IMPACTS OF PATCH-BURN GRAZING ON LIVESTOCK AND VEGETATION IN THE TALLGRASS PRAIRIE

by

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Abstract

Patch-burn grazing is a relatively new concept in terms of rangeland management. While numerous benefits have been associated with this system, in the tallgrass prairie of Kansas, cattle production and sustainability of rangeland are critical. In 2006, 253 ha at the KSU Bressner Range Research Unit in Woodson County, Kansas were subjected to spring patch-burn grazing (using one-third portions) and traditional full-burn grazing. Each treatment within the split-block design was replicated four times for 3 years. The objectives were to evaluate whether livestock performance would be compromised under this grazing system, to monitor the health of the rangeland, and to observe the usefulness of this tool as a potential control of the invasive plant sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don]. In regards to cattle performance, burn treatments had no significant difference in average daily gain ($p \geq 0.10$) in any of the 3 years. On average, cattle utilized 61% of the current year's forage production in patch-burned portions, which was higher ($p \leq 0.10$) than that of unburned (30%) and full-burn (41%) portions. Results of the botanical composition show forb and woody plant composition did not differ between treatments, however differences ($p \leq 0.10$) were present in grass composition. Total annual grasses increased 19.1 percentage units under patch-burn and 2.1 units under full-burn, while total perennial grasses decreased 18.4 and 1.1 units, respectively. When evaluated by treatment area (one-third portion), results indicated that the 3-year cycle did allow enough time for recovery. At 2 years after treatment (2-YAT), no significant difference in composition ($p \geq 0.10$) was present between initial patch-burn portions and the full-burn pastures. Finally, in only 1 year of the study did cattle statistically consume a greater percentage of sericea lespedeza plants ($p \leq 0.10$) in the patch-burned portions (92%) than in full-burned pastures (35%). Biomass utilization did not differ ($p \geq 0.10$) between burn treatments. Surprisingly, there was a trend for the number of plants in the sampled areas of the patch-burn portions to decrease throughout the cycle. However, at the conclusion of the 3-year cycle, sericea densities did not differ ($p \geq 0.10$) between treatments. Patch-burn grazing shows promise as a potential management tool for Kansas land managers.

Table of Contents

List of Figures

List of Tables

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Finally, I want to thank my family. I can always rely on my parents to be supportive of my endeavors. They never told me that something could not be accomplished. My wife and best friend, Amanda, has been my number one source of encouragement during this project and even pitched in to help move grazing exclosures. She is nothing short of amazing and I thank God everyday that I have her in my life.

Dedication

I would like to dedicate this to two very important people in my life. First, to my dad: I have many fond memories of us working pastures, feeding cattle, and telling stories on road trips. His deep passion for ranching rubbed off on me at a very early age and because of him, I carry with me many strong convictions about agriculture, family, and life in general. He has taught me most of the practical skills and knowledge that I have come to rely on everyday and has been my go-to person for advice on many of life's experiences. Thanks for everything, Dad. Hard work really does go a long way.

To my son, Callan: Although he has only been with us a short while, he has already had a profound impact on my life. I thought I had a great deal of determination and will to succeed, however being with him for the first few months of his life has been humbling and I now know I have a long way to go. He has taught me that miracles do come true and that no matter how long the journey or how great the challenge, one should never give up. Possibly one day you can look back on what I have been fortunate enough to achieve and in some way it will inspire you to pursue your dreams.

CHAPTER 1 - Performance and Forage Utilization of Stocker Cattle in a Patch-Burn Grazing System

Abstract

Theorized to closely mimic the historical patterns of lightning and the American bison (*Bos bison*), patch-burn grazing is the purposeful grazing of a portion of a management unit that has been prescribed burned, and then 12 months later burning another portion to move the grazing pressure, thus creating a shifting mosaic. While numerous benefits have been associated with this system, in the tallgrass prairie of Kansas, cattle production and sustainability of rangeland are critical. A study was initiated in 2006 on 253 ha at the KSU Bressner Range Research Unit in Woodson County, Kansas that included treatments of spring patch-burn grazing (using one-third portions) and traditional full-burn grazing. Each treatment within the split-block design was replicated four times for 3 years. The objectives of this study were 1) to evaluate whether livestock performance would be compromised under this grazing system, 2) to examine whether forage utilization and grazing distribution would be affected by patch-burn location, and 3) to describe the relationship between visual obstruction measurements and forage utilization using linear regression analyses. The mean average daily gains and percent utilization data were analyzed by calculating 90% confidence intervals. In regards to cattle performance, burn treatments had no significant difference in average daily gain ($p \geq 0.10$) in any of the 3 years (2006-08). On average, cattle utilized 61% of the current year's forage production in patch-burned portions, which was higher ($p \leq 0.10$) than that of the unburned (30%) and full-burn (41%) portions. Results also indicated that visual obstruction was an adequate method ($r^2=0.55$) in estimating current year's forage utilization. After one 3-year cycle, it appears that livestock gains are not sacrificed under this system and that patch-burn grazing can be an effective grazing distribution tool for Kansas ranchers.

Introduction

Many different grazing management systems are employed in the tallgrass prairie of Kansas. Depending on the type of enterprise (cow/calf or stocker), an operator will choose to implement the system that will maximize production and profit. Today, nearly 30% of the stocker operations in the Flint Hills utilize annual, dormant season fires combined with a short, intensive grazing period (Launchbaugh and Owensby 1978 and USDA-NASS 2009).

However, these modern day ranchers are not the first to understand the role that fire plays in meeting the nutritional demands and in manipulating the grazing patterns of large herbivores. For thousands of years, a fire-grazing interaction occurred throughout the Great Plains. Prior to aboriginal utilization of the tallgrass prairie, lightning served as the primary source of igniting the vegetation (Earls 2006). These random lightning strikes caused a shifting mosaic of disturbances across the landscape due to the concentration of American bison (*Bos bison*) and other large herbivores on recently burned areas. As a burned area began fresh growth, it would attract these grazers and become heavily utilized, leaving others less utilized. Throughout the year, another area would burn causing animals to again focus their foraging in the lush region of regrowth and allow for the rest and recovery of the previously burned grassland. This interaction would repeat itself all across the landscape, leading to a random disturbance (Weir et al. 2007).

Following aboriginal and Anglo-American presence, this interaction continued with the use of fire rather than lightning. As cattle slowly replaced the American bison on the prairie and as burning technology evolved in the twentieth century, ranchers studied and adapted this interaction to improve their grazing operations in profitability as well as environmentally. Today, prescribed fire is a core practice that plays an integral role in cattle operations all across the country. Operators have come to rely on the added performance and thorough grazing that are results of using this historical tool.

