Rangeland Ecol Manage 64:659–663 | November 2011 | DOI: 10.2111/REM-D-10-00192.1

Research Note

Pyric–Herbivory and Cattle Performance in Grassland Ecosystems

Ryan F. Limb,[1] Samuel D. Fuhlendorf,[2] David M. Engle,[3] John R. Weir,[4] R. Dwayne Elmore,[5] and Terrance G. Bidwell[6]

Authors are [1]Assistant Professor, Department of Rangeland Ecology and Management & Eastern Oregon Agricultural Research Center, Oregon State University, La Grande, OR 97850, USA; [2]Distinguished Professor; [3]Regents Professor; [4]Research Associate; [5]Assistant Professor and Extension Specialist; and [6]Professor and Extension Specialist, Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK, 74078 USA.

Abstract

Achieving economically optimum livestock production on rangelands can conflict with conservation strategies that require lower stocking rate to maintain wildlife habitat. Combining the spatial and temporal interaction of fire and grazing (pyric–herbivory) is a conservation-based approach to management that increases rangeland biodiversity by creating heterogeneous vegetation structure and composition. However, livestock production under pyric–herbivory has not been reported. In both mixed-grass prairie and tallgrass prairie, we compared livestock production in pastures with traditional fire and grazing management (continuous grazing, with periodic fire on tallgrass prairie and without fire on mixed-grass prairie) and conservation-based management (pyric–herbivory applied through patch burning) at a moderate stocking rate. Stocker cattle weight gain, calf weight gain, and cow body condition score did not differ ($P > 0.05$) between traditional and conservation-based management at the tallgrass prairie site for the duration of the 8-yr study. At the mixed-grass prairie site, stocker cattle gain did not differ in the first 4 yr, but stocker cattle gained more ($P \leq 0.05$) on conservation-based management and remained 27% greater for the duration of the 11-yr study. Moreover, variation among years in cattle performance was less on pastures under conservation management. Traditional management in mixed-grass prairie did not include fire, the process that likely was associated with increased stocker cattle performance under conservation management. We conclude that pyric–herbivory is a conservation-based rangeland management strategy that returns fire to the landscape without reduced stocking rate, deferment, or rest.

Resumen

Lograr el óptimo económico en la producción ganadera en pastizales puede interferir con estrategias de conservación que requieren baja carga animal para mantener el hábitat para la fauna silvestre. Combinando de manera espacial y temporal la interacción de fuego y pastoreo (fuego-herbivorismo) es un concepto con fundamente en la conservación para manejar el aumento de la biodiversidad del pastizal creando estructuras de vegetación y composición heterogéneas. Sin embargo, la producción de ganado bajo fuego-herbivorismo no se ha reportado. En ambas, praderas de pastos medianos y largos comparamos la producción ganadera en potreros con manejo tradicional de fuego y manejo del pastoreo (pastoreo continuo con periodos de fuego en praderas de pastos largos y manejo basado en la conservación (fuego-herbivorismo aplicado a través del quemas en parches) con carga animal moderada. Ganancia de peso en novillos en repasto, ganancia de peso en becerros y el grado de condición corporal de la vaca no fueron diferentes ($P > 0.05$) entre el manejo tradicional y el conservador en el sitio de pasto largos en ocho años de duración del estudio. En el sitio de pastos mixtos la ganancia de peso de novillos no fue diferente en los primeros cuatro años pero, los novillos en repasto ganaron más ($P \leq 0.05$) en el manejo basado en la conservación y se mantuvieron con un 27% mayor en los once años de duración del estudio. Por otra parte, la variación entre años en el desempeño del ganado fue menor en los potreros bajo el manejo de conservación. El manejo tradicional en praderas mixtas no incluyeron el fuego, el proceso probablemente estuvo asociado al incremento en el desempeño de los novillos bajo el manejo de conservación. Concluimos que el fuego-herbivorismo es una estrategia de manejo basado en la conservación del pastizal que reincorpora al fuego en el paisaje sin reducir la capacidad de carga, diferimiento o descanso.

