Plant Community Dynamics under Multiple Land Management Strategies

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Summary

We evaluated the effects of three different land management strategies on plant community dynamics. The land management strategies we evaluate are patch-burn grazing and modified twice-over rest rotation grazing, which are designed to create structural and compositional heterogeneity of plant communities, and conventional season-long grazing. Here we present results from 2019 growing season.

Introduction

Fire and grazing are naturally occurring disturbances that, along with climate and topo-edaphic differences, have been shaping plant communities for millions of years (Bowman et al., 2007; Bond and Keeley, 2005; Fuhlendorf and Smeins, 1998, 1999). Fire and grazing historically interacted with each other, otherwise known as pyric-herbivory, in the Great Plains, creating spatial and temporal heterogeneity in plant communities (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2009).

Pyric-herbivory occurs when large herbivores, such as bison or cattle, preferentially graze areas that recently have burned due to new growth being more palatable and nutritious (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009; Knapp et al., 1999; Vermeire et al., 2004). Large herbivores focus their grazing efforts on recently burned patches, which allows patches that previously were burned and grazed to recover (Fuhlendorf and Engle, 2001, 2004; Gates et al., 2017). These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and the probability that this patch will burn again, repeating the cycle of this fire-grazing interaction (Fuhlendorf and Engle, 2001, 2004).

Plant community composition and structure vary significantly in response to pyric-herbivory (Fuhlendorf and Engle, 2001, 2004). When fire burns across a grassland, it creates non-uniform, discrete patches of plant communities that vary in successional stages, forming a shifting mosaic of plant communities through time and space, which produces an overall diverse landscape (Fuhlendorf et al., 2009).

Pyric-herbivory produces heterogeneous landscapes of various successional stages of plant communities that differ in structure and biomass, and creates an overall diverse plant community (Fuhlendorf and Engle, 2001, 2004). Recently burned and grazed sites see an increase in forbs, annual species and bare ground, with a reduction in litter and graminoid species.

Because large herbivores concentrate grazing in burn patches, this allows for graminoids in past burn patches to recover from the previous fire and grazing (Fuhlendorf and Engle, 2004). The changes in structure and composition of a plant community creates heterogeneity on the landscape and in habitat, which in turn supports a diverse system of flora and fauna (Fox and Fox, 2000; Fuhlendorf et al., 2010; Ostfeld et al., 1997; Ricketts and Sandercock, 2016).

Present land management of grassland systems promotes uniform utilization that creates homogenous landscapes (Briske et al., 2003; Fuhlendorf et al., 2009). Due to present land management practices, fire and grazing have been decoupled, which has led to homogenous systems of non-native grasses, such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Dillemuth et al., 2009; Toledo et al., 2014). Although uniform moderate grazing can be beneficial to ground cover and soil disturbance, it fails to create heterogeneity of habitat structure essential for niche species at extreme ends of the habitat structural gradient (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016).

A solution to the decoupling of fire and grazing is the restoration of pyric-herbivory as a land management tool (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009). One such pyric-herbivory-based land management system is a patch-burn grazing system. It combines the historical elements of pyric-herbivory by creating discrete burned patches in a pasture that vary spatially and temporally, creating patches of recently burned, unburned and transitional areas (Fuhlendorf and Engle, 2001, 2004). This system of creating spatial and temporal changes on a landscape produces a shifting mosaic of plant communities, a wide variety of habitat structure and increased biodiversity.

To better understand the impacts of a patch-burn grazing system, we examine whether it can serve as a suitable conservation-based form of livestock management. This study will use replicated treatments to examine plant community measurements, such as diversity, richness, evenness and biomass production, to evaluate what effect focal grazing and fire, and rotational grazing with differing levels of grazing intensity have on these areas, and whether these grazing treatments create a shifting mosaic in the plant community and on a landscape level. In addition, we will evaluate what effect these grazing treatments have on Kentucky bluegrass and other non-native plant species.

Methods

Study Area

This study is conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains. This area is characterized by irregular, rolling plains and depressional wetlands.

The climate is characterized as temperate, and receives an average of 40.3 centimeters (51.9 inches) of precipitation and has an average temperature of 5.0 C (41.0 F) (1991-2019, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al., 2018).

Treatment Structure

Three treatments are applied to this study area, in which we compare three intervals of time since fire and non-burned areas of the patch-burn grazing treatment (PBG); two intervals of four differing grazing intensities of heavy, full, moderate and rested; and a season-long grazing treatment (SLG). Each 160-acre pasture used in these treatments is split into eight 20-acre plots with eight PBG pastures; 16- to 40-acre pastures with four grazed heavily, four grazed at full use, four grazed moderately and four rested; and four SLG pastures. All pastures are stocked with cow-calf pairs to achieve approximately a 40% to 60% degree of disappearance at a harvest efficiency of 30%.