Recently, patch-burn grazing has become a topic of interest for many range researchers as well as numerous ranchers throughout the tallgrass region. Theorized to closely mimic the historical patterns of lightning and the American bison, patch-burn grazing is the purposeful grazing of a portion of a management unit that has been prescribed burned, and then 12 months later burning another portion to move the grazing pressure, thus creating a shifting mosaic (Weir et al. 2007).

Numerous benefits have been associated with patch-burn grazing; however, the system has been promoted the most as a way to increase biodiversity, heterogeneity, and wildlife habitat (Fuhlendorf et al. 2006, Bidwell et al. 2009, NPS 2009). While these are all important, in the tallgrass prairie of Kansas, cattle production and longevity of rangeland are critical. The objectives of this study were 1) to evaluate whether livestock performance would be compromised under this grazing system, 2) to examine whether forage utilization and grazing distribution would be affected by patch-burn location, and 3) to describe the relationship between visual obstruction (VO) measurements and forage utilization using linear regression analyses.

Materials & Methods

Site Description

The KSU Bressner Range Research Unit in Woodson County, Kansas was selected as the site for this study. The research unit is owned by the Kansas State University Foundation and managed by an advisory council made up of area extension agents, extension specialists, and producers. This 253 ha unit (N1/2, S19, T25S, R15E and N1/2, S20, T25S, R15E) is located in east-central Kansas on the eastern edge of the Kansas Flint Hills region at 37° 51'54.18" N, 95° 48'16.15" W and is approximately 343 m above sea level. At this site, 13 soil types are represented, which fall into a total of 7 different ecological range sites (Appendix B). For the purposes of this study, the most widely represented range site was sampled. In this case, clay upland sites were chosen, which consist of moderately deep to deep soils that are somewhat poorly drained.Clay upland sites have natural potential vegetation of mixed grasses dominated by big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass [*Panicum virgatum* L.] (NRCS 2008). Growing-season (April – September) precipitation for the area was 45.39 cm, 94.69 cm, and 98.36 cm in 2006, 2007, and 2008, respectively. Long-term average annual precipitation for Woodson County is 106.98 cm, while annual growing-season precipitation is 69.52 cm (Knapp 2009).

Treatments and Sampling

The 253 ha of this unit were divided into 8 individual pastures, each consisting of approximately 32 ha (Figure A.1). Using a split-block experimental design, two treatments were implemented and replicated four times over 3 years (2006-08). Pastures were fenced only on the exterior boundary with no fences dividing the patches. All 8 pastures were burned on 13 April 2006, 9 April 2007, and 9 April 2008. Each of the north 4 pastures were patch-burn grazed on a one-third (11 ha) basis. Therefore, each patch in the patch treatment was burned once in the 3-year cycle. By the end of the study, a patch burn pasture would have one patch burned within 1 year, one patch burned 1 year prior, and one had not been burned for 2 years (design analogous to Fuhlendorf et al. 2006). Each of the south four pastures were subjected to the traditional method of full-burn grazing (Figure A.2).

Cattle were weighed individually using electronic scales (Tru-Test Incorporated, Mineral Wells, Texas) at the start and end of the grazing period. Using color-coded radio frequency identification (RFID) ear tags, they were randomly assigned to each of the eight pastures.

Cattle (n = 120, average initial weight = 252 kg) were stocked in patch treatment pastures from mid-April through mid-August using a three-quarter season (114-d) grazing period that was customary to the research unit (Lanham 2005) at a rate of 1.09 ha/hd. Cattle had free access to all areas within each pasture, so they could choose between burned and unburned patches in the patch treatment.

The remaining pastures were assigned the full-burn treatment and were designed to mimic similar grassland management used throughout the Flint Hills area. Treatment of these pastures consisted of an annual spring burn where all pastures were burned with a single fire every year. Again, cattle (n = 113, average initial weight = 252 kg) were stocked from mid-April through mid-August at a rate of 1.09 ha/hd and had free access to the entire area of each pasture.

At the conclusion of the grazing season in late August, one 10-point transect was established in each of the one-third portions of the patch-burn pastures and 2 were established in each of the full-burn pastures on clay upland range sites for a total of 20 transects. Distance between points was approximately 35 m. Use of the VO method in this study was based on the methods of Robel et al. (1970) with modifications of the measurement pole and the number of observations taken per transect. The measurement pole was a 1 m measuring stick marked at 1 cm intervals. A second 1 m measuring stick was utilized to locate an observation point 4 meters south from the measurement pole and 1 m above the ground level. The measurement pole was placed at the center of a 0.25 m^2 square frame that was placed on the ground at a randomly selected location alongside the transect.

While several recent studies that have employed the VO method (Volesky et al. 1999, Benkobi et al. 2000, Ganguli et al. 2000, Vermeire and Gillen 2001, Vermeire et al. 2002) modified the traditional 1 dm measuring interval to increments ranging from 2 cm to 5 cm, the low amounts of standing biomass in burned areas of the patch treatments in this study required an even smaller unit of measure. Similar to Derner and Augustine (2009), a single VO reading was taken at each point along the transect by having the measuring pole holder slide his index finger down the stick and recording the lowest height, to the nearest cm, at which the tip of the finger could no longer be seen.

At two randomly selected points along each transect where obstruction readings were also taken, the vegetation within the frame was clipped to ground level. A frame was also clipped from a grazing exclosure (1.55 m diameter) that was constructed from a wire cattle panel and located along each established transect. Vegetation from these 3 frames were then separated out into grass, forbs, and litter, oven dried for 48 hours at 60 °C, and weighed to 0.1 gm. Once processed, the mean weights of the clipped vegetation from within the grazing exclosures were converted to kg per ha and used as a representation of the current year's forage production.

Traditionally, the VO method has been used to quantify or estimate total herbage standing crop, which would include current year grass and forb growth along with any standing dead. Since a main objective of this study was to monitor utilization, defined as the percent of current annual production which is removed as a result of grazing (Bonham 1989), a relationship between VO measurements and current production was desired.

Thus, relationships were determined each year by regression analysis, using the dried weights of clipped current year's grass and forbs from the 3 clipped frames and the

3 corresponding VO measurements from each of the 20 transects for a total of 60 observations.

Once a relationship was established, all of the VO readings from within a given treatment area were entered into the prediction equation to estimate remaining available forage from the current year. The mean vegetation estimation from each treatment area was then compared back to the mean of all clipped exclosure weights to calculate percent utilization by the cattle as depicted in the equation: [(Exclosure Yield – Calculated Residual Pasture Yield) / Exclosure Yield] * 100 = % Utilization.