Key Words: biodiversity, conservation grazing, fire, heterogeneity, patch burn, vegetation structure

INTRODUCTION

Conservation of natural resources and promoting biodiversity is imperative to the long-term sustainability of rangeland resources, particularly on private lands, where profitable livestock production is a primary objective (West 1993). The normative view within the rangeland management profession is that proper grazing management requires spatially uniform moderate grazing, therefore minimizing excessively grazed and nongrazed areas (Vallentine 2001). Although spatially uniform moderate grazing may minimize soil disturbance and increase ground cover, and this might improve habitat for some faunal species, spatially uniform moderate grazing often fails to create sufficient habitat heterogeneity to support species with

Correspondence: Dr Ryan F. Limb, 205 Badgley Hall, One University Blvd, La Grande, OR 97850, USA. Email: ryan.limb@oregonstate.edu

Manuscript received 28 December 2010; manuscript accepted 2 June 2011.

requirements at both extremes of the vegetation structure gradient, thus constraining potential biodiversity (Knopf 1994; Fuhlendorf et al. 2006).

Rangelands are inherently diverse ecosystems capable of supporting multiple levels of trophic and taxonomic organization. Rangeland biodiversity, as outlined by West (1993), provides many essential ecosystem services dependent on sound land management. Mismanaged livestock grazing can lead to rangeland deterioration through shifts in species composition and modification of vegetation structure, negatively affecting biodiversity (O'Connor et al. 2010). Controlled livestock distribution and reduced grazing intensity can be implemented to enhance wildlife habitat and promote conservation of certain landscapes and some wildlife species. However, traditional approaches to rangeland management to enhance conservation are generally thought to reduce profits from livestock grazing enterprises because traditional approaches reduce the number of grazing animals (Dunn et al. 2010). Therefore, conservation-based livestock grazing practices that are both profitable and promote biodiversity are clearly needed (O'Connor et al. 2010).

Variability through space and time, an inherent trait of diverse ecosystems (Fuhlendorf and Engle 2004; Fuhlendorf et al. 2009), needs to be included in management decisions (Willis and Birks 2006). Combining the spatial and temporal interaction of fire and grazing (pyric–herbivory) is a conservation-based approach to management that increases rangeland biodiversity trophic levels and taxonomic orders by creating heterogeneous vegetation structure and composition (Fuhlendorf et al. 2006; Churchwell et al. 2008; Coppedge et al. 2008; Engle et al. 2008; Fuhlendorf et al. 2010). Discrete fires shifting in time across a landscape concentrates grazing while leaving unburned portions of the landscape largely undisturbed. The undisturbed areas have relatively tall and dense vegetation. Focal grazing on the recently burned areas maintains relatively short vegetation, and transition areas recovering from focal disturbance support diverse vegetation. The three different patch types create a structurally and compositionally heterogeneous landscape (Fuhlendorf and Engle 2001, 2004). Although biodiversity responses to pyric–herbivory are well documented, livestock performance under conservation-based land management with the use of pyric–herbivory has been untested.

Therefore, we compared performance of beef cattle under a conservation-based pyric–herbivory (described above) management to traditional (regionally) grazing management practices on mixed-grass prairie and tallgrass prairie in the southern Great Plains, United States. Although conservation management often entails reducing stocking rate or deferring grazing (Howe 1994; O'Connor et al. 2010), we neither reduced stocking rate nor deferred grazing under pyric–herbivory management because reducing stocking rate or deferring grazing would reduce cattle gain per unit area (Vallentine 2001). Because stocking rate was the same for the two treatments at each location, we assessed individual animal performance as the key performance comparison between treatments, assuming reduced per-head performance under pyric-herbivory management would render the practice unacceptable to managers of privately owned rangeland.