(c) The patch-burn grazing treatment is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf and Engle, 2001). Prescribed fire is applied to 12 plots in the spring of each year, with one to two plots being burned per pasture. Data from this treatment is analyzed by zero, one and two years since fire, and by non-burned plots.

(d) The season-long grazing treatment is intended to replicate a conventional cow-calf grazing management system and will serve as a controlled comparison for other treatments.

(e) *The modified twice-over rest rotation grazing* was designed to be similar to the patch-burn grazing treatment in that it is designed to produce structural heterogeneity across a grazing unit. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilized fencing to dictate cattle distribution and influence grazing. The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete sub-pastures that cattle cannot graze freely and grazed from mid-May to late October. Across the sub-pastures, cattle are rotated through twice and allowed to graze for approximately 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy use (60% to 80% disappearance of graminoid species), full use (40% to 60% disappearance of graminoid species), moderate use (20% to 40% disappearance of graminoid species) and rested sub-pastures, respectively. The first rotation uses 40% of the grazing days and the second rotation 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture,

heavy-use will become the rested pasture, moderate-use will become the full-use pasture and rested becomes moderate-use pasture. This rotation will create annual heavy disturbance in one sub-pasture and reduce annual heavy disturbance in the same location, which could result in changes to forage quality and loss of plant species (Fuhlendorf et al., 2017).

Data Collection

All vegetation data are measured using ¼ meter^2 frames. Vegetation composition will be assessed using canopy cover as a proxy. Vegetation cover is measured using 60-meter (m) transects per each plot and taking 31 measurements along each transect. Standing biomass will be collected by sampling four 1 m^2 exclosures per plot.

Three frames are sampled within each exclosure and three frames are sampled outside of each exclosure. Measuring the difference in biomass between in exclosure biomass and out-of-exclosure biomass, we calculate the degree of disappearance.

Results: Update

Biomass and Degree of Disappearance

Standing crop biomass for the season-long treatment averaged 4,985 pounds per acre (lb/ac), while the patch-burn treatment ranged from 4,133 to 4,559 lb/ac (Table 1). Nonburn, and one and two years since fire had about the same biomass, while the most recently burned plots, the zero years since fire, had the least in the patch-burn treatment.

Herbage production was lowest in the 2019 heavy-use treated pasture, compared with the 2019 full- and moderate-use treated pastures on the loamy ecological site (Table 2). We found no difference in herbage production by pasture use on the shallow loamy ecological site.

The degree of disappearance averaged 27% in the season-long treatment. In the patch-burn treatment, the degree of disappearance averaged 34% to 35% in non-burned and two-years-since-burn patches, compared with 53% and 42% in recently burned and one-year-since-burn patches (Figure 1). Within the modified twice-over rest rotation grazing treatment, the degree of disappearance for graminoid species was 57.2%, 40% and 31.7% in the heavy-, full- and moderate-use pastures, respectively (Figure 2).

Plant Community and Species Response

Diversity, species richness and evenness were all higher in the patch-burn treatment and modified twice-over rest-rotation grazing treatments compared with the season-long treatment (Table 1). Kentucky bluegrass (Figure 3), smooth brome (Figure 4) and snowberry (Figure 5) composition was lowest in recently burned plots, compared with all years-since-fire and nonburn patches. In the patch-burn grazing treatment, all species were lower in composition, with the exception of snowberry, which had similar composition in two-years-since-fire plots, compared with the season-long grazing treatment.

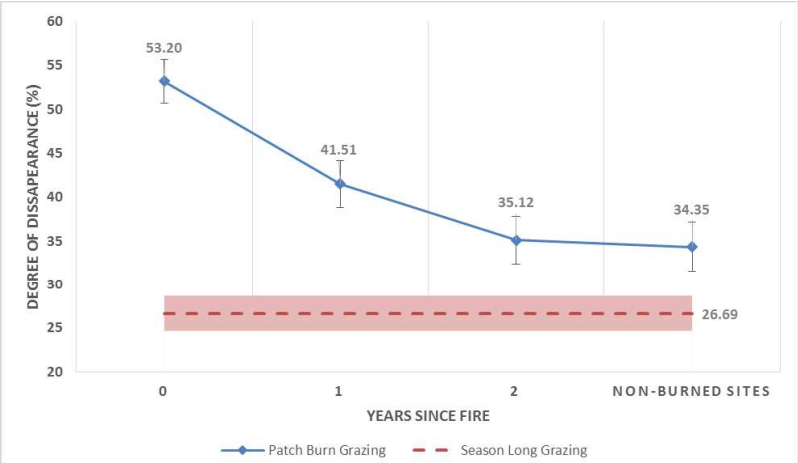

Figure 1. Degree of disappearance of patch-burn grazing treatment, showing change with time since fire, and season-long grazing treatment shown as a baseline at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