Statistical Analysis

Data were analyzed using the Descriptive Statistics function of Microsoft Office Excel (Microsoft Corporation, Redmond, Washington 2003). The mean average daily gain for each treatment and mean percent utilization for each treatment area were entered and analyzed by calculating 90% confidence intervals. Relationships between mean visual obstruction measurements and vegetation weights were calculated by using the Regression function of Microsoft Excel.

Results & Discussion

Cattle Performance

In terms of cattle performance, burn treatments had no significant differences in average daily gain ($p \geq 0.10$) in any of the 3 years (Table 1.1). The greatest gains were observed the initial year of the cycle, in 2006, on both patch-burn and full-burn treatments. For that year, average daily gains were 1.13 kg and 1.16 kg on patch-burn and full-burn treatments, respectively. Weir et al. (2007) documented similar results in Oklahoma for both yearling steers and un-weaned calves over a 4-year period.

The difference in performance among the 3 years can possibly be explained by a couple of different factors: weather and management. In the first year of the study, Woodson County experienced 35% below average precipitation (Table C.1). During the last 2 years of the study, growing season precipitation was 36% above the long-term average in 2007 and 42% above the long-term average in 2008. Despite being a drought year, gains in 2006 were consistent with those historically recorded on this research unit (Brazle 1999). However, in both of the last 2 years, gains were suppressed.

Van Soest (1982) explains that water stress tends to delay plant maturity, resulting in increased digestibility, but lower dry matter yields. Under drought stress, metabolic emphasis of the plant is shifted away from structural carbohydrate development and allows for a higher relative quality value of the forage. On the other hand, when non-stressful conditions occur such as in 2007 and 2008, plants experience a rapid maturation rate with an increase in structural carbohydrates and lignin synthesis. While forage yields are usually larger in these scenarios, plants reach phenological maturity more quickly, thus being more resistant to digestibility.

Parish and Rhinehart (2009) states that excessive rainfall can also lead to stocker cattle having a lower average daily gain despite having access to forage that might produce acceptable gains in most years. High moisture levels in pasture plants result in less dry matter consumed for a given quantity of forage. Consequently, many of the cattle may not have consumed enough dry matter to meet intake and nutrient demands.

Another factor that may have led to decreased performance was the management of the cattle prior to the grazing season. Although this research unit is owned and operated by the university, the pastures are annually leased and stocked by a private rancher. Therefore, it is difficult to hand select cattle for research trials. Between 2006 and 2007, the lease changed to a new rancher and as a result, new management of the cattle. In 2006, as sound practice would recommend, the stocker cattle had been purchased and delivered from a single location in the southern United States to the Woodson County, Kansas ranch well in advance of being processed and turned out for the study.

However, in 2007, the cattle were purchased and processed only a few days prior to grazing. In addition, rather than being procured from one location, these stocker cattle came from multiple sites in the southern and western United States. According to individual data, the western cattle did not perform as well as those of southern origin. Since the western cattle made up a larger percentage of the herd, the mean performance in 2007 was reduced.

The same lessee again stocked the pastures in 2008. While in 2008 the cattle were managed more appropriately as far as procurement location and time, the herd was extremely variable in frame size, weight, and conformation. Accordingly, most of the stocker cattle in 2008 were not ideal prospects for achieving optimum weight gains.

Forage Utilization and Grazing Distribution

Using the VO method described above, three linear regression analyses were performed (Figure 1.1). Regression equations for the three years were y = 49.611x + 1001.2 for 2006, y = 73.647x + 778.1 for 2007, and y = 76.434x + 995.94 for 2008. Coefficients of determination were 0.55, 0.58, and 0.51 for 2006, 2007, and 2008, respectively. Derner and Augustine (2009) accounted for only 48% of the variation in shortgrass steppe current year above ground biomass using VO. Similarly, over the 3 years of this study, VO accounted for only 55% of the variation in tallgrass prairie current year forage production.

Vermeire et al. (2002) recommends that a model should include only vegetation that affects the VO reading. In the previously mentioned regression analyses, total standing herbage was not considered. Perhaps, by not including the standing dead that most likely had a greater influence on height measurements, lower r^2 values were realized. This was still acceptable however, because the inclusion of standing dead in the VO calibration used to estimate only current year forage could have potentially skewed the utilization results.

However, when coefficients of determination were calculated in reference to total standing crop for this study, only slightly higher values of 0.82 in 2006, 0.65 in 2007, and 0.65 in 2008 were found. In the last few decades, VO has been used to estimate total standing crop in tallgrass prairie (Robel et al. 1970, Vermeire and Gillen 2001) and improved pastures (Harmoney et al. 1997) with considerably more success. Numerous studies (Benkobi et al. 2000, Ganguli et al. 2000, Vermeire and Gillen 2001, Vermeire et al. 2002) reported much higher r^2 values, similar to that of 0.96 in Robel et al. (1970).

Based on the vegetation that was clipped and weighed from each of the grazing exclosures, the actual total annual forage produced in 2006 was 3551 kg/ha, 3634 kg/ha in 2007, and 4067 kg/ha in 2008.

Upon entering the VO measurements into their respective equations and comparing the estimations back to actual annual production, on average, cattle utilized 61% of the current year's forage production in patch-burned portions, which was higher ($p \leq 0.10$) than that of the unburned (30%) and full-burn (41%) portions (Figure 1.2). In 2006 they consumed 64% of the forage in the patch-burned portions compared to 53% in the traditional full-burn pastures. In 2007, they again utilized 60% of the patch-treatment area and 36% of the full-burn. Similarly, in 2008, cattle utilized 59% of the available forage in the patch-burn grazed portions and 35% in the traditionally managed pastures. Several previous works (Vermeire et al. 2004 and Murray et al. 2007) suggest similar to slightly higher utilization of burned portions of patch treatments ranging from 55 to 78%.

In each instance of this study, the utilization of the full-burned pastures was significantly lower ($p \leq 0.10$) than that of the burned portions of the patch treatments. However, the utilization of the full-burn pastures was statistically the same ($p \geq 0.10$) as the unburned portions of the patch treatments in 2 of the 3 years (2007 and 2008).

In 2006, cattle consumed a higher percentage of forage in all areas than in 2007 or 2008. Stocking rates were the same each year, so the slightly higher consumption was likely a function of environmental factors. Due to drought conditions (35% below average precipitation) during the growing season in 2006, increased utilization was likely an effect of reduced forage availability.

Remarkably, the utilization trend was uniform in all areas among years. Within a given year of the 3-year cycle, cattle tended to utilize the current year's burned portions of the patch treatments the most (61%), followed by the portions of the patch treatments that were burned the year prior (34%), and consumed the least amount of forage (20%) in the areas that had 2 years of rest. Several factors may have had a role in this outcome: quality of available standing forage in relationship to timing of last burn, location of water, and distance of the unburned patch treatments from the current year's burn (Vermeire et al. 2004).