METHODS

The tallgrass prairie study area was located in north-central Oklahoma on the Oklahoma State University Research Range (lat 36°06′N; long 97°23′W) located 21 km southwest of Stillwater, Oklahoma (Stillwater hereafter). The Stillwater location (Fuhlendorf and Engle 2004; Limb et al. 2011) receives an average of 933 mm annual precipitation. The mixed-grass prairie study area was located in west central Oklahoma on the Oklahoma State University Marvin Klemme Range Research Station (lat 35°25′N; long 99°05′W) 15 km south of Clinton, Oklahoma (Klemme hereafter) in the Rolling Red Plains Resource area (Fuhlendorf et al. 2002; Limb et al. 2009) and receives an average of 778 mm annual precipitation. Both are study locations are dominated by eroded old fields that were abandoned by 1950.

Treatments were implemented in 1999 at both Stillwater and Klemme to compare traditional grazing practices in each region with the conservation-based pyric–herbivory approach with the use of a completely randomized experimental design. The management treatments are presented in detail in Table 1. Stocking rate was based on United States Department of Agriculture–Natural Resource Conservation Service (USDA-NRCS) recommended rates for Stillwater and Klemme, respectively. Stocker cattle were kept overnight without food and water to minimize forage and water weight before being weighed individually at the beginning (March) of each grazing season. To achieve recommended stocking rates, cattle (Stillwater $\bar{x} = 20$, Klemme $\bar{x} = 12$) were randomly placed on each treatment pasture for the duration of the grazing season. At the end of the grazing season (September) cattle were again kept overnight without food and water and individually weighed.

Seasonal grazing by stocker cattle at the Stillwater location was replaced with year-long grazing by cow–calf pairs ($\bar{x} = 8$) with no change in stocking rate in 2003. Cow body condition score (BCS) was determined for each animal monthly, at the Stillwater site, with the use of the 1–9 Herd scoring system (Herd and Sprott 1986). Calves were weighed within 24 h of birth and again at weaning (mid-October) to determine calf weight gain. A 20-mm-diameter supplemental protein pellet (40% protein by dry weight at 0.9 $kg \cdot animal^{-1} \cdot day^{-1}$) was provided at the Stillwater location when mean BCS began to decline and warm-season herbaceous vegetation growth stopped (November–March in traditional pastures and January–March only in conservation pastures).

We calculated the mean stocker weight gain and calf weight gain for each pasture each year. Monthly BCS was averaged within pastures to determine a mean annual score. We subjected annual means (stocker cattle gain and calf gain) and monthly mean BCS to a two-tailed *t* test (Steel et al. 1997) to determine if individual animal performance (gain or BCS) on pastures managed with conservation-based grazing differed from individual animal performance on traditionally managed pastures.

RESULTS

Performance of stocker cattle at Stillwater for traditionally grazed pastures did not differ ($P > 0.05$) from performance on pastures managed with conservation-based grazing over the 4-yr

Table 1. Comparison of experimental treatments of traditional and conservation-based management at Stillwater (tallgrass prairie) and Klemme (mixed-grass prairie). Pastures managed traditionally at Stillwater were burned in their entirety every 3 yr, and individual patches within pastures under conservation management were burned seasonally with a complete burn rotation every 3 yr. Traditionally managed pastures at Klemme were not burned, and individual patches within pastures under conservation management were burned every 4 yr in the spring. Animal unit months (AUM) were consistent between treatments at each location.

	Stillwater		Klemme	
Vegetation type	Tallgrass prairie		Mixed-grass prairie	
Management type	Traditional	Conservation	Traditional	Conservation
Fire return	3 yr	3 yr	None	4 yr
Fire season	Spring	Spring and summer	None	Spring
Patches	1	6	1	4
Replications	3	3	2	2
Mean pasture area (ha)	60	60	50	50
Animal unit	Yearling mixed-breed yearling stocker cattle (1999–2002) Cow–calf (2003–2006)		Yearling mixed-breed yearling stocker cattle	
Stocking rate	0.83 ha · AUM^{-1}		0.63 ha · AUM^{-1}	
Measurement	Yearling weight gain Cow body condition, calf weaning weight		Yearling weight gain	
Grazing season	15 March–15 September (1999–2002) Year-long (2002–2006)		15 March–15 September	
Study duration	1999–2006		1999–2009	

study period (Fig. 1). The range among years of weight gained by stocker cattle in traditionally grazed pastures (45 kg) was nearly 94% greater than the range among years of weight gained by stocker cattle in conservation-based pastures (23 kg). Similarly, calf weaning weight and cow BCS did not differ ($P > 0.05$) between traditional and conservation-based grazing for the 4-yr study period (Fig. 2). However, temporal variation in calf weaning weight was less under conservation-based management (variance = 81) than under traditional management (variance = 128). At our tallgrass prairie location, average livestock production did not differ among treatments, but conservation-based management again reduced the variability over years.

