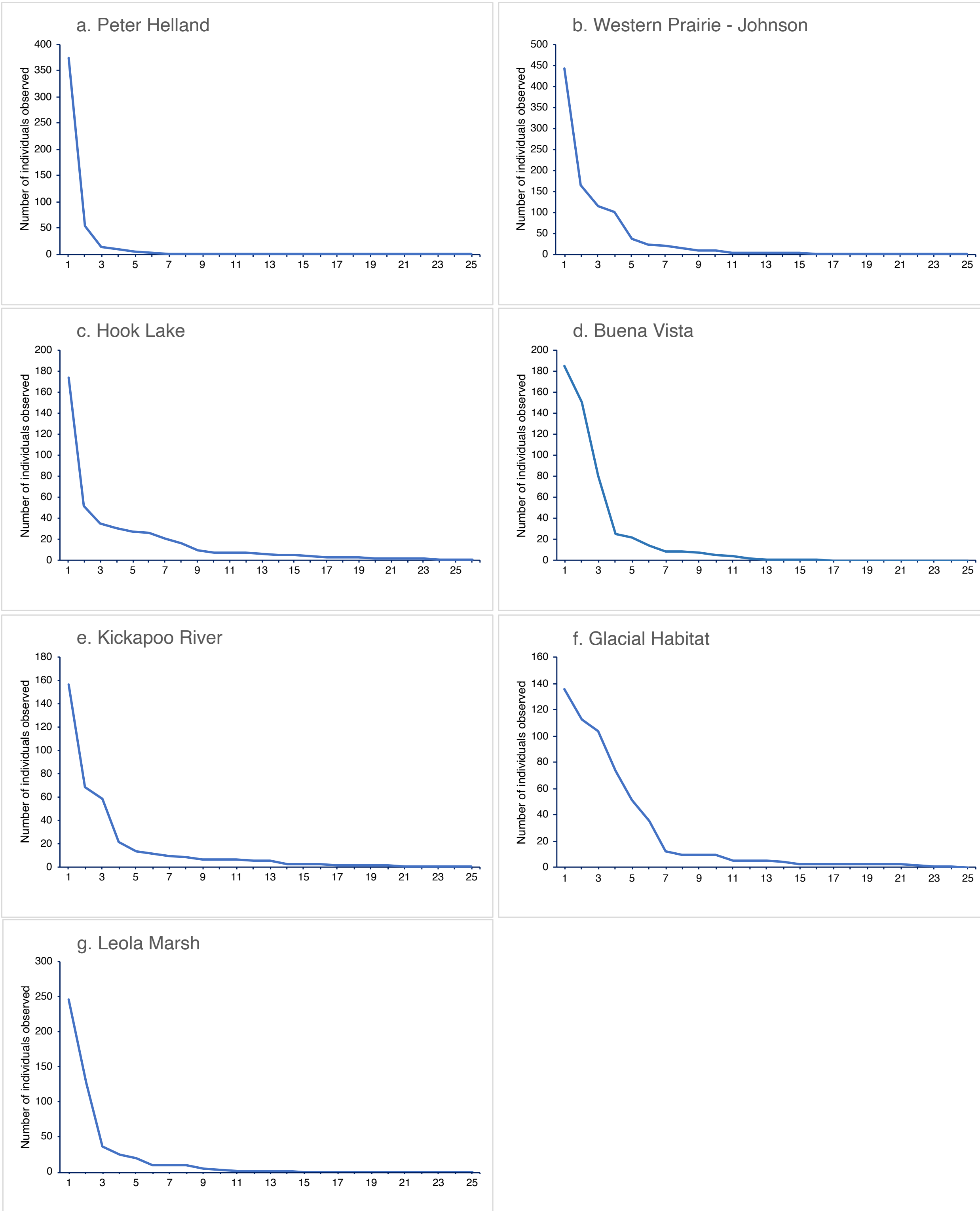

Figure 2. Species rank abundance curves for each site. Number of species observed at each ranged from a total of 10 (Peter Helland) to 26 (Hook Lake). The y-axes are not consistent between sites because more than one species was typically observed at a given point along the transect, which means that percent cover was greater than 100%.

Figure 3: Highland steers grazing at Hook Lake Wildlife Area (a), Holstein heifers grazing at the Johnson property in Western Prairie Habitat Restoration Area (b) and Red Angus cow-calf pairs grazing at Buena Vista Wildlife Area (c) in June 2019.

Site Name:	**Parcel name:**	
Date visited:	***Location:***	
Manager(s):	**Region:** **Counties:** **Township:** **Road access:**	
	Site Characteristics: **Acreage:** **Terrain:**	
	Boundaries and Landmarks:	***North*** ***East*** ***South*** ***West***
	Fencing: **Water:** **Shade:** **Soil Notes:**	
	Management: **History:** **Goals:**	
	Public uses:	**Useage [low-high]** **Types**
	Notable Wildlife:	**Birds** **Mammals** **Other**
	Notable Vegetation:	**Woody** **Grass** **Broadleaf**
	Estimate of % brush cover:	
Additional notes:		

Figure 4. Grassland site description tool. This worksheet was used for notetaking during conversational interviews with land managers while scoping potential grazing sites in Wisconsin in 2015. Tools like this one could be expanded to more effectively and holistically evaluate sites and their suitability for both wildlife conservation and livestock production goals.

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Chapter 3. Applications for trait maps and imagery spectroscopy in grassland management and conservation planning

ABSTRACT

Grassland monitoring provides critical information for land managers to protect wildlife and inform land-use policies, but using traditional field methods for documenting and quantifying change in vegetation across diverse, variable grassland habitat is challenging under time and budget constraints. Advances in hyperspectral remote sensing technology are providing increasingly accurate ways to assess plant community composition and attributes across different landscapes, but challenges in data processing and image acquisition have limited the use of technology in grassland management. To address this gap, we explored the potential applications of hyperspectral imagery in grassland management and decision-making using a case study of grazed public grassland areas in Wisconsin. We used field measurements and a collection of low altitude airborne hyperspectral images from NASA's Airborne Visible/Infrared Imaging Spectometer (AVIRIS-NG) as a basis to discuss the opportunities and barriers in using remote sensing for grassland management and conservation grazing. We demonstrate ways that classified maps of vegetation cover and tissue chemistry can enhance conservation planning and monitoring, and describe startegies to incorporate remote sensing imagery into decision-making for more successful partnerships in conservation agriculture.

1. INTRODUCTION

1.1 *Challenges for monitoring and managing grassland habitat*

Protecting grassland ecosystems is critical for human welfare in a changing global climate (Lal, 2002; Rasel et al., 2017; Reeves et al., 2016; David Tilman & Downing, 1994). With their diverse, perennial cover and deep, carbon-storing root systems, understanding changes in grassland plant community can provide insights into primary productivity, wildlife habitat, and other ecosystem services like soil protection, water quality enhancement, agricultural production, and climate regulation (D'Ottavio et al., 2018; Hoover et al., 2014; D. Tilman et al., 2012; Vogel et al., 2012). Grassland field monitoring with transect sampling techniques has been used by state and federal agencies in North America since the late 1800s (Elzinga et al., 1998; Parker, 1954; Woods & Ruyle, 2015). Land managers use common measurable vegetation attributes to describe the variability and diversity of grassland plant communities, including the density of individual plants, leaf cover, frequency of occurrence, and vegetation production or yield (Canfield, 1941; Elzinga et al., 1998). These longstanding approaches to field sampling do not require expensive equipment beyond tape measures and a few guidebooks; the real cost of range monitoring through transect sampling and visual estimates is time. In addition to significant labor requirements, field monitoring is inherently biased. Land managers and cattle ranchers frequently rely on 'representative areas' of the overall landscape when exhaustive sampling is not feasible, which means the true heterogeneity of grassland plant community is rarely captured (Elzinga et al., 1998; Mansour et al., 2012; Tromp & Epema, 1998). As financial and political constraints limit the ability of public agencies to invest in monitoring and managing grassland habitat, it is becoming increasingly urgent to find new ways to assess change the unique variability of grasslands (Nagendra et al., 2013).

Advances in remotely sensed imagery and spectroscopy offer exciting new ways to supplement time-intensive field sampling, using patterns of reflectance and absorption of electromagnetic radiation to assess changes in land cover and vegetation. Researchers have successfully used imagery from satellite and airborne sensors to estimate primary productivity (Dyer et al., 1991; Seaquist et al., 2003), plant tissue chemistry attributes, and the overall palatability and digestibility of vegetation for livestock in grassland systems (Beeri et al., 2007). Indices such as the Normalized Vegetation Difference Index (NDVI) are frequently used to estimate photosynthetically active radiation and calculate gross primary productivity (Nestola et al., 2016; Numata et al., 2007; Wang et al., 2016), to further derive information about the health and production of grasslands and pastures. In addition, new sources of imagery from hyperspectral sensors—which divides the electromagnetic spectrum up into hundreds of bands compared to the 3-10 used in multispectral imagery—are expanding potential uses of remote sensing in grassland monitoring to assess the subtle differences in vegetation reflectance at a fine spatial and spectral resolution (Ishii & Washitani, 2013; Möckel et al., 2014; Wachendorf et al., 2017). This work indicates that remote sensing has the potential to supplement the labor and time needed for field sampling and reduce the harvest of biomass for lab analysis, ultimately presenting cost-effective, spatially explicit approaches to grassland conservation.

Even with these advances, integrating remote sensing data into day-to-day decision-making for grassland conservation and management is limited in practice. The technical expertise and time-intensive data processing needed to use remote sensing imagery and develop maps present significant barriers to incorporating that imagery into conservation planning and monitoring (Nagendra et al., 2013). In addition, the dynamic management of grasslands and removal of biomss through prescribed burning, mowing, and grazing may limit the the usability of imagery and what kinds of changes can be detected through imagery. Limited research has explored the feasibility of using hyperspectral imagery for grassland management under grazing or articulate the types of decisions that the imagery could inform in grassland conservation or management. As interest in perennial grassland systems and their role in enhancing ecosystem services grows, strategies to manage grassland resources collaboratively through innovative technology and partnerships are likely to increase. Given that only about 4.6% of grasslands worldwide are protected for conservation (Asner et al., 2004; Foley et al., 2005) the need for collaborative management to preserve and improve perennial grassland cover is more urgent than ever among state agencies, non-profits, agricultural producers, and businesses. To explore the use of hyperspectral imagrey as a grassland monitoring and collaborative conservation tool, we use a case study of managed grazing on state wildlife areas in Wisconsin and discuss the potential applications of remote sensing and mapping in grassland management and decision-making.