Conclusions

Prescribed burning remains one of the most effective and widely used management tools to improve weight gains and manipulate grazing distribution of stocker cattle on native rangeland. Patch-burn grazing will most likely never be universally applied to the private ranches of the Flint Hills that have come to rely on traditional single fire, intensive grazing type systems (Fuhlendorf and Engle 2001 and Hamilton 2007). However, patch-burn grazing does provide for the same stocker cattle performance as traditionally managed three-quarter season grazing systems (Brazle et al. 1999) and has proven itself as an effective grazing distribution tool.

Although extremely labor intensive, patch-burn grazing could possibly be used in conjunction with traditional management practices. For the rancher or land manager that is seeking a tool for reclamation of mismanaged grassland or has issues with grazing land erosion, this system might very well fit into the plan. It can be used to defer graze an area, in this case, up to 2 years, while still utilizing a given pasture. In other patch-burn systems, one could design a 4- to 8-year rotation, giving even more time for the eroded areas to repair themselves.

In summary, the results of this study indicate that patch-burn grazing provides an alternative paradigm in rangeland management that maintains a comparable level of animal performance, and, perhaps, a more effective means of manipulating grazing distribution than older, more commonly accepted management systems.

Tables and Figures

Table 1.1 Summer stocker cattle performance, 2006-2008

Year	2006		2007		2008	
Treatment	PB	FB	PB	FB	PB	FB
Days	113	113	114	114	114	114
Head	120	115	120	112	120	112
Weight in, kg	258.37	255.20	263.80	264.25	233.48	230.71
Weight out, kg	385.97	385.97	371.04	372.39	355.66	352.49
Gain, kg	127.60	130.77	107.24	108.14	122.18	121.78
ADG, kg *	1.13 [a]	1.16 [a]	0.94 [a]	0.95 [a]	1.07 [a]	1.07 [a]

Treatments: PB=Patch-Burn, FB=Full Burn
*Means followed by the same letter in the same year are not significantly different ($p \geq 0.10$)

Figure 1.1 Regression analyses of visual obstruction measurements and standing current year biomass

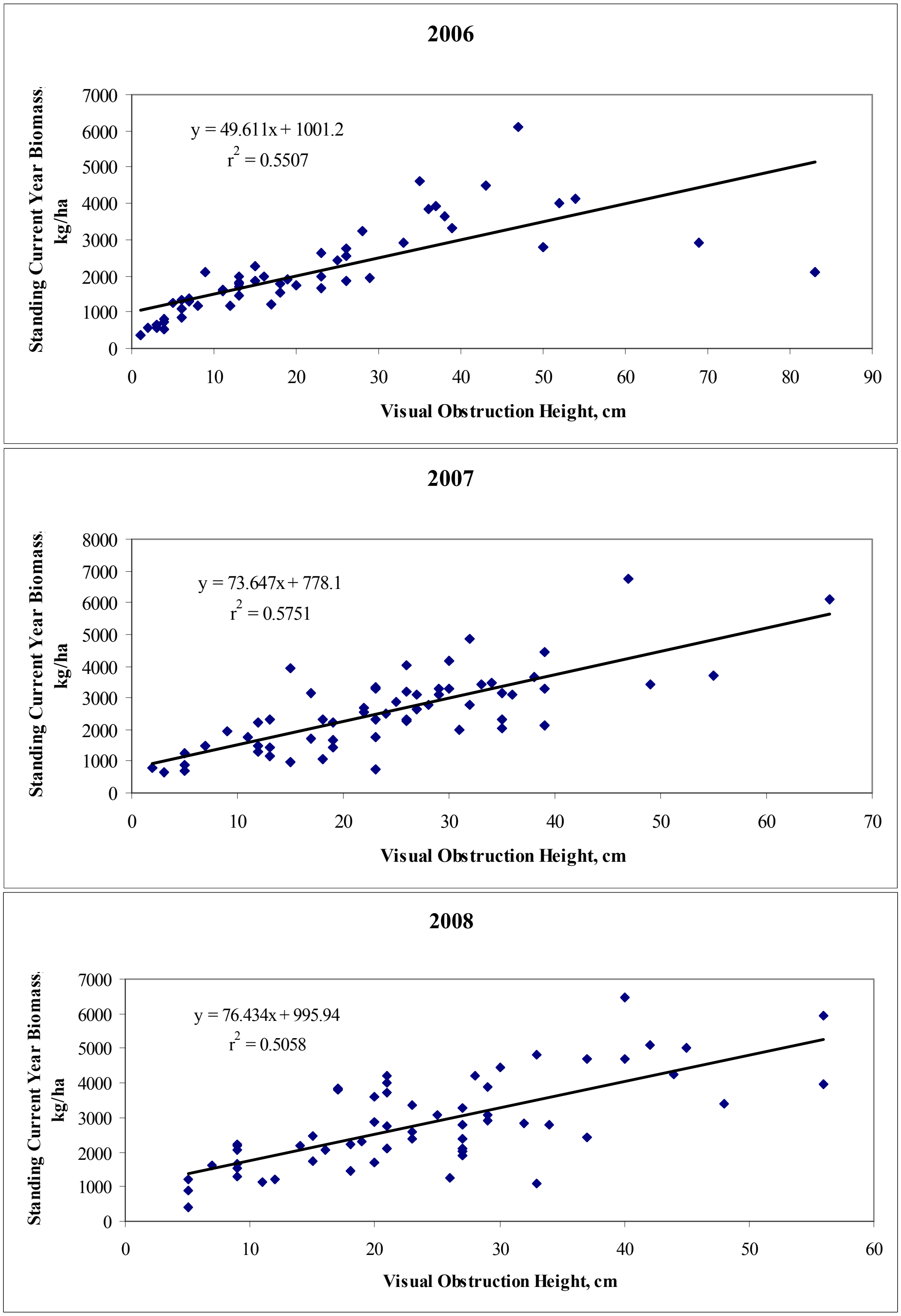
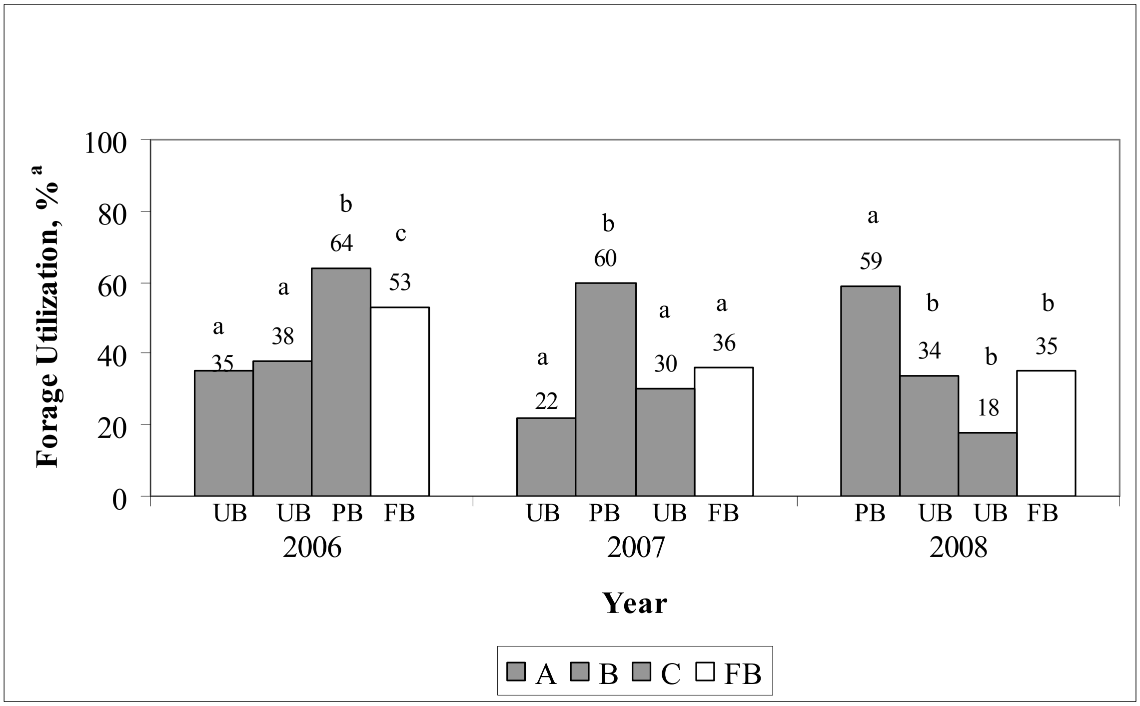