Performance of stocker cattle at Klemme did not differ in the first 4 yr of the study, but by the fifth year, 2003, stocker cattle gained more by an average of >18 kg per animal in the conservation-based grazing pastures than traditionally grazed pastures ($P \leq 0.05$), and gain averaged >22 kg per animal more for the remaining 7 yr of the study (Fig. 1). Temporal variation in stocker cattle weight gain did not differ between the two treatments. However, beginning in 2003, the mean difference between traditional and conservation pastures increased at a rate of 27% annually.

DISCUSSION

Profitability is generally considered an imperative on private rangelands to maintain the economic viability of a ranching operation depending on livestock grazing for income. However, rangeland and wildlife conservation strategies are often viewed as reducing cattle production, which decreases the likelihood of implementation without government cost-share or similar incentives (Langpap 2006). We compared cattle performance in pastures with traditional and conservation-based management. Our 8-yr study in a tallgrass prairie revealed that conservation-based management performed at least equal to traditional management. Furthermore, conservation-based management in mixed-grass prairie exceeded traditional management during the final 7 yr of the 11-yr study. Enhanced cattle performance on mixed-grass prairie likely resulted from recently burned areas that were available to cattle under conservation grazing, whereas cattle did not have access to recently burned areas under traditional management. Burning is not traditionally practiced in the mixed-grass prairie region, in part because woody-plant encroachment is relatively slow (Fuhlendorf and Smeins 1999).

The ecological interaction between grazing animals and fire historically created a patchy landscape supporting diverse assemblages of flora and fauna (Fuhlendorf and Engle 2001), but traditional management has decoupled the ecological interaction of fire and grazing so that stocking rate must be reduced to achieve diverse vegetation structure (Fuhlendorf et al. 2009; Limb et al. 2009). Even if individual animal performance increases, overall livestock production will decline if conservation management requires a reduction in stocking rate (McCollum et al. 1999; Vallentine 2001).

Fire is necessary to control woody plant encroachment in most North American grasslands (Archer 1994; Fuhlendorf and Smeins 1997), and fire enhances livestock performance by enhancing forage production, palatability, and crude protein content (Allen et al. 1976; McGinty et al. 1983). Fire, unlike other management tools, appears to return the greatest benefit when implemented as a regime that mimics the historic fire-disturbance processes. We found that the benefits of pyric–herbivory can be context dependent such that benefits may or may not be observed immediately. This was demonstrated when benefits of fire were not achieved early in the reintroduction of fire at Klemme, but enhanced cattle performance was observed following a complete fire rotation.

Seasonal nutrient deficiencies are common in rangeland forages across central and western North America (Williams 1953).