1.2 Grazing for grassland management in Wisconsin

Public grassland habitat and recreation areas in the north central region of North America are typically managed with controlled burning, grazing, herbicide applications, and mowing (Murray et al., 2008; Ribic & Sample, 2001; Sample & Mossman, 1997; The Wildlife Trusts, 2018). Though grazing for rangeland management has been extensively studied in western North America, changing climate and increased interest in public-private agricultural partnerships are opening up new questions about conservation grazing as a land management tool in the north central region. Applications of grazing management range widely across different locations and conditions, and the degree of "success" can be highly dependent on soil type and structure, seasonal temperature and precipitation, land management history, and the timing and intensity of grazing (Briske et al., 2011, 2003). Rotational grazing in the Midwest can increase plant community diversity by promoting persistence of warm season grasses in cool-season pastures (Barnhart, 1994; Byers et al., 2017; Jog et al., 2008) and reducing large woody or invasive shrubs that shade and outcompete herbaceous grassland species (Bailey et al., 1990; Naeth et al., 1991; Oates et al., 2011). However, when inappropriately applied, grazing management strategies can also increase shrub encroachment (Briggs et al., 2002; Liu et al., 2013) and exotic species, particularly in long term grazing scenarios in wetter conditions (Lyseng et al., 2018). As practitioners consider grazing as a management technique for wildlife, they are faced with tradeoffs between factors that contribute to quality grassland habitat and those that contribute to maximum forage production and quality for animal nutrition. Many species of Midwestern grassland birds prefer warm season grasses and other species less palatable for cattle as nesting habitat, and maintaining vegetation with more cover for wildlife can mean sacrificing nutrition for livestock (Chamberlain et al., 2012). Forage quality is the extent to which pasture feed contributes to animal performance, growth, and preference, a measure of digestible and undigestible plant parts which can be influenced by texture, leafiness, moisture, or plant compounds (Bruinenberg et al., 2002). Identifying ways to mitigate risk, monitor habitat change, and inform decision-making for land managers and livestock producers is essential to make conservation grazing a successful and sustainable approach for grassland management.

The Wisconsin Department of Natural Resources (WDNR) is responsible for maintaining approximately 28,000 hectares of public-access grasslands for wildlife management and public recreation and education (Wisconsin Department of Natural Resources, 2018). Encouraged by recent grazing management initiatives from Minnesota Department of Natural Resources and from environmental groups such as The Nature Conservancy, the WDNR began a concerted effort to pilot test grazing on state wildlife areas in 2015, in conjunction with a grant-funded initiative from the University of Wisconsin-Madison (UW-Madison) (Hoch, 2013; The Wildlife Trusts, 2018). After a year of scoping activities to explore the opportunities and challenges of establishing grazing as a management tool, a group of land managers and administrators at the WDNR, researchers from UW-Madison, local cattle producers, and grazing specialists from a nonprofit, the Wallace Center *Pasture Project*, collaborated to implement and monitor cattle grazing on five state wildlife areas in 2016. Multiple researchers worked with the establishment of pilot projects to assess the processes and effects of collaborative grazing management, including the effect of cattle grazing on grassland bird presence (Asper, 2017) and on reduction of woody and non-native plant species (Grace, 2018). We addressed the use of airborne hyperspectral imagery to supplement conservation decision-making, collected in conjunction with rapid field sampling during the first grazing season. Planning and monitoring are essential for effective management of grasslands as both habitat and as pasture, and field sampling methods cannot always capture spatial variability needed to estimate available habitat cover for wildlife and plan grazing rotations for livestock. We further explore applications of high-resolution hyperspectral imagery in conjunction with field sampling and discuss strategies to incorporate remote sensing data into decision-making, risk management, and successful partnerships in grassland conservation agriculture.

2. METHODS

2.1 Study sites

The five grassland study sites were public wildlife areas managed by the WDNR selected to pilot test cattle grazing as a management tool for improving habitat for grassland songbirds and upland game bird species (**Table 1**). Sites were geographically located across Wisconsin in the southwest (Kickapoo River Wildlife Area), south central (Hook Lake Wildlife Area), central (Peter Helland and Buena Vista Wildlife Areas) and northwest (Johnson Property, Western Prairie Habitat Restoration Area). Johnson was not grazed in 2016 and initiated grazing management in 2017. Conservation species of interest included bobolinks (*Dolichonyx oryzivorus*), grasshopper sparrows (*Ammodramus savannarum*), Henslow's sparrow (*Ammodramus henslowii*), upland game birds such as pheasant and grouse species, and at Buena Vista Wildlife area, greater prairie chickens (*Tympanuchus cupido*). Four sites were grazed in 2016; the Johnson property at Western Prairie Habitat Restoration Area had fencing installation delays and did not initiate grazing until 2017. Grazing practices and animal stocking density varied between sites, coordinated between the land manager and grazier at each location. Three sites were subdivided into paddocks and rotationally grazed, moving animals between paddocks every two days to two weeks. One site (Peter Helland) was continuously grazed, giving cattle access to forage across the entire site.

2.2 Field sampling

We conducted a rapid field assessment to assess dominant vegetation cover types and forage quality coinciding with the hyperspectral image collection between 22 August and 2 September 2016. Because of the timing of image collection, four sites were actively being grazed during the field measurements. We randomly sampled from within a range of nine to twelve 20 x 20-m plots at each site in representative areas. Plots were established in conjunction with other research projects after walking the site with land managers to identify areas of management interest (areas of woody encroachment or low plant community diversity) and areas appropriate for the participating livestock graziers to work around (sampling within only one or two paddocks) (Elzinga et al., 1998).

We randomly placed four 0.5 x 0.5-m quadrats in each plot, visually estimated the dominant plant species cover from one of five functional groups and harvested the biomass to a 10-cm residual height, recording the dominant species and group. We describe species here in five classes of vegetation cover of interest to both land managers and graziers. These are cool season or C_3 grasses, warm season or C_4 grasses, legumes, broadleaf species or non-leguminous forbs, and woody species or shrubs (Jog et al., 2008). The collected biomass was dried, ground, and analyzed with Near Infrared Spectroscopy (NIRS) to calculate forage quality attributes such as lignin, protein, mineral content, and energy content (Marten et al., 1989; Moore et al., 2010; Paine et al., 1999). Relative forage quality or RFQ is calculated by multiplying dry matter intake DMI or DRYMI) and total digestible nutrients and dividing them by 1.23 to make the mean and range comparable to relative feed value (RFV), which is calculated from dry matter intake and digestible dry matter divided by 1.29 (chosen so that RFV is 100 for mature alfalfa) (Jeranyama & Garcia, 2004; Moore et al., 2010; Newman et al., 2006). RFQ is considered a better predictor of quality in mixed forages of grasses, legumes, and forbs than RVF. We anticipated palatability to be an important consideration for land managers and graziers in a successful grazing partnership, but because the timing of grazing events varied across sites, biomass or forage quantity was not part of our analysis. Forage quality attributes were averaged at the plot level.

2.3 Image collection and processing

We acquired 24 images of our five sites from a one-time flyover by NASA's Airborne Visible/Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG), which makes spectral measurements from 380 to 2510 nm with approximately 5-nm spectral resolution (Hamlin et al., 2011; Lundeen & Gowey, 2017; Serbin et al., 2015; Singh et al., 2015). Our images were collected at a flight altitude of 5,400 m at 1-m pixel resolution. To predict vegetation traits from imaging spectroscopy and develop maps of forage quality indicators, we used a partial-least squares regression (PLSR) to transform the predictor and response variables, finding underlying vectors and producing calibration factors and a linear model that reduced the data set (Singh et al. 2015; Ferner et al., 2014; Townsend et al. 2003). PLSR reduces the volume of spectral data by applying a linear transformation to identify a small number of 'latent' vectors with a high explanatory power for forage quality variables in the subsequent regression (Ferner et al. 2014; Wold et al. 2001). The approach to estimating forage quality and canopy traits was informed by Singh and coauthors (2015), developing models with 500 permutations of the dataset and splitting the data 70/30 for calibration and validation. The trait extraction from spectra and modeling is discussed more extensively by Mittra and coauthors (manuscript forthcoming), informed by literature on relating remotely sensed data to foliar chemistry (Curran, 1989). To evaluate model fit, we calculated the root mean square error (RMSE) and bias in calibration and validation.

We developed maps of both forage quality attributes extracted and predicted from the imagery and vegetation cover types. To develop a classified map of cover types, we used a Random Forest supervised classification using training polygons from five cover types (Meyer et al., 2017): cool season (C_3 grasses), warm season grasses (C_4), legumes, other broadleaf species, woody or shrub species. We used georeferenced ground data from field sampling, selecting the pixel at the center of the field-sampled quadrat and its 8 neighbor pixels at 1-m resolution. We used a 5-fold cross-validation to subdivide the data during classification and ran the classification 5 times with an 80/20 split for calibration and validation. We averaged the results and used the average fit to develop maps (Burai et al., 2015; Chan & Paelinckx, 2008; Meyer et al., 2017; Pullanagari et al., 2016).

3. RESULTS

3.1 Plant community cover

We took visual estimates of plant community cover, identifying the dominant vegetation type in each quadrat, and calculating percent cover by the number of quadrats of each type divided by the number of quadrats sampled at each site. Most sites were dominated by cool season grasses and non-legume broadleaf species (**Table 2**). Common cool season grasses present included Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermus*), and reed canary grass (*Phalaris arundinacea*). Kickapoo River Wildlife area had large areas of the warm season grass big bluestem (*Andropogon gerardii*). Common broadleaf species included Canada goldenrod (*Solidago canadensis*) and stinging nettle (*Urtica dioica*), and common legumes included red clover (Trifolium pratense) and white clover (Trifolium repens). Woody vegetation types varied between sites, but common species observed included prickly ash (*Zanthoxylum americanum*) at the Johnson Property, aspen (*Populus tremuloides*), willow (*Salix* spp.), and *Spiraea alba* at Buena Vista Wildlife Area, and bush honeysuckle (*Lonicera x bella*) and dogwood (*Cornus* spp.) at Hook Lake Wildlife Area.

Using the georeferenced field data for training points, we developed classified maps of each site using 5 vegetation cover classes. Additional cover types including bare soil, forest, water, roads, and buildings were hand digitized and masked out for classification. Initial comparison between the maps and field data was calculated by difference between percent cover in field data and the percent cover predicted by the total pixels, in each cover class divided by the total number of non-mask pixels. Maps indicated overall sites were dominated by cool season grasses and broadleaf species, with patches of warm season grasses (Kickapoo River) and areas of woody encroachment (Hook Lake) (**Fig. 1**).