Figure 1.2 Estimated forage utilization by stocker cattle using visual obstruction, 2006-2008



* Treatments: UB=Unburned, PB=Patch-Burned, FB=Full-Burned

[a] Means denoted by the same letter in the same year are not significantly different ($p \geq 0.10$)

CHAPTER 2 - Effects of Patch-Burn Grazing on the Botanical Composition of the Tallgrass Prairie

Abstract

Patch-burn grazing is a relatively new concept in terms of rangeland management. While this system has been promoted as a way to increase heterogeneity and wildlife habitat, preserving the integrity of the native tallgrass prairie is critical. In 2006, 253 ha at the KSU Bressner Range Research Unit in Woodson County, Kansas were subjected to spring patch-burn grazing (using one-third portions) and traditional full-burn grazing. Each treatment within the split-block design was replicated four times for 3 years. The objectives of this study were 1) to monitor the health of the prairie through botanical composition using modified step-point and 2) to determine if a 3-year patch-burn cycle allows enough rest for the initial prescribed burn portion to recover. The mean changes in percent composition were analyzed by calculating 90% confidence intervals. Results of the study show that, while forb and woody plant composition did not differ between treatments, statistical differences ($p \leq 0.10$) in grass composition existed. Total annual grasses increased 19.1 percentage units under patch-burning and 2.1 percentage units under full-burning, while total perennial grasses decreased 18.4 and 1.1 percentage units, respectively. When evaluated by treatment area (one-third portion), results indicated that the first 3-year cycle did allow enough time for recovery. At 2 years after treatment (2-YAT), no significant difference in composition ($p \geq 0.10$) existed between the first patch-burn portions and the full-burn pastures. Patch-burn grazing may be attractive to those land managers who are seeking to potentially enhance the biodiversity or heterogeneity in portions of their operation without having to commit to a long-term approach.

Introduction

Unlike most of the original tallgrass prairie on the North American continent, the Flint Hills of Kansas and Oklahoma have escaped cultivation. The greater Flint Hills region is made of rough topography with shallow, rocky soils. Because agricultural producers could not farm this terrain, ranching has become the primary economic land use (Hamilton 2007).

Over the last several decades, yearling cattle have roamed the countryside on large tracts of native rangeland that have been subjected to an annual spring burn, coupled with a short, intensive grazing period in an attempt to maximize production while minimizing long-term degradation. This has become known to the region as a "traditional" yearling stocker operation (Launchbaugh and Owensby 1978).

Recently, this traditional management style has been scrutinized for its uniform grazing use across entire pastures creating a homogenous landscape with lowered biodiversity potential (Hamilton 2007). While it does increase livestock production (Smith and Owensby 1978), suggestions have been made that this annual burn – intensive stock protocol focuses largely on only two elements of grazing management: distribution of grazing in space and time and grazing intensity. This management system may promote the dominance of only a few key forage species, the uniform utilization of plants and areas, and a reduction of landscape heterogeneity (Fuhlendorf and Engle 2001).

The Nature Conservancy (2000) maintains that homogenizing range practices are one of the leading sources of ecological stress in the Flint Hills. In light of this, new attention is being paid to the historic fire-grazing interactions that took place hundreds of years ago involving the American bison (*Bos bison)*. Alternative management approaches are now being proposed that can facilitate heterogeneity through fire and grazing disturbances of focal points that shift through time, producing a shifting mosaic which enhances biodiversity (Fuhlendorf et al. 2006).

Patch-burn grazing is one such approach that is a relatively new concept in terms of rangeland management. This practice involves burning and grazing portions of a management unit and then moving the grazing pressure by burning another section, creating the shifting mosaic. Livestock concentrate their time on these patches and typically utilize all the palatable plants within the entire burned patch. Then, within a given amount of time, another portion is burned, moving the focal grazing point to the new patch burn. Following the heavy utilization, a transition state of bare ground, forbs, and low amounts of standing biomass and litter occurs. Depending on the design, as new patches are burned each year, the initial prescribed burn portion will receive very little grazing pressure, which will allow biomass and litter to accumulate. In turn, patches that accumulate biomass and litter are ready to start another cycle (Weir et al. 2007).

While this system has been promoted as a way to increase heterogeneity and wildlife habitat (Fuhlendorf et al. 2006, Bidwell et al. 2009, NPS 2009), preserving the integrity of the native tallgrass prairie is critical. The objectives of this study were to monitor the health of the prairie through botanical composition comparisons and to determine if a 3-year patch-burn cycle allows enough rest for the initial prescribed burn portion to recover.