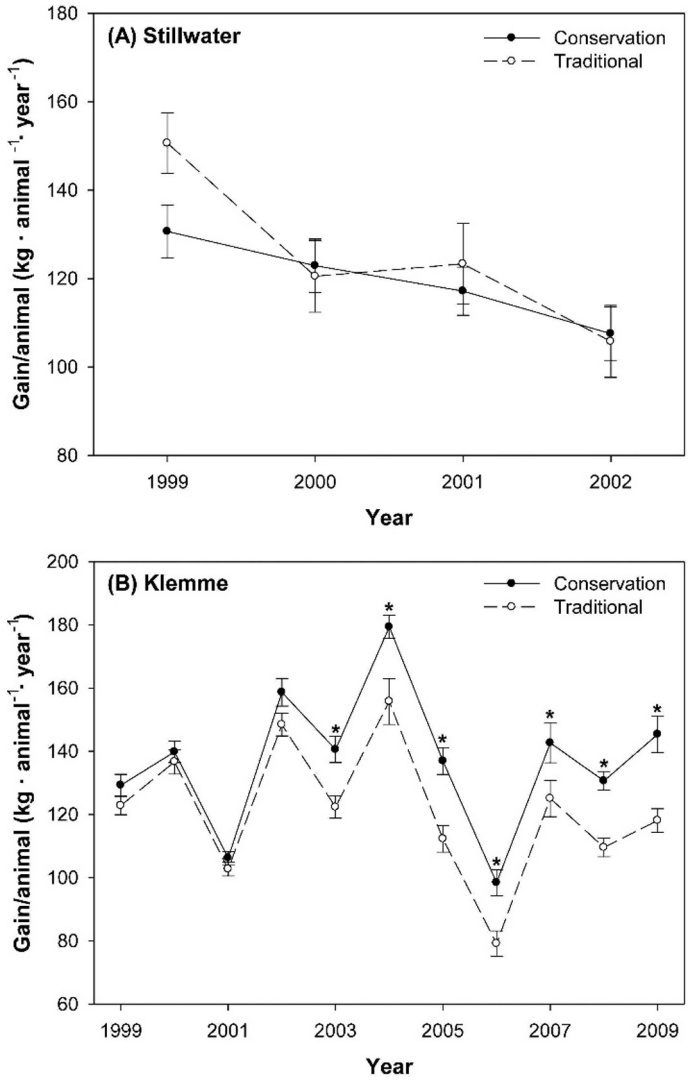

Figure 1. Stocker cattle weight gain at the (**A**) Stillwater site and the (**B**) Klemme site. Vertical lines represent ± one standard error. An asterisk (*) denotes statistical differences between conservation and traditional management ($P \leq 0.05$).

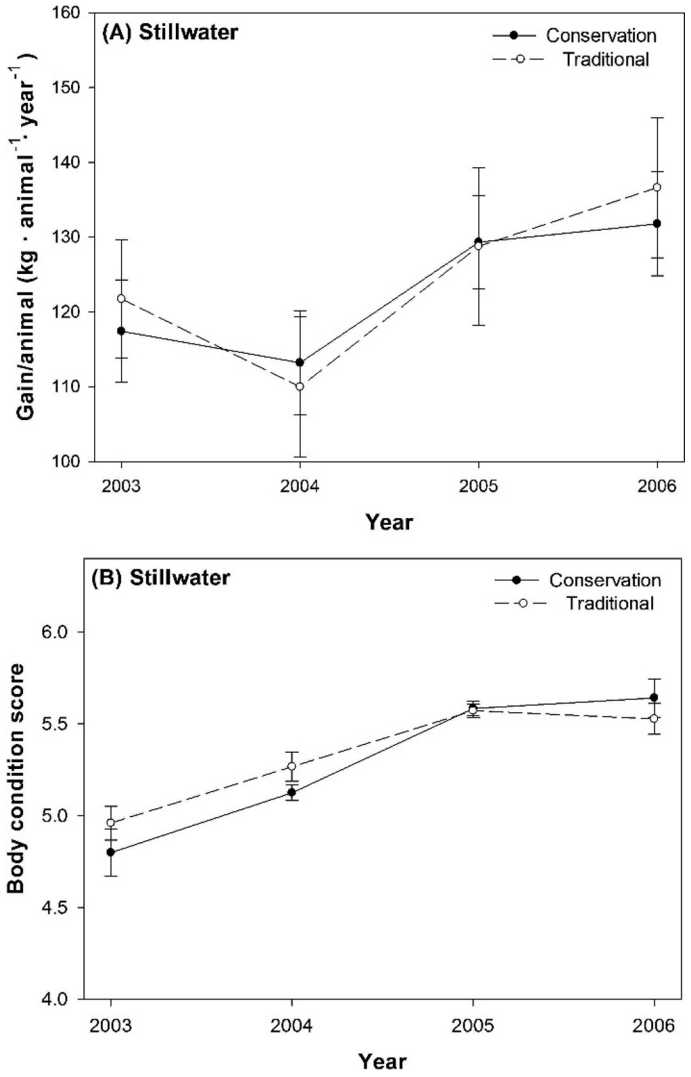

Figure 2. Calf weaning weight at the Stillwater site (**A**) and cow body condition score at the Stillwater site (**B**). Vertical lines represent ± one standard error.