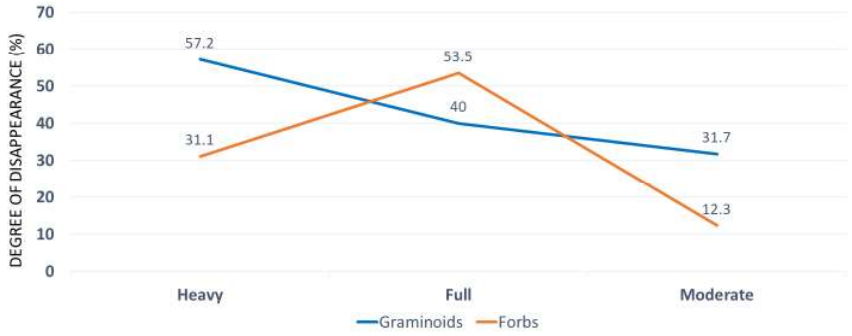

Figure 2. Degree of disappearance at end of the grazing period on the modified twice-over rest-rotation grazing treatment by pasture use (heavy – 60-80%; full – 40-60%, moderate - 20-40%) at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

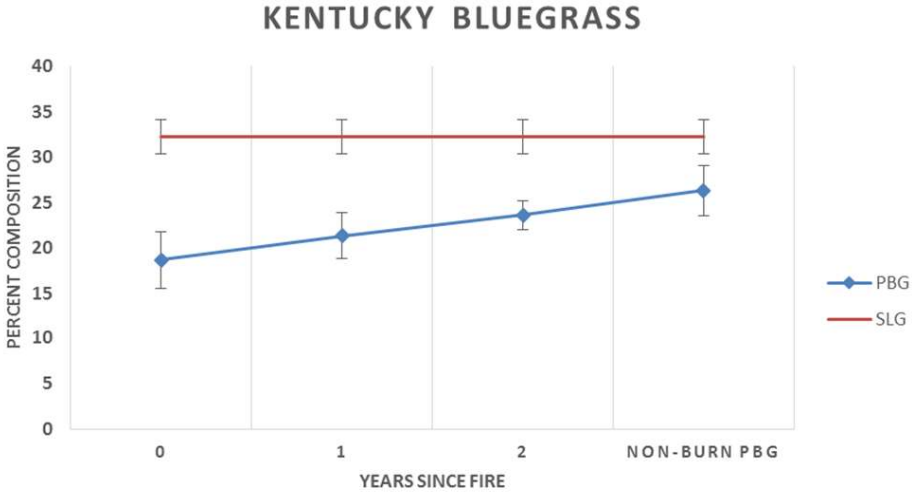

Figure 3. *Poa pratensis* (Kentucky bluegrass) compostion in patch-burn grazing treatment (PBG) and season-long grazing treatment (SLG).

Figure 4. *Bromus inermis* (smooth brome) composition in patch-burn grazing treatment (PBG) and season-long treatment (SLG)

Figure 5. *Symphoricarpos orbiculatus* (snowberry) composition in patch-burn grazing treatment (PBG) and season-long treatment (SLG)

Table 1. Mean effect (mean ± SE) each treatment had on four plant community measurements, with patch-bun grazing and modified twice-over rest-rotation grazing being split up by years since fire and pasture use, respectively, at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

Plant Community Measurements				
Treatment	**Diversity[1]**	**Richness**	**Evenness**	**Standing Crop Biomass (lbs/ac)**
Season Long Grazing	1.95 ± 0.07	28.4 ± 1.58	0.59 ± 0.01	4,985 ± 123
Patch-Burn Grazing *Years Since Fire:*				
0	2.70 ± 0.07	45.5 ± 2.11	0.71 ± 0.01	4,133 ± 213
1	2.68 ± 0.09	40.2 ± 2.21	0.73 ± 0.01	4,559 ± 221
2	2.61 ± 0.1	41.7 ± 2.16	0.70 ± 0.02	4,462 ± 200
Non-burned	2.56 ± 0.09	40.5 ± 1.66	0.70 ± 0.02	4,326 ± 163
Modified Twice-over Rest-rotation Grazing *Pasture Use:*				
Moderate	3.42 ± 0.11	55.25 ± 3.33	0.85 ± 0.02	4,166 ± 189
Full	3.41 ± 0.09	50.75 ± 3.35	0.87 ± 0.02	4,504 ± 238
Heavy	3.52 ± 0.03	57 ± 2.42	0.87 ± 0	3,640 ± 148
Rested	3.48 ± 0.06	57.25 ± 3.61	0.86 ± 0.01	4,044 ± 295