Materials & Methods

Site Description

The KSU Bressner Range Research Unit in Woodson County, Kansas was selected as the site for this study. This research facility is owned by the Kansas State University Foundation and managed by an advisory council made up of area extension agents, extension specialists, and producers. This 253 ha unit (N1/2, S19, T25S, R15E and N1/2, S20, T25S, R15E) is located in east central Kansas on the eastern edge of the Kansas Flint Hills region at 37° 51’54.18” N, 95° 48’16.15” W and is approximately 343 m above sea level. At this site, 13 soil types are represented, which fall into a total of 7 different ecological range sites (Appendix B). For the purposes of this study, the most widely represented range site was sampled. In this case, clay upland sites were chosen, which consist of moderately deep to deep soils that are somewhat poorly drained. Clay upland sites have natural potential vegetation of mixed grasses dominated by big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass [*Panicum virgatum* L.] (NRCS 2008). Growing-season (April – September) precipitation for the area was 45.39 cm, 94.69 cm, and 98.36 cm in 2006, 2007, and 2008, respectively. Long-term average annual precipitation for Woodson County is 106.98 cm, while annual growing-season precipitation is 69.52 cm (Knapp 2009).

Treatments and Sampling

The 253 ha of this unit were divided into 8 individual pastures, each consisting of approximately 32 ha (Figure A.1). Using a split-block experimental design, two treatments were implemented and replicated four times over 3 years (2006-08). Pastures were fenced only on the exterior boundary with no fences dividing the patches. All 8 pastures were burned on 13 April 2006, 9 April in 2007, and 9 April 2008. Each of the north 4 pastures were patch-burn grazed on a one-third (11 hectare) basis. Therefore, each patch in the patch treatment was burned once in the 3-year cycle. By the end of the study, a patch-burn pasture would have one patch burned within 1 year, one patch burned 1 year prior, and one had not been burned for 2 years (design analogous to Fuhlendorf et al. 2006). Each of the south four pastures were subjected to the traditional method of full-burn grazing (Figure A.2).

Cattle (n = 120, average initial weight = 252 kg) were stocked in patch treatment pastures from mid-April through mid-August using a three-quarter season (114-d) grazing period that was customary to the research unit (Lanham 2005) at a rate of 1.09 ha/hd. Cattle had free access to all areas within each pasture, so they could choose between burned and unburned patches in the patch treatment.

The remaining pastures were assigned the full-burn treatment and were designed to mimic similar grassland management used throughout the Flint Hills area. Treatment of these pastures consisted of an annual spring burn where all pastures were burned with a single fire every year. Again, cattle (n = 113, average initial weight = 252 kg) were stocked from mid-April through mid-August at a rate of 1.09 ha/hd and had free access to the entire area of each pasture.

One 100-point transect was established in each of the one-third portions of the patch-burn pastures and 2 were established in each of the full-burn pastures on clay upland range sites for a total of 20 transects. Using the modified step-point method (Owensby 1973) to measure botanical composition, a total of 2000 points were sampled each year using a home constructed point frame (Figure E.2). At approximately every 4 m along a transect legs of the point frame were placed at the end of the sampler's boot where his foot hit the ground. The frame was then leaned forward until point contact was made at the soil surface. Non-plant hits were recorded as either bare ground or litter and the species nearest to the point in a forward, 180° arc was recorded. Plant hits were recorded by species. In addition, the nearest forb or woody plant was recorded after a hit on grass or when the closest plant was a grass. Step-point sampling was completed at the end of the grazing period during the months of August and September of each year.

The purpose of this study was to monitor and compare rangeland health under the traditional versus non-traditional management system. Therefore, the mean percent change in botanical composition of all of the full-burn pastures served as the traditionally accepted compositional change to which the patch treatment compositional changes were compared. A patch-burn portion was considered to be recovered if, at the end of the cycle, the compositional change of that portion was statistically similar to the mean change that occurred in the full-burn pastures.

Statistical Analysis

Data were analyzed using the Descriptive Statistics function of Microsoft Office Excel (Microsoft Corporation, Redmond, Washington 2003). The mean changes in percent composition for each treatment area were entered and analyzed by calculating 90% confidence intervals.

Results & Discussion

Over 90 different species of grasses, forbs, and woody plants were observed along the 20 step-point transects (Appendix D). Dominant species included big bluestem, little bluestem, swtichgrass, Indiangrass, sedges [*Carex* spp.], western ragweed [*Ambrosia psilostachya* DC.], and smooth-seed wildbean [*Strophostyles leiosperma* (T. & G.) Piper].

When analyzed by treatment over all 3 years, results show that three of the four main warm-season native perennials (big bluestem, little bluestem, and switchgrass) all decreased under both treatments (Table 2.1). Indiangrass, on the other hand, increased 2.0 percentage units under patch-burn grazing and 2.4 units under full-burn grazing.

As a whole, under both treatments, perennial grasses decreased while annual grasses increased. Over the course of the 3 year cycle, total perennial grasses decreased 18.4 percentage units under patch-burn treatment, which was significantly more ($p \leq 0.10$) than those under full-burn (-1.1). These results on the three-quarter season full-burn are contrary to findings of a study done at the same location from 1990-1998 which found that big bluestem, Indiangrass, and switchgrass all increased under full-burn treatment and total perennial grasses increased 1.3 percentage units (Brazle et al. 1999).

Averaged over 3 years, total annual grasses increased 19.1 percentage units under patch-burning, which was statistically higher ($p \leq 0.10$) than the 2.1 unit increase in the full-burned pastures. Crabgrass [*Digitaria sanguinalis* (L.) Scop.] and yellow foxtail [*Setaria pumila* (Poir.) Roem.& J.A. Schultes] accounted for the largest percentage of the increase. In a given year, the burned portion of the patch treatment experienced a shift of almost 30 percentage units from perennial grasses to annual grasses. However, in years of lessened grazing pressure, that shift was reversed (Table 2.2).

Visually, a transition state of forbs did occur 1 year after treatment [1-YAT] (Figure E.1). However, no statistically significant increase in forb composition ($p \geq 0.10$) occurred between treatments (Tables 2.1 & 2.2). Although not significant, there was a trend for perennial forbs to decrease under both treatments and for annual forbs to increase. Both trends were slightly more evident under patch-burn.

At 2 years after treatment (2-YAT), the initial prescribed burn portions (Patch-Burn C) showed no statistical difference in total grasses, forbs, or woody plants ($p \geq 0.10$) compared to those of the full-burn treatment (Table 2.2). This perennial grass recovery from annual grass invasion was perhaps aided by abundant rainfall. During the last 2 years of the study, growing season precipitation was 36% above the long-term average in 2007 and 42% above the long-term average in 2008 (Table C.1).