Consequently, livestock producers must develop strategies that minimize supplemental inputs (DelCurto et al. 2000), which is the single largest factor influencing net return (Miller et al. 2001). Relatively frequent fire was incorporated into both land management strategies at Stillwater, and stocking rate was constant between treatments and years. However, the highly variable spatial pattern of fire in the conservation-based pastures provided continual access to relatively high-quality forage. As a result, supplemental feed requirements were approximately 40% less in conservation-based pastures to maintain acceptable livestock condition. Reduced feeding costs coupled with the ability to maintain stocking rates suggest that conservation-based grazing can promote biodiversity and support sustainable livestock production.

MANAGEMENT IMPLICATIONS

Conservation practices in grasslands have drawn attention recently and are likely to continue because of declining grassland obligate bird populations that require various plant structures and compositions (Sauer et al. 2008). Managers of privately owned rangeland are often reluctant to participate in conservation practices because they require stocking-rate reductions that reduce ranch profitability. Diversity at multiple trophic levels increased in the conservation-based pastures (Engle et al. 2008; Fuhlendorf et al. 2010), and the results of our study demonstrate that diversity can be enhanced (see previous pyric–herbivory studies) without reducing livestock production. These replicated long-term studies across two contrasting locations demonstrate that pyric–herbivory successfully returns fire to the landscape, which can limit woody-plant encroachment (Archer 1994), and enhances biodiversity without reducing livestock production that would result ordinarily from reduced stocking rates or deferment following fires. Results from this study also can serve as a platform for additional research related to livestock production and biodiversity. In particular, as outlined by Parr and Anderson (2006), more research is needed to address spatial relationships

(both patch size and arrangement) between landscape heterogeneity, biodiversity, and land management.

ACKNOWLEDGMENTS

This research was funded by the Oklahoma Agricultural Experiment Station and the National Research Initiative of the US Department of Agriculture Cooperative State Research, Education and Extension Service, grant numbers 2003-35101-12928 and 2006-35320-17476. We thank C. Stansberry, C. Worthington, and numerous technicians for assistance with various aspects of this study.

LITERATURE CITED

Allen, L. J., L. H. Harbers, R. R. Schalles, C. E. Owensby, and E. F. Smith. 1976. Range burning and fertilizing related to nutritive value of bluestem grasses. *Journal of Range Management* 29:306–308.

Archer, S. 1994. Woody plant encroachment into Southwestern grasslands and savannas: rates, patterns, and proximate causes. In: M. Vavra, W. A. Laycock, and R. D. Pieper [eds.]. Ecological implications of livestock herbivory in the West. Denver, CO: Society for Range Management. p. 13–68.

Churchwell, R. T., C. A. Davis, S. D. Fuhlendorf, and D. M. Engle. 2008. Effects of patch-burn management on dickcissel nest success in a tallgrass prairie. *Journal of Wildlife Management* 72:1596–1604.

Coppedge, B. R., S. D. Fuhlendorf, W. C. Harrell, and D. M. Engle. 2008. Avian community response to vegetation and structural features in grasslands managed with fire and grazing. *Biological Conservation* 14:1196–1203.

DelCurto, T., B. W. Hess, J. E. Huston, and K. C. Olson. 2000. Optimum supplementation strategies for beef cattle consuming low-quality roughages in the western United States. *Journal of Animal Science* 77:1–16.

Dunn, B. H., A. J. Smart, R. N. Gates, P. S. Johnson, M. K. Beutler, M. K. Diersen, and L. L. Janssen. 2010. Long-term production and profitability from grazing cattle in the northern mixed grass prairie. *Rangeland Ecology and Management* 63:233–242.