In part because the relatively small number of field samples were unbalanced between cover classes and between sites, the classifier tended to under-predict the rarer cover classes (woody and legume species, and at most sites, warm season grasses) and over-predict the more dominant cover types, particularly broadleaf species (**Table 3**). However, when we assessed the overall accuracy of classification across sites, the results were much more promising. The average overall accuracy of the classified maps was 87.1%, calculated with the number of pixels correctly classified (2758) divided by the total number of test pixels (3168) (Jensen, 1996). Producer's accuracy—the probability the producer of the map classified a pixel correctly for a given category, or how well an area can be classified—ranged from 50% accuracy on the cover classes with the smallest area to 90% accuracy on cool season grasses (**Table 4**). User's accuracy—the probability that a classified pixel correctly represents that class on the ground—ranged from 83.3% to 100% accuracy. We calculated Cohen's Kappa coefficient to as (observed accuracy – expected accuracy) / (1 – expected accuracy) and calculated a coefficient of 0.87058, indicating high agreement between predicted and ground-sampled values. This accuracy might indicate that a land manager could use the mapping to locate areas of concern or interest on a given property, such as woody shrub encroachment at Hook Lake (**Fig. 2**), with some degree of reliability.

3.2 Forage quality

Relative forage quality (RFQ) and other forage quality metrics derived from field harvested biomass and laboratory Near Infrared Spectroscopy measurements. RFQ is a calculation of the overall digestibility of forage and how much cattle can eat, using fiber digestibility and total digestive nutrients (energy available) in the forage. The mean calculated RFQ across sites were low compared to managed pasture, particularly at Kickapoo River, which had the highest proportion of warm season grasses in the biomass harvested (**Table 5**). However, the maximum RFQ averaged to the plot level showed a range of values acceptable to achieve weight gain in a number of animal classes (Paulson, 2007) (**Table 6**). Though RFQ did not perform as well as other forage quality parameters such metabolizable energy (ME), protein (CP), or acid detergent fiber (ADF), it is a popular index that many cattle producers use to assess their pastures (De Bruijn & Bork, 2006; R. D. Horrocks & Vallentine, 1999) and we chose to include it in our mapping (**Table 7**). Other indices including Total Digestible Nutrients (TDN) performed much better, and it appears that the poor relationship of RFQ was related to the model for Dry Matter Intake (DMI).

We used the model to map RFQ across sites (**Fig. 3**) to help identify areas of high and low quality within the vegetation cover in our classified maps (**Fig. 1**). In addition to RQF as a more generalizable forage quality metric, we identified potential applications in mapping specific nutrients in plant tissue (**Fig. 4**) or in assessing potential overgrazing or direction of cattle rotation in heavily grazed areas (**Fig. 5**). This exploratory use of imagery provides a number of outlets for decision-making in animal nutrition and has the potential to reduce the quantity of biomass harvest and time needed to conduct NIRS in the lab (Obermeier et al., 2019).

4. DISCUSSION

4.1 Trait maps in grazing management and planning

Even with unbalanced rapid field sampling for calibration, we obtained good fits for models of forage quality parameters and overall accuracy of classified vegetation maps. To us, this begs the question: how can practitioners use spatially explicit mapping and modeling of grassland vegetation to inform day-to-day decision-making? In instances like ours with one-time image collection, these maps can be used as planning tools. Public land managers need to assess the “suitability” of different conservation practices for specific resource management and habitat improvement goals. Planning, scheduling, and estimating costs of different strategies are important for effective implementation, and imagery that shows baseline or near baseline conditions can help evaluate those management strategies. Visualizing and quantifying vegetation cover type has the potential to predict habitat utilization by different wildlife species of interest. Grassland bird species are sensitive to vegetation height and density, and cover class may be a predictor of utilization by different species. For example, Henslow’s Sparrows prefer high grass density with a deep litter layer for nesting habitat, while Grasshopper Sparrows prefer shorter grass height, bare ground, and higher disturbance intensities (Sample & Mossman 1997; Hubbard et al. 2006; Asper 2017). Using mapping to assess the size and distribution of different vegetation classes could aid the planning of grazing, mowing, or other grassland management treatments around potentially sensitive areas to save time and labor scoping that habitat on the ground. Establishing rest-paddocks or excluded areas could benefit the Greater Prairie Chicken and other species that prefer more dense vegetation cover (Niemuth 2000; Asper 2017) and streamline field surveys with pre-selection of areas of interest and likely wildlife utilization.

Producers considering grazing their livestock on public land face similar decisions to manage animal health and minimize risk. Maps of forage quality to estimate parameters like lignin, protein, and even mineral can address producer questions about how to time their grazing rotations at the start of the season and indicate where to stockpile forage (**Fig. 4**). Using a map of forage parameters to supplement the traditional biomass harvest and pasture plate can help producers plan the stocking density, animal type, and budget supplementary feed or minerals during the season. While land managers and graziers will likely bring different goals and experiences to grazing management, developing maps that serve both of their needs for record keeping, cost calculations, and vegetation growth projections in grassland systems could help establish common terminology and identify potential costs and intended activities in a way that improves transparency and trust.

4.2 Limitations and considerations for future imagery use

While there is significant promise in the potential for hyperspectral imagery and mapping to inform decision-making and land management partnerships, there are still a number of limitations both to our case study and the use of modeling and mapping more broadly. Developing a balanced set of training data for different vegetation classes proved challenging for us during the grazing season and is likely a source of bias in our modeling and mapping. In addition, identifying plant community composition and forage quality attributes on the fine scale provided by field sampling requires extremely high spatial resolution that is not readily available from most aerial images (Wang et al., 2018). In many cases, the variation in spatial heterogeneity of plant community was not captured even with a one-meter pixel size, and our rapid field sampling may not have captured enough variation. Our data collection was also limited to the top-most part of the vegetation canopy—our classification does not account for small forbs and grasses in the understory of the plant community.

In addition to the lack of high spatial resolution that can provide information on individual species, researchers may not always have the flexibility to look for unique spectral signatures in even high-resolution images (Reeves et al., 2016). Hyperspectral data is improving options for these fine-scale reflectance measurements by including more narrow bands, but the issue of image analysis speaks to a larger trend in remote sensing: in general, our methods for interpreting and using images have not yet caught up with our ability to collect remotely sensed data. Because capacity to collect data has outpaced our ability to extract it, analysis still requires time-consuming image processing, hand-digitizing vegetation classes, and interpretation and validation of the resulting data.

4.3 Future implications for imagery in monitoring

Though our current methods require extensive processing and we are still refining our models for species composition and tissue chemistry, there is enormous potential in remote sensing for monitoring as hyperspectral data becomes more readily available for research and education. In situations with additional image collection over more time points, maps derived from hyperspectral imagery have enormous promise for monitoring grassland habitat. Land managers can quantify changes in vegetation cover, identify areas of woody encroachment, plan spot-treatment of herbicides (**Fig. 2**), and potentially use cover classes like the warm season grasses as an indicator of other desirable species. They can also address areas of overuse or overgrazing on areas that are challenging to access on foot or in instances where change might not be obvious. Our trait maps of forage quality clearly show recently grazed areas at Kickapoo River and Hook Lake Wildlife Areas. This kind of mapping potentially could detect overgrazing or other land use activities such damage from all-terrain vehicle use. While remote sensing already has been used to detect pest or disease outbreaks, forage quality could be a responsive indicator that serves the dual purpose of providing nutritional information for livestock grazing in addition to data on plant phenology and vegetation health. For livestock producers, forage quality trait mapping over the course of the season could provide real-time decision-making information to adapt stocking density of the herd or plan supplementary feed according to availability and palatability of forage. Depending on the size of the grassland site and timing of image processing, evidence of grazing and defoliation could provide an indicator for cattle outside fenced areas. The imagery could provide a tool to communicate goals, practices, and areas of concern between land managers and producers.

Risk management and liability are critical factors for successful partnerships in grazing on public land. Collecting a timely, holistic picture of how grazing is impacting both habitat cover and forage quality could prevent habitat damage or nutritional deficiency in animals before either problem becomes severe. In addition, many grazing partnerships are based on an evaluation of services exchanged, a calculation of how grazing supplements other land management activities or the value of the feed cattle are receiving on public lands. Forage quality mapping provides evidence for how the value of feed changes over time, and vegetation cover maps provide data on the extent to which cattle are accomplishing habitat goals. The ability to spatially document and quantify changes could enable more fair grazing contracts that account for change and reward effective grazing practices.

5. CONCLUSIONS

Remote sensing increasingly offers the ability to ask multi-scalar questions, combining field measurements landscape-level data about spatial variability, productivity, and regional trends for grassland management and monitoring. Developing maps from hyperspectral imagery for grassland management and monitoring has clear applications in monitoring indicators of interest in complex systems, identifying and prioritizing activities, and estimating costs and scheduling. Further refinement of our ground-sampling methods to increase the amount and diversity of georeferenced training data will likely reduce the biases in our smaller cover classes, and creating mixed classes of multiple vegetation types may help improve the accuracy and applications for classified maps in areas with vegetation at multiple canopy heights or sub-pixel patch sizes. While imagery and mapping alone cannot yet completely replace the relatively simple and well-tested methods of sampling grassland species composition and traits, hyperspectral processing continues to open up possibilities for managers and producers interested in spatial variation and landscape-level questions. As public and private agencies around the world move forward with developing satellite-mounted hyperspectral sensors, we will have greater capacity than ever before to coordinate landscape-level conservation and management.

6. TABLES AND FIGURES

Table 1. Site characteristics of state wildlife areas implementing grazing that were surveyed in 2016. Soil types were accessed through the Natural Resources Conservation Service Soil Web Survey.

Site	Size (ha)	Latitude	Longitude	Soil Type	Grazing mgmt.	Graze date	Cattle type
Peter Helland	40.87	43.52721	-89.18289	Adrian muck; Houghton muck; Gilford fine sandy loam	Continuous	Sept. 1	Mixed dairy heifers
Johnson	24.28	45.20598	-92.41965	Santiago silt loam; Otterholt silt loam; Amery loam	Ungrazed	N/A	N/A
Hook Lake	11.41	42.93905	-89.31844	Dodge and Kidder silt loam	Rotational	Aug. 25	Highland cow-calf pairs
Buena Vista	91.05	44.36485	-89.58359	Newson mucky loamy sand	Rotational	Aug.7	Red Angus cow-calf pairs
Kickapoo River	7.61	43.29387	-90.83322	Ettrick silt loam; Windward loamy sand	Rotational	Aug. 30	Red Angus cow-calf pairs

Table 2. **Visual estimates of dominant plant cover averaged by site from field assessment**s. Sampling was unbalanced because of grazing removal of biomass and flooding in plots, number of sub-samples (quadrats) per site ranged from 36 to 48.