Species richness did not differ ($p \geq 0.10$) between patch-burn and full-burn treatments (Table 2.3). Likewise, the mean number of species found along transects in each of the four treatment areas (Table 2.4) did not differ ($p \geq 0.10$). Generally, 24 to 26 species were recorded regardless of treatment.

Conclusions

Within a given cycle of the patch-burn grazing system total annual grasses tend to flourish at the expense of perennials. Hanselka et al. (2002) explains this occurrence best by stating that patch grazing causes tall perennial grasses to be replaced by shorter perennial grasses, then with annual grasses until bare ground is finally exposed. They go on to say that productive species are progressively replaced by less productive and less palatable species.

In the case of this study, the transition state of bare ground, forbs, and low amounts of standing biomass and litter that occurred 1-YAT was most likely due to forbs being more visible, not more abundant. As stated in the results, forbs did not significantly increase in any of the 3 years of the patch treatment, even under increased grazing pressure. Other studies have determined that forbs increase dramatically within recently burned and grazed patches (Hamilton 2007). The patch burning and increased grazing pressure on burned plots can promote up to 60% more forb production and change the sites from grass-dominated to forb-dominated communities (Vermeire et al. 2004).

Even so, perennial grasses do indeed make a recovery within a 3-year cycle. Hamilton (2007) explains that native warm-season grasses regain dominance several years post-burn. Without having "several years" defined, the findings of this study hold consistent with those of Coppedge et al. (1998) which states that in the tallgrass prairie, grasses regain dominance within 2 or 3 years after patches are burned and grazed. While one can conclude that the traditional full-burn grazing system tended to better maintain an equilibrium of perennial grasses, annual grasses, and forbs across years, botanically speaking, the 3-year cycle of this study did allow enough time for transition and recovery.

In summary, the results of this study indicate that by increasing spatial and temporal heterogeneity of grassland disturbances, patch-burn grazing increases vegetation variability. While limited to current and 1 year post-burned sites, these changes in vegetation are short-lived. Moreover, these changes that can occur within a few years timeframe may be attractive to those land managers who are seeking to potentially enhance the biodiversity in portions of their operation without having to commit to a long-term approach. Possibly, the patch-burn grazing practice could be integrated into a management plan that includes a number of grazing systems.

Tables

Table 2.1 Change in percent botanical composition by treatment, 2006-2008

Treatment	Patch-Burn	Full-Burn
Plant		
Big bluestem	-10.3 [a]	- 6.0 [a]
Little bluestem	- 7.5 [a]	- 1.9 [a]
Indiangrass	2.0 [a]	2.4 [a]
Switchgrass	- 3.0 [a]	- 1.1 [a]
Total Perennial Grasses	-18.4 [a]	- 1.1 [b]
Total Annual Grasses	19.1 [a]	2.1 [b]
Total Perennial Forbs	- 2.2 [a]	- 1.5 [a]
Total Annual Forbs	2.1 [a]	0.7 [a]
Total Woody Plants	- 0.3 [a]	- 0.2 [a]

*Means followed by the same letter in the same row are not significantly different ($p \geq 0.10$)

Table 2.2 Change in percent botanical composition by treatment area, 2006-2008

Treatment Area	Patch-Burn A	Patch-Burn B	Patch-Burn C	Full-Burn
Plant				
Big bluestem	-11.0 [a]	- 8.7 [a]	-11.3 [a]	- 6.0 [a]
Little bluestem	-12.0 [a]	- 8.4 [ab]	- 2.0 [ab]	- 1.9 [b]
Indiangrass	- 5.0 [a]	1.8 [ab]	9.3 [b]	2.4 [b]
Switchgrass	- 2.5 [a]	- 2.7 [a]	- 3.8 [a]	- 1.1 [a]
Total Perennial Grasses	-29.8 [a]	-24.5 [ab]	- 1.5 [bc]	- 1.0 [c]
Total Annual Grasses	26.3 [a]	26.0 [a]	4.8 [ab]	2.0 [b]
Total Perennial Forbs	- 0.9 [a]	- 3.5 [a]	- 3.9 [a]	- 1.5 [a]
Total Annual Forbs	3.4 [a]	2.0 [a]	0.9 [a]	0.7 [a]
Total Woody Plants	- 0.3 [a]	- 0.3 [a]	- 0.2 [a]	- 0.2 [a]

*Means followed by the same letter in the same row are not significantly different ($p \geq 0.10$)

Table 2.3 Species richness by treatment, 2006-2008

Treatment	Patch-Burn	Full-Burn
Number of species	24.47 [a]	26.17 [a]

*Means followed by the same letter in the same row are not significantly different ($p \geq 0.10$)

Table 2.4 Species richness by treatment area, 2006-2008

Treatment Area	Patch-Burn A	Patch-Burn B	Patch-Burn C	Full-Burn
Number of species	24.83 [a]	25.00 [a]	23.58 [a]	26.17 [a]

*Means followed by the same letter in the same row are not significantly different ($p \geq 0.10$)

CHAPTER 3 - Management of Sericea Lespedeza Using Patch-Burn Grazing

Abstract

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] has become one of the greatest challenges ranchers and land managers face in the Kansas Flint Hills. Its highly invasive nature and unpalatable qualities at later growth stages have led to the infestation of thousands of acres of native rangeland in eastern Kansas. The objective of this study was to observe the usefulness of patch-burn grazing as a potential control method of this invasive plant by monitoring utilization of the plants and recording changes in plant densities. This study was initiated in 2006 on 253 ha at the KSU Bressner Range Research Unit in Woodson County, Kansas. Treatments included spring patch-burn grazing (using one-third portions) and traditional full-burn grazing. Each treatment within the split-block design was replicated four times for 3 years. The mean number of plants grazed, mean percent biomass utilized, and mean densities were analyzed by calculating 90% confidence intervals. Results showed that in only 1 year of the study did cattle statistically consume a higher percentage of plants ($p \leq 0.10$) in the patch-burned portion (92%) than in the full-burned (35%). Sericea lespedeza biomass utilization did not differ ($p \geq 0.10$) between patch-burn and full-burned area. Suprisingly, the number of stems in the sampled areas of the patch-burn portions tended to decrease throughout the cycle. However, at the conclusion of the 3-year cycle, densities did not differ ($p \geq 0.10$) between treatments. An integrated approach utilizing the fire-grazing interaction of patch-burn grazing could be a viable option for ranchers and land managers to use in accomplishing the goal of long-term management and control of sericea lespedeza.

Introduction

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don], or Chinese bush clover, is an introduced perennial legume native to eastern Asia that has become one of the greatest challenges ranchers and land managers face in the Kansas Flint Hills. Its highly invasive nature and unpalatable qualities at later growth stages have led to the infestation of thousands of acres of native rangeland in eastern Kansas.