Engle, D. M., S. D. Fuhlendorf, A. Roper, and D. M. Leslie, Jr. 2008. Invertebrate community response to a shifting mosaic of habitat. *Rangeland Ecology and Management* 61:55–62.

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. G. Hamilton. 2009. Pyric–herbivory: rewilding landscapes through re-coupling fire and grazing. *Conservation Biology* 23:588–598.

Fuhlendorf, S. D., W. C. Harrell, D. M. Engle, R. G. Hamilton, C. A. Davis, and D. M. Leslie, Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. *Ecological Applications* 16:1706–1716.

Fuhlendorf, S. D., and F. E. Smeins. 1997. Long-term vegetation dynamics mediated by herbivores, weather and fire in a *Juniperus-Quercus* savanna. *Journal of Vegetation Science* 8:819–828.

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

Fuhlendorf, S. D., D. E. Townsend II, R. D. Elmore, and D. M. Engle. 2010. Pyric–herbivory to promote rangeland heterogeneity: evidence from small mammal communities. *Rangeland Ecology & Management* 6:670–678.

Fuhlendorf, S. D., H. Zhang, T. R. Tunnell, D. M. Engle, and A. F. Cross. 2002. Effects of grazing on restoration of southern mixed prairie soils. *Restoration Ecology* 10:401–407.

Herd, D. B., and L. R. Sprott. 1986. Body condition, nutrition and reproduction of beef cows. *Texas Agriculture Extension Bulletin* 15226. 11 p.

Howe, H. F. 1994. Managing species-diversity in tallgrass prairie—assumptions and implications. *Conservation Biology* 8:691–704.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. *Studies in Avian Biology* 15:247–257.

Langpap, C. 2006. Conservation of endangered species: can incentives work for private landowners? *Ecological Economics* 57:558–572.

Limb, R. F., S. D. Fuhlendorf, D. M. Engle, and J. D. Kerby. 2011. Growing-season disturbance in tallgrass prairie: evaluating fire and grazing on *Schizachyrium scoparium*. *Rangeland Ecology & Management* 64:28–36.

Limb, R. F., S. D. Fuhlendorf, and D. E. Townsend. 2009. Heterogeneity of thermal extremes: driven by disturbance or inherent in the landscape. *Environmental Management* 43:100–106.

McCollum, F. T., III, R. L. Gillen, B. R. Karges, and M. E. Hodges. 1999. Stocker cattle response to grazing management in tallgrass prairie. *Journal of Range Management* 52:120–126.

McGinty, A., F. E. Smeins, and L. B. Merrill. 1983. Influence of spring burning on cattle diets and performance on the Edwards Plateau. *Journal of Range Management* 36:175–179.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. F. Parrett, L. L. Berger, and D. R. Strohbehn. 2001. Critical control points for profitability in the cow-calf enterprise. A.S. Leaflet R1750. 2001 Beef Research Report—Iowa State University.

O'Connor, T. G., P. Kuyler, K. P. Kirkman, and B. Corcoran. 2010. Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland? *African Journal of Range and Forage Science* 27:67–76.

Parr, C. L., and A. N. Anderson. 2006. Patch mosaic burning for biodiversity conservation: a critique of the pyrodiversity paradigm. *Conservation Biology* 20:1610–1619.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966–2007. Version 5.15.2008. Laurel, MD: USGS Patuxent Wildlife Research Center.

Steel, R. D., J. H. Torrie, and D. A. Dickey. 1997. Principles and procedures of statistics a biometrical approach. 3rd ed. Boston, MA: McGraw-Hill. p. 557–558.

Vallentine, J. F. 2001. Grazing management. 2nd ed. San Diego, CA: Academic Press. 659 p.

West, N. E. 1993. Biodiversity of rangelands. *Journal of Range Management* 46:2–13.

Williams, J. S. 1953. Seasonal trends of minerals and proteins in prairie grasses. *Journal of Range Management* 6:100–108.

Willis, K. J., and H. J. B. Birks. 2006. What is natural? The need for a long-term perspective in biodiversity conservation. *Science* 314:1261–1265.