	Peter Helland	Johnson	Hook Lake	Buena Vista	Kickapoo
Broadleaf	8.5%	67.3%	51.1%	31.8%	36.1%
Cool season grass	91.5%	24.5%	38.3%	65.9%	22.2%
Woody	0.0%	8.2%	6.4%	0.0%	2.8%
Warm season grass	0.0%	0.0%	0.0%	0.0%	36.1%
Legume	0.0%	0.0%	4.3%	2.3%	2.8%
Total plots sampled:	12	12	12	11	9

Table 3. Difference between field-sampled and classification-predicted vegetation cover at each site. Differences are calculated by percent map cover minus percent field cover for each site, so -3.4% indicates the map data cover in a given cover class was 3.4% less than what the field sampling estimated.

	Peter Helland	Johnson	Hook Lake	Buena Vista	Kickapoo
Broadleaf	+3.4%	+0.8%	+13.8%	+9.9%	+33.7%
Cool season grass	-3.4%	+7.3%	-3.8%	-7.8%	+5.4%
Woody	0.0%	-8.2%	-6.1%	0.0%	-2.8%
Warm season grass	0.0%	0.0%	+0.1%	0.0%	-33.6%
Legume	0.0%	0.0%	-4.1%	-2.1%	-2.8%

Table 4. Confusion matrix indicating overall accuracy of mapped cover classes across all 5 sites. 'Est' refers to estimated type, or the algorithm-predicted classification, and 'act' refers to actual type, or pixels with a field-derived reference to confirm their cover class. 'CS' is cool-season grass, 'WS' is warm-season grass. Our Kappa coefficient was calculated as 0.87058, from 3168 total pixels sampled.

	act_Broadleaf	act_CS grass	act_Woody	act_WS grass	act_Legume	Total:	User's accuracy:
est_Broadleaf	914	144	24	38	3	1123	81.4%
est_CS grass	137	1567	3	4	8	1719	91.2%
est_Woody	2	3	27	0	0	32	84.4%
est_WS grass	18	14	0	219	12	263	83.3%
est_Legume	0	0	0	0	31	31	100.0%
Total	1071	1728	54	261	54	2758	
Producer's accuracy:	85.3%	90.7%	50.0%	83.9%	57.4%	Overall accuracy: 87.1%	

Table 5. Relative Forage Quality (RFQ) across grassland sites, averaged by plot at the time of 2016 AVIRIS imaging (RFQ = DMI *TDN/1.23) from lab-extracted values through Near Infrared Spectroscopy (NIRS).

Site	Mean RFQ	Min. RFQ	Max. RFQ
Peter Helland	95.873	72.398	107.127
Johnson	88.755	71.442	94.772
Hook Lake	84.031	63.949	113.096
Buena Vista	84.891	70.120	104.304
Kickapoo River	50.324	40.908	61.348

Table 6. Ranges for relative forage quality needs to achieve healthy weight gain, based cattle type and age (adapted from Undersander 2003; Jeranyama and Garcia 2004).

Animal type and age (months)	RFQ range
Heifer, 18-24 mo.	100-200
Dry cow	
Heifer, 12-18 mo.	
Beef cow and calf	115-130
Lactating dairy cow (200 days)	
Heifer, 3-12 mo.	125-150
Stocker cattle	
Lactating dairy cow, first 3 mo.	
Dairy calf	140-160

Table 7. Calibration and validation statistics for selected forage quality parameters from PLSR analysis from 223 quadrats (subplots), 156 randomly selected for calibration (70%) and the remaining 67 for validation (30%).

	Calibration (70%)			Validation (30%)		
	R^2	RMSE	Bias	R^2	RMSE	Bias
Acid Detergent Fiber (ADF)	0.761	3.328	-0.008	0.749	3.804	-0.171
Fat	0.734	0.34	0.001	0.785	0.319	0.067
Potassium (k)	0.692	0.36	0.001	0.422	0.432	-0.120
Lignin	0.66	1.196	0.012	0.432	1.755	-0.255
metabolizable energy (ME)	0.761	0.059	0	0.697	0.071	-0.003
Magnesium (Mg)	0.601	0.074	0	0.669	0.072	-0.019
Protein (CP)	0.813	2.053	0.014	0.798	2.230	-0.712
Relative Forage Quality (RFQ)	0.53	15.23	0	0.500	15.930	-2.180

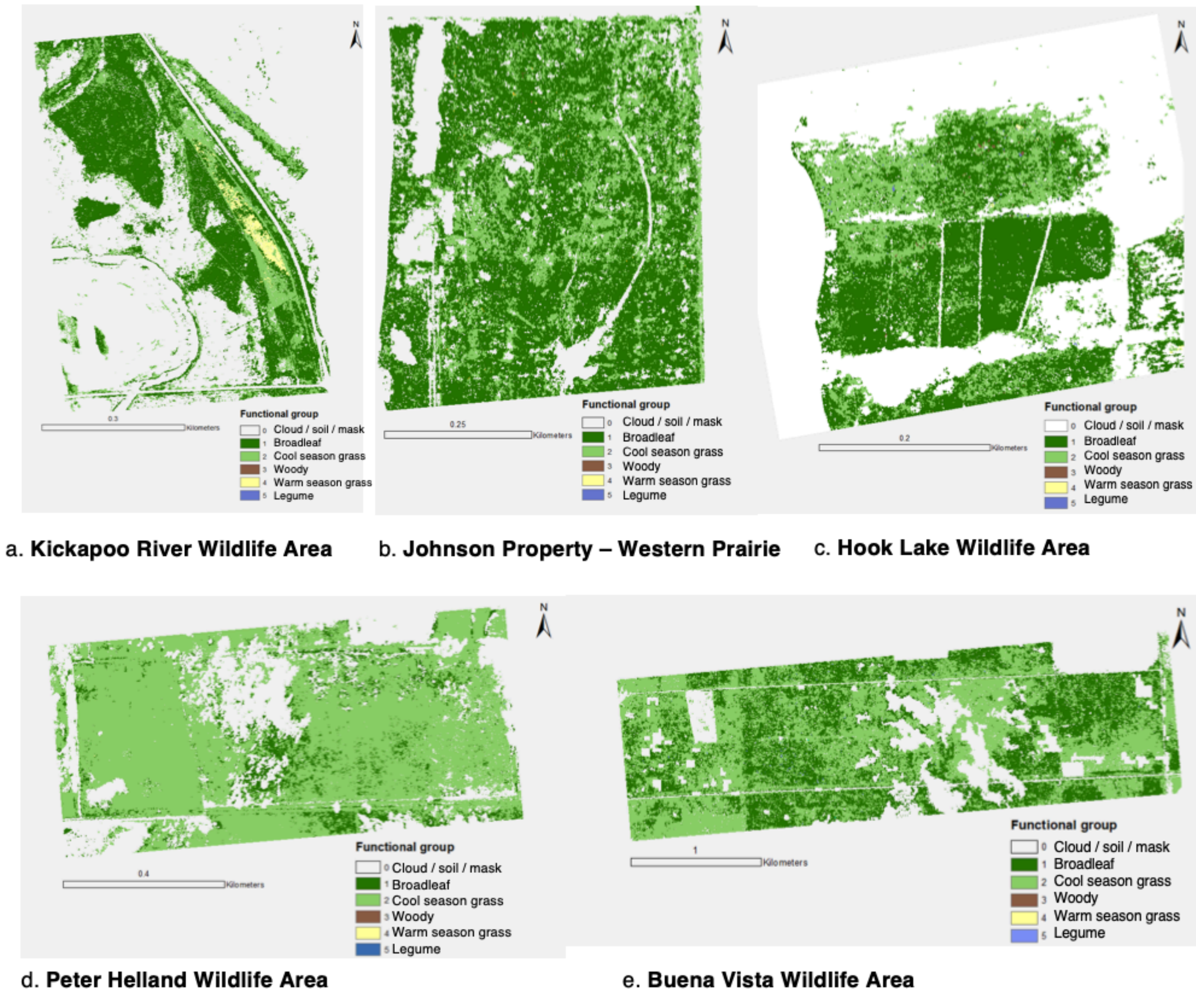


Figure 1. Classified maps of vegetation cover at five grazing sites developed with a supervised classification using Random Forest, showing cool season grasses (light green), broadleaf species (dark green) and some warm season grasses (at Kickapoo River) as the dominant cover classes across sites.

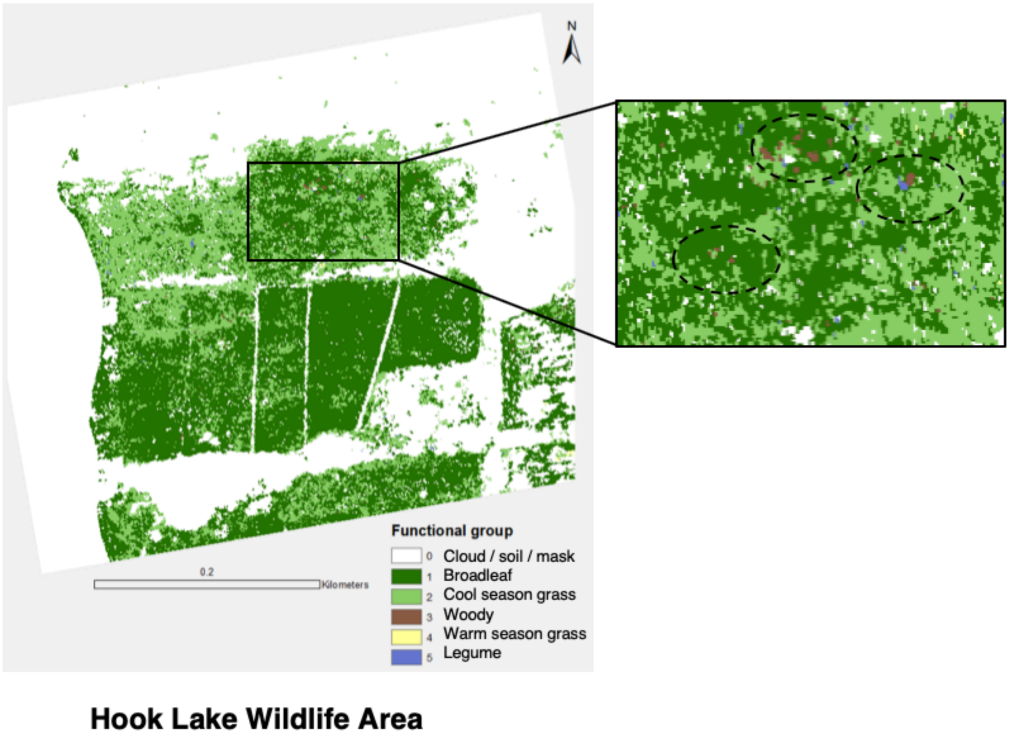


Figure 2. Classified map of Hook Lake Wildlife Area enlarged to show woody shrub encroachment (brown pixels, circled).