[1] Shannon-Weaver Diversity Index

Table 2. Mean pasture use effect on total herbage production (mean ± SE) in the modified twice-over rest rotation grazing treatment at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

2019 Pasture Use[1]	2018 Pasture Use	Loamy Ecological Site[2]	Shallow Loamy Ecological Site[2]
Rested	Heavy	4,044 ± 295.3	3,552 ± 168.5
Moderate	Rested	4,166 ± 189.2	4,050 ± 307.4
Full	Light	4,504 ± 238.0	3,719 ± 211.3
Heavy	Full	3,640 ± 147.6	3,660 ± 362.1

[1]Rested pasture was not grazed for one growing season, moderate use pasture were grazed at a planned 20-40% degree of graminoid disappearance, full use pasture were grazed at a planned 40-60% degree of graminoid disappearance, and heavy use pasture use pasture were grazed at a planned 60-80% degree of graminoid Disappearance.
[2]Total herbage production will not include standing litter.

Literature Cited

Bond, W.J., and J.E. Keeley. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology & Evolution 20:387-394.

Bowman, D., J.K. Balch, P. Artaxo, W.J. Bond, J.M. Carlson, M.A. Cochrane, C.M. D'Antonio, R.S. DeFries, J.C. Doyle, S.P. Harrison, F.H. Johnston, J.E. Keeley, M.A. Krawchuk, C.A. Kull, J.B. Marston, M.A. Moritz, I.C. Prentice, C.I. Roos, A.C. Scott, T.W. Swetnam, G.R. van der Werf and S.J. Pyne. 2009. Fire in the earth system. Science 324:481-484.

Briske, D.D., S.D. Fuhlendorf and F.E. Smeins. 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. Journal of Applied Ecology 40:601-614.

Dillemuth, F.P., E.A. Rietschier and J.T. Cronin. 2009. Patch dynamics of a native grass in relation to the spread of invasive smooth brome (Bromus inermis). Biological Invasions 11:1381-1391.

Fox, B.J., and M.D. Fox. 2000. Factors determining mammal species richness on habitat islands and isolates: habitat diversity, disturbance, species interactions and guild assembly rules. Global Ecology and Biogeography 9:19-37.

Fuhlendorf, S.D., and Smeins, F.E. 1998. Soil heterogeneity influence on plant species response to grazing within a semi-arid savanna. Plant Ecol. 138, 89-96.

Fuhlendorf, S.D., and Smeins, F.E. 1999. Scaling effects of grazing in a semi-arid grassland. Journal of Vegetation Science 10, 731-738.

Fuhlendorf, S.D., and D.M. Engle. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. Bioscience 51:625-632.

Fuhlendorf, S.D., and D.M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604-614.

Fuhlendorf, S.D., D.M. Engle, J. Kerby and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588-598.

Fuhlendorf, S.D., D.E. Townsend, R.D. Elmore and D.M. Engle. 2010. Pyric-herbivory to promote rangeland heterogeneity: evidence from small mammal communities. Rangeland Ecology & Management 63:670-678.

Fuhlendorf, S. D., R. W. S. Fynn, D. A. McGranahan, and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management. In: D. D. Briske (ed.). Rangeland Systems: Processes, Management and Challenges. p. 169-196.

Gates, E.A., L.T. Vermeire, C.B. Marlow and R.C. Waterman. 2017. Fire and Season of Postfire Defoliation Effects on Biomass, Composition, and Cover in Mixed-Grass Prairie. Rangeland Ecology & Management 70:430-436.

Knapp, A.K., Blair, J.M., Briggs, J.M., Collins, S.L., Hartnett, D.C., Johnson, L.C., Towne, E.G., 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49, 39–50.

Limb, R.F., T.J. Hovick, J.E. Norland and J.M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. Agriculture Ecosystems & Environment 257:113-119.

Ostfeld, R S., S.T. Pickett, M. Shachak and G.E. Likens. 1997. Defining scientific issues. In: S.T. Pickett, R.S. Ostfeld, M. Shachak and G.E. Likens [EDS.]. The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. New York, N.Y., USA: Chapman and Hall. p. 3–10.

Ricketts, A.M., and B.K. Sandercock. 2016. Patch-burn grazing increases habitat heterogeneity and biodiversity of small mammals in managed rangelands. Ecosphere 7.

Toledo, D., M. Sanderson, K. Spaeth, J. Hendrickson and J. Printz. 2014. Extent of Kentucky bluegrass and its effect on native plant species diversity and ecosystem services in the Northern Great Plains of the United States. Invasive Plant Science and Management 7:543-552.

Vermeire, L.T., Mitchell, R.B., Fuhlendorf, S.D., Gillen, R.L., 2004. Patch burning effects on grazing distribution. Rangeland Ecology & Management 57, 248–252.