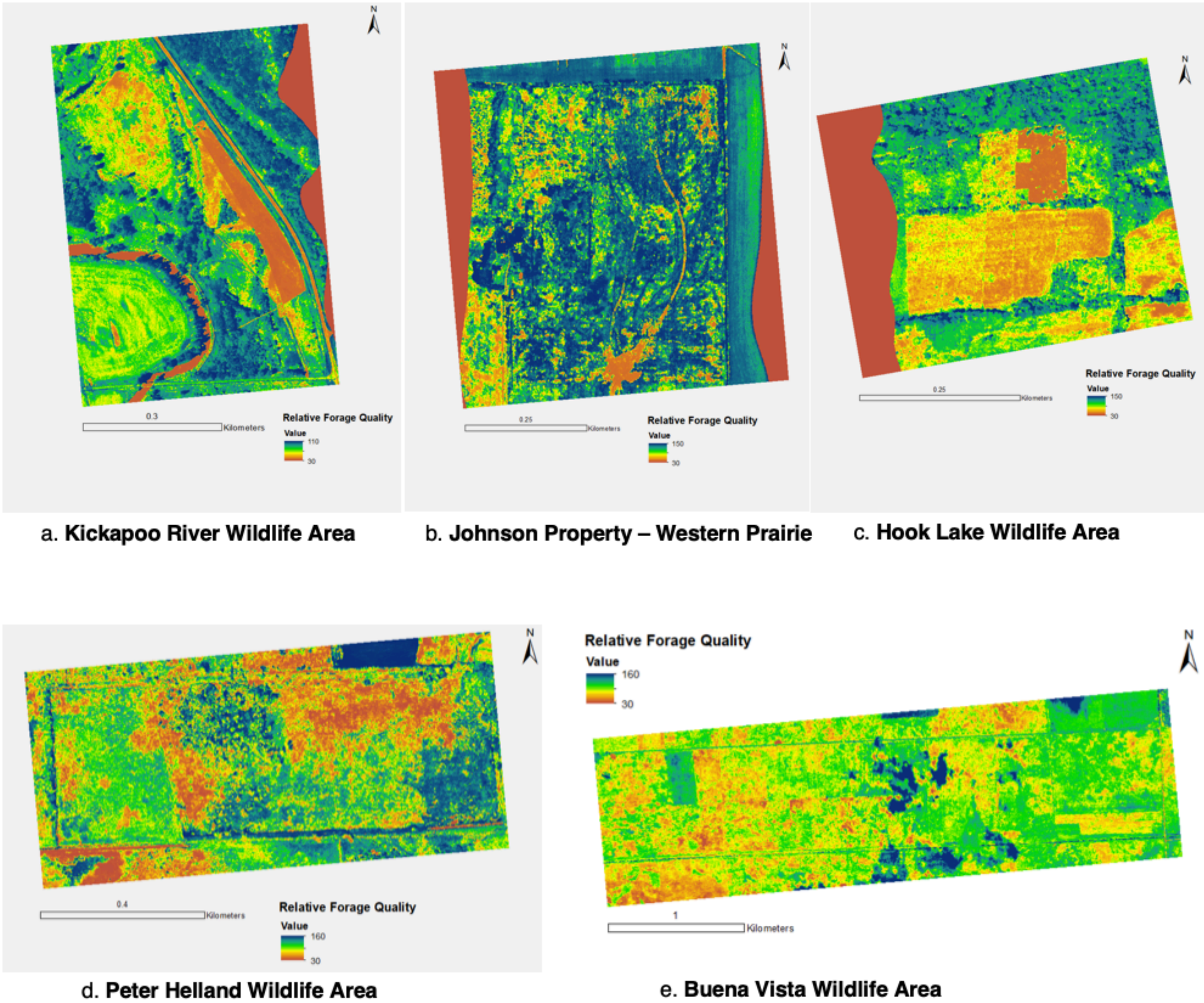
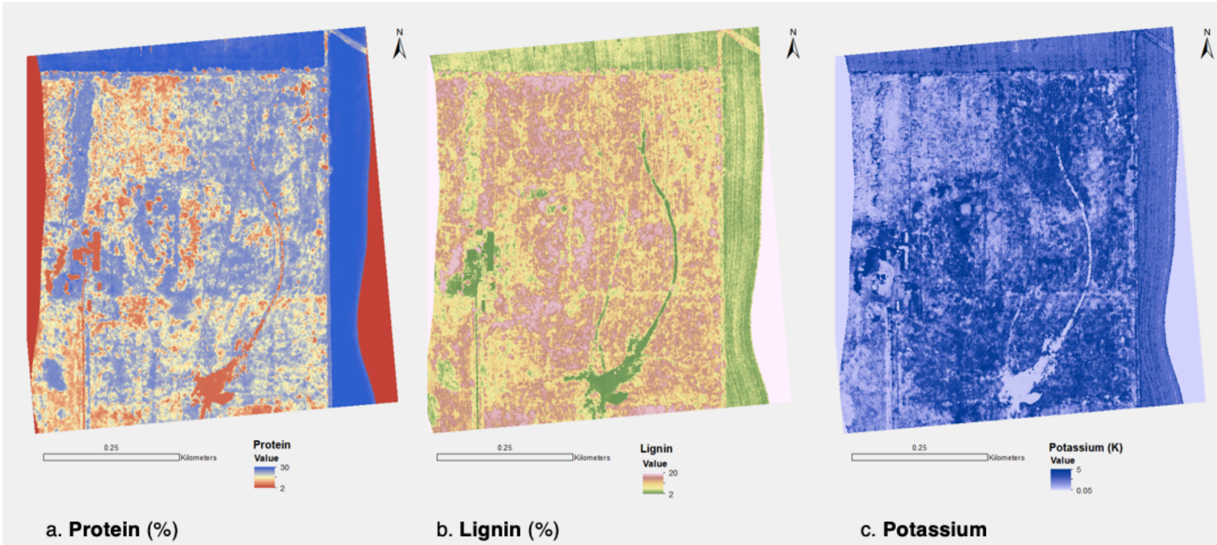


Figure 3. Trait maps of estimated Relative Forage Quality (RFQ) across five grassland sites. RFQ values range from 30 (red) to 160 (blue).



Johnson Property – Western Prairie

Figure 4. Trait maps of estimated protein (a), lignin (b), and protein (c) content at Johnson in August 2016.

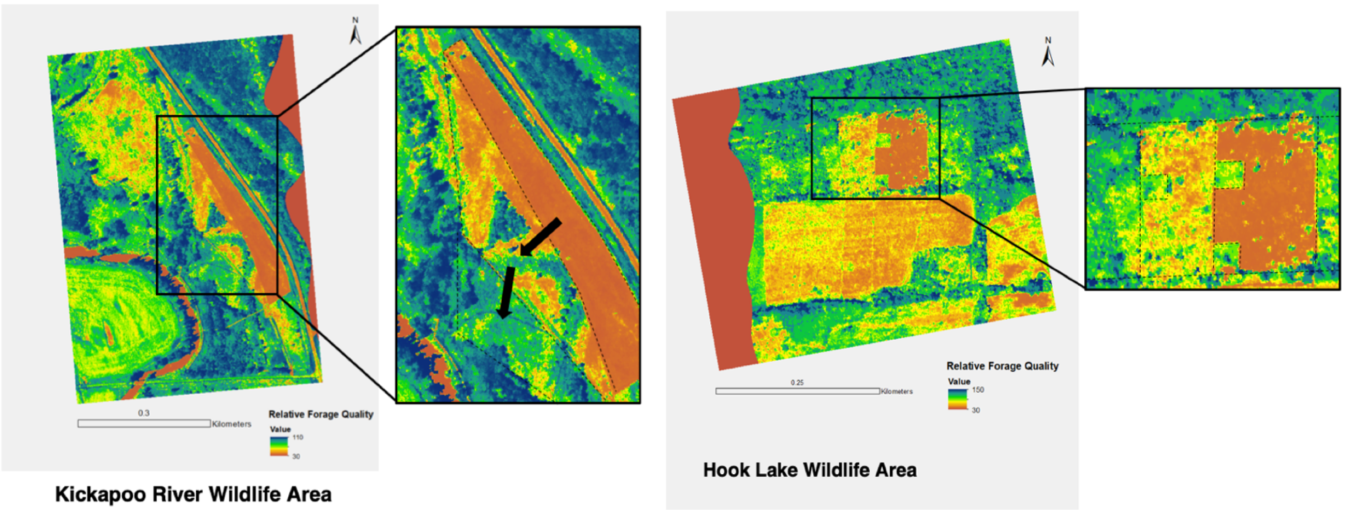


Figure 5. Trait maps of Kickapoo River Wildlife Area (top) and Hook Lake Wildlife Area (bottom) enlarged to show areas of recent grazing. The dotted lines indicate fencing at the borders of paddocks. The arrows on the map of Kickapoo River indicate the direction that the cattle were being rotated from the recently grazed northern paddock toward the southwest paddocks. At Hook Lake the excluded research areas (20 x 20-m plots) are clearly visible as ungrazed compared to the grazed paddocks around them.

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8. APPENDIX

Table 8. Calculations for percent cover of each vegetation type by site, extracted from classified maps. The number of pixels per class were pulled from the attributes table in ArcMap, and the calculated percent cover excludes the image classified as cloud / soil / or masked cover type.

	Peter Helland		Johnson		Hook Lake		Buena Vista		Kickapoo	
	Pixels	Percent	Pixels	Percent	Pixels	Percent	Pixels	Percent	Pixels	Percent
cloud / soil / mask	132178		202137		112943		72369		267428	
broadleaf	42935	11.90%	196630	68.10%	54820	64.90%	105423	41.70%	131450	69.80%
cool season grass	317170	88.10%	91665	31.80%	29148	34.50%	146882	58.10%	52035	27.60%
woody	2	0.00%	86	0.00%	240	0.30%	9	0.00%	0	0.00%
warm season grass	78	0.00%	10	0.00%	102	0.10%	0	0.00%	4688	2.50%
legume	15	0.00%	136	0.00%	195	0.20%	387	0.20%	85	0.00%
Total pixels	492378		490664		197448		325070		455686	
Pixels excluding mask	**360200**	**100.0%**	**288527**	**100.0%**	**84505**	**100.0%**	**252701**	**100.0%**	**188258**	**100.0%**

Table 9. Comparison of field sampled and predicted vegetation cover in each class.

Cover	Peter Helland		Johnson		Hook Lake		Buena Vista		Kickapoo	
	Field	Pred.	Field	Pred.	Field	Pred.	Field	Pred.	Field	Pred.
Broadleaf	8.5%	11.90%	67.3%	68.10%	51.1%	64.9%	31.8%	41.7%	36.1%	69.80%
CS grass	91.5%	88.10%	24.5%	31.80%	38.3%	34.5%	65.9%	58.1%	22.2%	27.60%
Woody	0.0%	0.00%	8.2%	0.00%	6.4%	0.3%	0.0%	0.0%	2.8%	0.00%
WS grass	0.0%	0.00%	0.0%	0.00%	0.0%	0.1%	0.0%	0.0%	36.1%	2.50%
Legume	0.0%	0.00%	0.0%	0.00%	4.3%	0.2%	2.3%	0.2%	2.8%	0.00%

Table 10. Mean forage quality metrics at each of the five sites calculated from Near Infrared Spectroscopy in the lab.

Site	Protein	IVTDMD30	Lignin	dNDF48	NDFD48	Fat
Buena Vista	12.0	63.9	10.0	31.6	51.6	2.6
Hook Lake	10.6	54.8	12.3	25.4	44.2	2.4
Johnson	11.1	58.4	12.4	27.3	48.1	2.9
Kickapoo	5.8	48.8	11.0	35.2	45.4	1.4
Peter Helland	18.6	69.7	8.8	33.8	58.5	2.2

Table 11. Forage quantity at time of sampling, estimated from 0.5 m samples clipped at 15cm residual height and air-dried, and calculated in kilograms per hectare (raw data).

Site	Mean quantity	Min. quantity	Max. quantity
		kg ha^{-1}	
Peter Helland	647	2	1588
Johnson	477	13	1659
Hook Lake	1244	299	2985
Buena Vista	1272	155	2476
Kickapoo	824	267	2366

Chapter 4. Using principles-focused evaluation in conservation and land management

ABSTRACT

Evaluation is a critical part of effective environmental conservation and land management, but using traditional, outcome-based approaches to assess collaborative management in changing environmental and socio-political landscapes provides an incomplete and inflexible strategy to monitor the success or failure of that management. Evaluation needs to address not just the outcomes of conservation and agricultural practices, but the systems and variables contributing to those outcomes. We argue that principles-focused evaluation provides a useful framework to track learning, adaptation, and iteration of collaborative management because of its inherent emphasis on complexity and systems, using principles instead of traditional linear outcome models assess progress and change. We explore the potential use of principles-focused evaluation to assess an ongoing effort to graze cattle on public grasslands in Wisconsin for habitat management. We use literature review and a document analysis to briefly describe the project, identify evaluable principles and their indicators that could be shared between the different collaborators, and discuss lessons-learned to illustrate the application of principles-focused evaluation in rapidly developing and changing environmental contexts.

1. INTRODUCTION

1.1 The need for evaluation in collaborative land management

Collaborative management of natural and agricultural resources is rapidly growing as a strategy to meet the needs of social-ecological systems, reducing conflict and developing relationships among different stakeholders and interest groups for more resilient and sustainable resource use (D Armitage et al., 2009; Butler et al., 2015). In contrast to top-down or state-mandated strategies of resource use and conservation, collaborative management frequently uses iterative and learning-oriented approaches to management, sharing responsibilities among stakeholders and adapting to multiple environmental, social, and economic issues with the goal of ultimately to producing better, more sustainable management decisions (Bown et al., 2013; Conley & Moote, 2003; Olsson et al., 2014; Plummer et al., 2012). However, funders and participants often struggle to assess whether these collaborative efforts adequately address public and private interests and whether they are worth the investment of the time, effort, and social capital, and frequently face challenges attempting to generalize their practices to other issues or management scenarios (Plummer et al., 2017).

The use of monitoring and evaluation in conservation and land management provides a set of methods to address these gaps in knowledge, using systematic approaches to track progress toward conservation goals, increase accountability and document use of funding, and to respond to environmental implications of poor management (Mascia et al., 2014). Program evaluation provides a framework to measure the merit or worth of programs or policies (Hogan, 2009) and differs from research or academic inquiry more generally in that it is nearly always applied, politically situated, and built around the premise that an evaluation will produce judgments and recommendations about program quality or effectiveness (Mertens, 2010). In typical evaluations of natural resources management, evaluators can assess characteristics of a process, such as inclusiveness with stakeholders during public input sessions or decision-making methods in implementation activities, or evaluate the outcomes of the new management (Conley & Moote, 2003; Schwartz et al., 2017; Woodhouse et al., 2015). Documenting outcomes is easiest when they have quantifiable indicators like number of acres restored to wildlife habitat, demand for a particular program, or biophysical changes like increased soil organic matter or presence of rare species that indicate environmental health (Conley & Moote, 2003) (**Table 1**). Though modern evaluation methodologies began in the realm of public education to measure student performance and test new programs (Hogan, 2009) they have expanded into many areas including business, industry, public policy, and international development (Coryn et al., 2011).

Even with numerous resources from other fields and sectors to draw from, collaborative conservation and agricultural management still struggles to implement and use program evaluation to enhance management (Heinze & Ruonavaara, 1999; Kapos et al., 2008). Because of the context-dependent and often long-term nature of changes resulting from land management and conservation, common approaches remain fairly limited to measure success or learning, compare the effectiveness of different programs, or describe assumptions or challenges that practitioners face (Kapos et al., 2010). Salafsky and Margoluis (2003) have noted that use of evaluation has developed with a similar trajectory across other disciplines and sectors, moving away from heavy reliance on external, “summative” evaluations of a program at its completion toward “formative” evaluation that encourages iteration and participation of different key implementers and stakeholders over the course of a program. They argue that in conservation and land management, evaluation is still often treated as a one-off event, and needs to be integrated into the systems for designing and monitoring management to promote learning and adaptation for more sustainable resource governance (Salafasky & Margoluis, 2003; Stem et al., 2005). Until then, ineffective evaluation in conservation can lead to negative consequences, including inaccurate assessment of management activities, misallocation of evaluation resources and unreasonable expectations of evaluation activities, and misguided conservation activities that result in reduced perceived value of evaluation as a practice (Mascia et al., 2014; Wilder & Walpole, 2008).

It is becoming increasingly clear that conservation and land management need evaluation strategies that can address the complexity of changes in both the biophysical landscape as well as the human-driven values, needs, and interests that direct the use of those resources across multiple spatial and temporal scales. Evaluation in conservation needs to assess strategies to address both short and long-term goals and outcomes, and the increasingly adaptive approaches needed to handle conservation in a changing global climate (Blue Marble Evaluation, 2019). As the complexity of management under extreme weather events, disaster recovery, and political or organizational change comes to the forefront of conservation planning, developing evaluation strategies to guide management will become more important than ever.

1.2 Principles-focused evaluation for conservation and agriculture in a changing climate

In contrast to more traditional formative or summative evaluation design, "principles-focused" program evaluation describes a set of strategies to assess programs, policies, or work unfolding in dynamic, complex environments when goals or programs are constantly adapting (Patton, 2018). This relatively recent approach—developed by evaluator Dr. Michael Quinn Patton—is used to identify the "principles" that unite different groups and their work or activities in these systems, and can provide a way to describe and evaluate activities even without a unified set of goals or cohesive, consistent plan of work. Principles define direction but are not prescriptive, are grounded in values and based on evidence about how to be effective, and must be interpreted and applied contextually to give direction toward outcomes and impacts. More specifically, principles for evaluation can be defined using Patton's GUIDE framework, which describes principles as *guiding, useful, inspiring, developmental, and evaluable* (Patton, 2018) "Guiding" here indicates that principles should specify a direction for action, making them prescriptive, directional, and effectiveness oriented. "Useful" principles are descriptive and provide information on how to be effective, which means supporting choices and decisions. "Inspiring" indicates that principles are values-based, meaningful, and invoke a sense of purpose in the groups using them. "Developmental" principles are context-sensitive and enduring over time in complex changing context, and "evaluable" means that it is possible to document and judge whether a principle is being followed, what results, and if that principle has impact on program goals (Patton 2018; p. 38). Examples of principles from public health sectors include "support youth to develop and express their own perspectives and voice" from a youth-project with ChildFund International, or "engage in health and recreation as Māori" from the *He Oranga Poutama*, an indigenous health organization of New Zealand (Patton, 2018). Principles can be compared to 'best practices', but best practices arguably prescribe specific activities that lead to likely outcomes only in relatively simple contexts, where principles can guide action and decision-making in more complex and dynamic situations (Patton, 2011; Waylen & Blackstock, 2017).

We argue that principles-focused evaluation provides an appealing new approach for evaluation in collaborative conservation and natural resources management projects because of its inherent emphasis on complexity and systems. Collaborative management to implement environmental conservation and agricultural practices requires navigating many different values, motivations, perceptions as well as public and private funding sources, legal responsibilities, and activities for successful implementation (D Armitage et al., 2009; Derek Armitage et al., 2008; Greiner et al., 2009; Plummer et al., 2017). We explore the use of principles-focused evaluation as an approach to assess an ongoing effort to graze cattle on public grasslands in Wisconsin for habitat management. We use literature review and a document analysis to briefly describe the project, identify evaluable principles and their indicators that could be shared between the different collaborators, and discuss lessons-learned to illustrate the application of principles-focused evaluation in rapidly developing and changing contexts.

2. METHODS

2.1 Describing collaborative grazing management and research project

The grazing research project discussed here was initiated by a University of Wisconsin-Madison (UW-Madison) agroecology research group with the goal of exploring solutions for both public grassland management and land access among private livestock producers in Wisconsin (more extensively described in Chapter 2). The research group proposed that improved understanding of rotational grazing and its subsequent effects on plant communities, soil properties, its socioeconomic benefits and pitfalls, and its role in public-private management partnerships could provide critical insights for grassland conservation, producer profitability, and many ecosystem services in Wisconsin and the Midwest United States. Grazing management that incorporates wildlife habitat objectives—referred to as “conservation grazing”—offers an approach to maintain and improve public grasslands while increasing the profitability of grass-fed beef and dairy. The agroecological emphasis of the research group and the public-private scope of the proposal necessitated a collaborative, transdisciplinary approach, working between public land managers and administrators at the Wisconsin Department of Natural Resources (WDNR), private graziers and grazing specialists associated with the Wallace Center's *Pasture Project,* and other conservation and agricultural education groups to investigate the questions around grazing on public lands. These three organizations (UW-Madison, WDNR, and the *Pasture Project*) and their respective mission statements and documented goals are the main components of our analysis. We developed shared principles for this project using evidence from their shared work to research, implement, and monitor grazing management on public state wildlife areas starting in 2015.

2.2. Literature and document review

We conducted a thematic literature review on scholarship related to program evaluation, monitoring, and assessment in land management, conservation, restoration, and adaptive collaborative management. This literature search contextualized a document review of materials related to research group activities, including meetings and communications (Bowen, 2009; Frechtling, 2002). The main document discussed here is a Memorandum of Understanding (MOU) associated with the grant funded project "Understanding the Opportunities and Challenges Associated with Grazing Public Grasslands of Wisconsin" (MSN169238) between the UW-Madison research group and WDNR administrators effective from October 1, 2015 to September 30, 2019 (Appendix). We identified evaluable principles and indicators from these documents using Patton's GUIDE framework with the goal of providing next steps for discussion between organizations and continued evaluation planning.

3. RESULTS

3.1 Development of grazing management and research principles

We used open coding of the organizational mission statements and project materials to develop four core, shared guiding principles for the implementation of grazing management from an analysis of the individual organizational mission statements of the UW-Madison (*Mission - University of Wisconsin–Madison*, n.d.), the WDNR (*Mission - About the DNR - Wisconsin DNR*, n.d.) and Pasture Project (*How The Pasture Project Works | Pasture Project*, n.d.) (**Table 2**). All three mission statements had themes related to public knowledge, environmental protection and sustainability, collaboration, and public good. Our proposed principles offer direction for activities in a changing context by emphasizing learning and sustainability as values throughout the collaboration activities and implementation of management.

Though the themes contributing to these four core principles were present in all organizational mission statements, they varied in how the ideas were prioritized in each. “Encourage learning and increase public knowledge” is an explicit goal in UW-Madison’s mission, while it is implied through ideas like “supporting farmer networks” for the Pasture Project and “To work with people to understand each other's views” for the WDNR (**Table 2**). “Preserve and improve natural resources to benefit future generations” is a central part of the mission statement of the WDNR, and addressed more subtly in documents related to the mission statement of the Pasture Project and UW-Madison.

3.2 Evaluability of core principles

We developed a number of example practices and evaluable indicators that would follow the four core principles, drawing on stakeholder meeting notes and the MOU between the WDNR and UW-Madison (**Table 3**). These practices included strategies to share knowledge gained through the research and implementation process, build organizational capacity and knowledge with shared resources and documentation, and engage the public through different venues. This process allowed us to explore the extent that principles would be evaluable on both short and long timelines, and how they might be adapted to changing contexts.

4. DISCUSSION

Land management through grazing in Wisconsin is arguably an essentially principles-driven endeavor. Our list of guiding principles is by no means extensive but provides a critical look at how an evaluator might start to link the activities and the organizations involved in grazing implementation and monitoring to assess their joint activities and progress in a complex environment. The planning, implementation, and monitoring of collaborative grazing management in Wisconsin evolved both in overall goals and individual actors and participants since the MOU was put in place between the WDNR and UW-Madison in 2015. The outcomes and objectives were not clearly established at the start of the project beyond those described in the MOU, which can be summarized as:

- Gain improved understanding of grazing as a management tool;
- Gain improved understanding of grazing implementation on public land;
- Share knowledge about what was learned;
- Assess cost-effectiveness of grazing as a management practice compared to other practices.

While the four objectives described in the MOU continue to be relevant to the collaborative efforts, they fail to capture additional learning, growth, innovation, and changes in context that have occurred in areas like project communication, social network growth, and institutional knowledge. Between 2015 and 2019, an agency reorganization and a statewide election altered the structure, priorities, and activities of the WDNR. Three graduate student researchers completed their monitoring projects and left the grazing research group, and the *Pasture Project* received additional federal funding to support grazing education and development of decision support tools to aid grazing implementation. In addition, the WDNR hired a full-time grazing specialist and allocated $250,000 for grazing infrastructure in 2017 and has received over 50 proposals for grassland sites to implement grazing management. Using shared principles to guide evaluation, such as "Encourage learning and increase public knowledge" instead of "… make available to resource managers, landowners, other researchers, and other interested public such facts, methods, literature, and new findings discovered through this process" provides an opportunity to evaluate organizational learning of the different participating groups, or to report on emerging ideas or processes not directly attributable to the research findings. This flexibility allows for both short- and long-term planning as opposed to the endpoint objectives described in the MOU and can be used to measure progress and change in priorities with more frequency.

In our study, the principle "support organizational connections and new collaborations" is not included in the objectives laid out in the MOU, but has arguably been the largest area of growth in the development and implementation of grazing management. The project practices that have informed and been informed by that principle include building institutional knowledge, processes, and contacts related to grazing within the DNR and among other grazing networks and agricultural educators (**Table 3**). The implementation of grazing on public demonstration sites around the state has create new opportunities for cross-organizational communication and exchange of ideas at public talks and workshops. While none of these developments are currently part of an evaluation plan, they provide evidence for how the collaboration has adapted over time to address changing needs and interests. Possible indicators of the adherence to or the effectiveness of this principle include the change in the number of organizations involved in grazing implementation, the frequency and type of interactions, and the processes or projects that have emerged specifically from collaboration, including new funding proposals and research collaborations in different locations.

Conservation agriculture is inherently collaborative, complex, and driven by values at multiple scales, from state and federal agencies that incentivize or restrict different management practices, nonprofits that support education or implementation, university research and outreach, and standards or rewards driven by agribusiness. All of those groups have different motivations and goals, and all are subject to changes in individual actors or members as well as broader changes related to policy, funding, and climate. In more traditional, outcomes-based monitoring and evaluation, an evaluator could attempt to measure a collaborative effort against the broader collective goals of the participants, or against similar efforts taken in other sectors or regions. However, these two strategies do not select for the appropriateness of goals or confounding contextual influences in other comparable projects, and may miss unanticipated outcomes. It may also be challenging to find a comparable effort with enough shared characteristics to make that comparison meaningful. Similarly, evaluators can compare collaborative efforts to theory, but causal links between theory and outcomes are challenging to prove. These strategies pose potential barriers for evaluators attempting to generate lessons learned or program recommendations. Principles-focused evaluation, on the other hand, provides a more flexible set of tools to document change and adapt programming as it unfolds.

5. CONCLUSIONS

In short, principles-focused evaluation draws on systems-thinking and developmental evaluation approaches that use evaluative logic, data collection, and reporting to inform the growth and adaptation of programs. We argue that this approach to evaluation is better positioned to overcome the common constraints to evaluating conservation success, including unclear objectives, ineffective information management, the long time frames of conservation outcomes, and lack of incentives for evaluation that come with managing conservation projects in a changing global climate. Conservation grazing in Wisconsin and the effort to develop, implement, and monitor new management on public land provides an example of how this framework for evaluation could provide a useful way to integrate evaluation into collaborative program development. This study provides a brief window to examine how shared principles can be developed from project materials and activities, and strategies to generate the practices and indicators that could be used to track them. Documenting learning, innovation, and unexpected changes throughout collaborative management can improve communication, planning, and facilitate more successful partnerships in conservation agriculture.

6. TABLES

Table 1. Examples of evaluation criteria in collaborative natural resources management (adapted from Conley and Moote, 2003).

Process criteria	Environmental outcome criteria	Socioeconomic outcome criteria
• Broadly shared vision • Clear feasible goals • Inclusive participation • Open, accessible, transparent process • Clear, written plan • Consensus-based decision-making • Consistent with laws and policies	• Improved habitat • Land protections • Improved land management practices • Biological diversity preserved or increased • Soil and water resources are conserved and enhanced	• Relationships built or strengthened • Increased trust • Improved knowledge or understanding • Increased employment • Improved capacity for conflict resolution

Table 2. The organizational mission statements of the Wallace Center Pasture Project, Wisconsin Department of Natural Resources, and the University of Wisconsin-Madison, and proposed principles to evaluate their shared activities in the implementation and monitoring of grazing management on public lands. The mission statements are coded 1-4 to indicate where they correspond with the themes of the proposed evaluable principles.

Wisconsin Department of Natural Resources (2018)	Wallace Center Pasture Project (2011)	University of Wisconsin-Madison (1988)
"Our mission: To protect and enhance our natural resources: our air, land and water; our wildlife, fish and forests and the ecosystems that sustain all life (2). To provide a healthy, sustainable environment and a full range of outdoor opportunities (4). To ensure the right of all people to use and enjoy these resources in their work and leisure (4). To work with people to understand each other's views (1) and to carry out the public will (3). And in this partnership consider the future and generations to follow (2)."	"The Pasture Project exists to increase the acreage in the Upper Mississippi River Basin that is under more environmentally-sustainable management (2). The primary ways we do this are: By helping farmers and landowners integrate livestock and rotational grazing on their farms (1). By supporting the network (3) of farmers and advocates promoting soil health and the many practices that develop it (1). By directly tackling major educational, political, economic, and social barriers (3) to reintegrating livestock (4)."	"The primary purpose of the University of Wisconsin-Madison is to provide a learning environment in which faculty, staff and students can discover, examine critically, preserve and transmit the knowledge (3), wisdom and values (1) that will help ensure the survival of this and future generations and improve the quality of life for all (4) . The university seeks to help students to develop an understanding and appreciation for the complex cultural and physical worlds (2) in which they live and to realize their highest potential of intellectual, physical and human development (1)."

Principles that unite work by these three organizations:

1. Encourage learning and increase public knowledge;
2. Preserve and improve natural resources to benefit future generations;
3. Support organizational connections and new collaborations;
4. Contribute to the public quality of life.

Table 3. Core principles and example practices and indicators that could be used to measure the activities and success of grazing management and collaboration in Wisconsin.

Principles	Practices (examples)	Indicators (examples)
1. Encourage learning and increase public knowledge	• Identify key barriers and opportunities in grazing management through collaborative research; • Share findings through reports, bulletins, and articles, press releases; • Provide opportunities for public input and dialogue;	• Completion of research projects • Publications • Proposals • Presentations, demonstrations, and pasture walks
2. Preserve and improve natural resources to benefit future generations	• Implement sustainable land management practices that support a variety of ecosystem services; • Increase habitat heterogeneity and biodiversity; • Maintain or increase population of native species;	• Documented habitat and wildlife goals • Selection process for management tools • Progress toward goals • Evaluation and adaptation of management practices
3. Support organizational connections and new collaborations	• Build institutional knowledge about grazing practices, contracts, and outreach; • Create opportunities for cross-organizational communication, discussion, and input;	• Number and type of organizations involved or engaged in management • Strength or frequency of interactions • Processes or projects from collaboration
4. Contribute to the public quality of life	• Increase access to resources that enable public education and recreation; • Engage with local communities about grazing	• Public perception of the value of conservation agriculture • Public use or interest in grazing sites

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8. APPENDIX

Figure 1. Memorandum of Understanding between the WDNR and UW-Madison research team for the grazing public lands project.

MSN191452 Rickenbach

Memorandum of Understanding
between the
Wisconsin Department of Natural Resources (WDNR)
and
the Board of Regents of the University of Wisconsin System (University)
on behalf of the
Agroecology Program

I. **Purpose:** The University and WDNR enter into this agreement to provide for active cooperation in research of the opportunities and challenges associated with grazing public grasslands of Wisconsin. This collaboration is a result of, but not limited to, a USDA Hatch-funded research project (MSN169238) entitled "Understanding Opportunities and Challenges Associated with Grazing Public Grasslands of Wisconsin" running from October 1, 2014 to September 30, 2019.

II. **Objectives:**

1. Evaluate the effectiveness of rotational grazing strategies on woody species cover and density, forage production and quality, herbaceous plant cover and composition, and the grassland bird community in three WDNR Grassland Conservation Areas.
2. Assess social and institutional opportunities and barriers to implementing private grazing on WDNR lands.
3. To the extent allowed by law, make available to resource managers, landowners, other researchers, and other interested public, such facts, methods, literature and new findings discovered through this research and disseminate research findings through the publication of reports, bulletins, circulars, and articles, and including scientific, technical, semi-popular and popular media; and
4. Assess cost effectiveness of grazing techniques in comparison to other land management tools.

III. **Covenants of Agreement**

A. **The University agrees to:**

1. Recognize as "participating collaborators" personnel of the WDNR by acknowledging the work of and partnership with WDNR in public materials about the joint project as appropriate;
2. Provide a study plan for the research related to this MOU that is in compliance with state laws and WDNR regulations, policies and management objectives for the property where the grazing will occur;
3. Provide input for the grazing plan at each site to ensure that the needs of the research are met;
4. Designate staff to provide leadership and cooperation in planning, developing, and executing research, demonstration projects, education, publications and other outreach activities;
5. Obtain and apply foliar herbicide by certified herbicide applicators for herbicide suppression treatment;
6. When present on WDNR property, leave grazing parcel perimeter fencing and other infrastructure as they find it and avoid disturbing livestock;
7. Share experimental results from the research under this MOU with WDNR;
8. Call meetings with appropriate WDNR staff for the purpose of coordinating research and outreach activities;
9. In consultation with WDNR, lead and collaborate with other university organizations in on-going outreach (to the public) and in-reach (to other researchers);
10. Obtain all permits and approvals required by law to conduct the research;
11. Maintain records generated for or utilized to implement this MOU for a period of four (4) years following the end date of the MOU;
12. Provide WDNR with labor and materials mutually deemed necessary for experimental observation; and
13. Not impede WDNR or public access to WDNR lands.

B. **The WDNR agrees to:**

1. Recognize as "participating collaborators" personnel of the University by acknowledging the work of and partnership with The University in public materials about the joint project as appropriate;

2. Review and approve managed grazing plans to ensure their compliance with state laws and WDNR regulations, policies and management objectives for the property where the grazing will occur;
3. Provide and construct at its own expense, through contract or pursuant to an agreement with grazers a perimeter fence for grazing parcels in accordance with managed grazing plans on the properties where grazing will occur;
4. Oversee grazers' adherence to the managed grazing plan and take any enforcement action allowed by law as deemed appropriate by the WDNR;
5. Provide machinery and personnel to mow/burn portions of the grazing paddocks according to the specifications of managed grazing plans; post informational/educational signage on WDNR lands impacted by the project to ensure appropriate public notification of management activities;
6. Assess cost effectiveness of grazing techniques in comparison to other land management tools.
7. Provide appropriate permits and authorizations as required for conducting work under this MOU on WDNR lands;
8. To the extent allowed by law and consistent with WDNR policies and management objectives for a property, allow unimpeded access of researchers, equipment and vehicles as necessary to conduct this research on WDNR lands;
9. Provide logistical support to researchers (e.g., mowing of access and parking areas, necessary permits for vehicle and equipment access);
10. Collaborate in planning, developing, and executing research, demonstration projects, education, publications and other outreach activities;
11. Collaborate in on-going outreach (to the public) and in-reach (to other researchers); and
12. Subject to DNR approval, allow installation of semi-permanent structures for research purposes and vet such structures for compliance to legal and managerial requirements.

C. **It is mutually agreed:**

1. All activities performed pursuant to this MOU shall be implemented in a joint and collaborative manner between both parties, unless otherwise specified;
2. Specific activities to be carried out, including timeframes and deadlines, shall be mutually agreed upon by the parties;
3. Managed grazing plans may be reviewed and revised by mutual agreement of the parties, except that revisions that are necessary to maintain compliance with state laws and WDNR regulations, policies and management objectives for the property for which the plan will apply may be made by WDNR following notice to University.
4. To the extent allowed by law, the parties may exchange information necessary to inform one another and interested stakeholders of plans, progress, needs and trends related to the subject of and activities conducted pursuant to this MOU;
5. The parties shall jointly and annually evaluate the overall success and effects of the project; and
6. No managed grazing plan may be implemented on any property owned or managed by WDNR without first seeking the approval of the appropriate WDNR personnel; such plans shall be compliant with state laws and WDNR regulations, policies and management objectives for the property where the grazing will occur.

IV. **Data.** Any data generated from this project will be stored and maintained by the parties for a period of two years following the expiration or termination of this MOU, including any extensions. To the extent allowed by law, data generated from this project shall be shared by and between the parties upon the request of one party to the other. All data and works of authorship produced or generated by the University under this MOU shall remain the property of the University's Principal Investigator with irrevocable right to publish, reproduce, distribute and use in any manner and for any purpose. Authorship on publications may be independent or joint as appropriate and as decided by participating collaborators directly involved in research and outreach activities; and credit for cooperation of participating collaborators will be given where appropriate.

V. **Independent Status.** Each participating collaborator recognizes they are independent for all purposes, including worker's compensation.

VI. **Non-Binding Agreement**. This MOU is non-binding and is not a contract for implementation of activities

VII. **Effective Date**. This MOU shall begin on October 1, 2015, and end on September 30, 2017. This MOU may be renewed or extended upon mutual written agreement and signature of all parties. While the agreement covers a 4-year period, the project may be continued if in the best interest of both parties decided after mutual consent and signature to extend the agreement for an additional period of time.

VIII. **Termination**. Either Party, through their respective representatives, may terminate their participation in this MOU. In such event, termination will take place upon thirty (30) day written notice to the other parties. During the thirty (30) day period of notice, all parties shall make efforts to wrap up any ongoing activities conducted pursuant to this MOU.

IX. **Maintenance of Records.** Each institution shall be responsible for maintaining its own records of activities undertaken subsequent to this MOU and have financial management for their own costs incurred.

X. **Obligations**. This MOU does not obligate either party to work exclusively with the other or constitute either organization the agent of the other. Nothing herein shall be deemed to constitute a legal or contractually binding partnership or joint venture between the parties. No financially binding commitments will be transferred between the Parties as a result of this MOU.

XI. **Contact Information.** The following contact information should be utilized for changes, questions and other administrative matters:

UW Madison Administration Matters:	Research & Sponsored Programs 21 N. Park Street, Suite 6401 Madison, Wisconsin 53715-1218 preaward@rsp.wisc.edu 608-262-3822
UW Madison Technical Matters:	Dr. Mark Rickenbach College of Agricultural & Life Sciences Forest & Wildlife Ecology 226 Russell Laboratories, 1630 Linden Drive Madison, Wisconsin 53706 mark.richenbach@wisc.edu 608-263-6710
Wisconsin DNR	Wisconsin Department of Natural Resources Tim Lizotte, Public Lands Specialist 101 South Webster Street Madison, WI 53706 Timothy.Lizotte@wisconsin.gov

XII. Signatures

Wisconsin Department of Natural Resources

Name: Cathy Stepp
Title: Secretary, Wisconsin DNR
Date: 5-24-2016

Board of Regents of the University of Wisconsin System

Name: Robert Gratzl
Title: Managing Officer,
Research & Sponsored Programs
Date: 6/1/16

UMI Abstract

EVALUATING TOOLS AND TRADEOFFS FOR SUCCESSFUL GRAZING PARTNERSHIPS ON WISCONSIN PUBLIC GRASSLANDS

Greta K. Landis

Under the supervision of Professor Randall D. Jackson, Environment & Resources
Laura Paine, Paine Family Farm and Senior Outreach Specialist, Agronomy
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The temperate grasslands and prairies of North America are critical ecosystems in changing global climate. Their perennial vegetation cover and extensive root systems improve soil structure and water quality, foster biodiversity and microbial activity, and, under the right conditions, sequester carbon. As conventional agricultural systems of livestock and commodity crop production in the United States become less and less environmentally and economically viable, there is increasing interest in bringing grassland systems back into beef and dairy production, moving animals back onto the landscape through managed grazing. However, a largescale transition to grassland-based agriculture that balances agricultural priorities with other ecosystem services cannot rely on individual efforts. This agroecological transformation will require partnerships, bringing together public grassland managers, state agencies, and nonprofits alongside livestock farmers and agricultural businesses.

The broad objective of this work was to assess the key tradeoffs in public-private grazing partnerships and explore tools that can make grazing on public grasslands a successful strategy to encourage conservation in agricultural production. Using a pilot initiative of grazing cattle on public-access wildlife areas in Wisconsin, this dissertation investigated a diverse set of

considerations for partnerships. We explored the influence of public perception in public-private agricultural management initiatives. We considered strategies to assess suitability of grasslands for grazing initiatives and monitor habitat change, using traditional field measurements and low-altitude airborne hyperspectral imaging spectroscopy. Finally, we discussed program evaluation approaches that can help capture progress and learning in the complex, dynamic context of managed grazing and other conservation efforts. Throughout this work we collaborated with public grassland managers and livestock producers to understand the processes and potential outcomes of grazing management, as well as the information needed for key decisions throughout grazing implementation. The results of this dissertation demonstrate the necessity of a transdisciplinary approach to partnerships in conservation and land management, and illustrate a set of applied tools to help those partnerships successfully transform our agricultural systems.