First introduced as a tool to control soil erosion, sericea lespedeza gained popularity in the southeastern United States for its value as forage for livestock, wildlife habitat, and seed production. During the 1930s, it was introduced to southeast Kansas where it was planted for cover on strip-mined land. From the 1940s and into the 1970s it was used as wildlife habitat around state and federal reservoirs, and in the 1950s it was used in soil bank plantings along with introduced grasses (Rossow et al. 2009).

Today, ranchers and land managers are experiencing invasion of rangelands at rates approaching 2% increases in vegetative cover per year (Cummings et al. 2007b). From 1998 to 2002, Kansas acres that were identified with having this plant increased almost 100% (KSRE 2000 and Rossow et al. 2009). While mostly concentrated to the eastern one-third of Kansas, it has spread westward through the Conservation Reserve Program (CRP) that is administered by the United State Department of Agriculture (USDA). Occurrences have been reported in 73 of the 105 counties in Kansas, with several more being suspect (Ohlenbusch et al. 1999).

Sericea was declared a statewide noxious weed by the Kansas legislature in 2000 (making it the only state in the U.S. to name a federally listed forage crop as such). Sericea lespedeza's tendency to be free of insect and disease problems, competitive nature with other vegetation, and capability to thrive in a variety of environmental conditions continues to change how grazing lands are managed.

Several control options are being implemented on these grazing lands. Mowing, spraying, burning, grazing, and even biological control are being exercised. However, each has their limitations on effectiveness in controlling this introduced legume. Fire can reduce seed germination if exposed to high enough temperatures and, if timed properly, can destroy seedlings, but this method alone is not effective in eradicating sericea lespedeza and in most cases results in more dense stands (Cummings et al. 2007a). Likewise, intensive grazing by cattle can be used to suppress new plant growth. However, a high level of tannins and maturity lead to avoidance by grazers.

While not one of these individual options will eliminate sericea lespedeza permanently, utilization of multiple methods may be the best option. Patch-burn grazing is a relatively new tool in rangeland management that integrates both fire and intensive grazing. This technique is an alternative to all forms of traditional grazing management by using a patchwork of small burned areas within a larger landscape to concentrate cattle and their grazing without the use of fences.

The objective of this study was to observe the usefulness of patch-burn grazing as a potential control method of this invasive plant by monitoring utilization of the plants and recording changes in plant densities.

Materials & Methods

Site Description

The KSU Bressner Range Research Unit in Woodson County, Kansas was selected as the site for this study. This facility is owned by the Kansas State University Foundation and managed by an advisory council made up of area extension agents, extension specialists, and producers. This 253 ha unit (N1/2, S19, T25S, R15E and N1/2, S20, T25S, R15E) is located in east central Kansas on the eastern edge of the Kansas Flint Hills region at 37° 51'54.18" N, 95° 48'16.15" W and is approximately 343 m above sea level. At this site, 13 soils are represented, which fall into a total of 7 different ecological range sites (Appendix B). Dominant species include big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass [*Panicum virgatum* L.] (NRCS 2008). Growing-season (April – September) precipitation for the area was 45.39 cm, 94.69 cm, and 98.36 cm in 2006, 2007, and 2008, respectively. Long-term average annual precipitation for Woodson County is 106.98 cm, while annual growing-season precipitation is 69.52 cm (Knapp 2009).

Treatments and Sampling

The 253 ha of this unit were divided into 8 individual pastures, each consisting of approximately 32 ha (Figure A.1). Using a split-block experimental design, two burning management treatments were implemented and replicated four times over 3 years (2006-08). Pastures were fenced only on the exterior boundary with no fences dividing the patches. All 8 pastures were burned on 13 April 2006, 9 April 2007, and 9 April 2008.

Each of the north 4 pastures were patch-burn grazed on a one-third (11 ha) basis. Therefore, each patch in the patch treatment was burned once in the 3-year cycle. By the end of the study, a patch burn pasture would have one patch burned within 1 year, one patch burned 1 year prior, and one had not been burned for 2 years (design analogous to Fuhlendorf et al. 2006). Each of the south four pastures were subjected to the traditional method of full-burn grazing (Figure A.2).

Cattle (n = 120, average initial weight = 252 kg) were stocked in patch treatment pastures from mid-April through mid-August using a three-quarter season (114-d) grazing period at a rate of 1.09 ha/hd that was customary to the research unit (Lanham 2005). Cattle had free access to all areas within each pasture, so they could choose between burned and unburned patches in the patch treatment.

The remaining pastures were assigned the full-burn treatment and were designed to mimic similar grassland management used throughout the Flint Hills area. Treatment of these pastures consisted of an annual spring burn where all pastures were burned with a single fire every year. Again, cattle (n = 113, average initial weight = 252 kg) were stocked from mid-April through mid-August at a rate of 1.09 ha/hd and had free access to the entire area of each pasture.

One 30.5 meter transect was established in each of the one-third portions of the patch-burn pastures (excluding all 3 portions of Pasture #1 because a sufficient population of sericea lespedeza plants could not be found) and one was established in each of the full-burn pastures for a total of 13 transects. Using a 1 m measuring stick, the nearest sericea lespedeza plant to the transect, at 1.5 m intervals, was measured to the closest cm and designated as grazed or ungrazed. A total of 20 plants were evaluated along each transect. Those plants that were designated as grazed, compared to those that were not, allowed for calculation of the mean percent of total plants grazed.

Blocksome (2006) showed that sericea lespedeza plant height and biomass utilization have a nearly direct linear relationship with each successive percentage unit of plant height removed increasing biomass utilization by nearly equal amounts. For this study, the mean height of grazed plants along a given transect were compared to the mean ungrazed height to calculate percent of plant height removed by the cattle as depicted in the equation: [(Ungrazed Plant Height – Grazed Plant Height) / Ungrazed Plant Height] *

100 = % of Plant Height Removed. Considering the relationship described in Blocksome (2006), percent biomass utilization would be nearly equal to the calculated percent plant height removed.

At the same 1.5 m interval, a 0.25 m^2 frame was placed on the ground on alternating sides of the transect (Figure E.3). The number of plants within the frame were counted and recorded to monitor changes in density. Transect measurements were taken at the end of the grazing period during the months of August and September of each year.

Statistical Analysis

Data were analyzed using the Descriptive Statistics function of Microsoft Office Excel (Microsoft Corporation, Redmond, Washington 2003). The mean number of plants grazed, mean biomass utilization, and mean densities for each treatment area were entered and analyzed by calculating 90% confidence intervals.

Results & Discussion

Only in 2006 were any statistical differences ($p \leq 0.10$) found between treatments in the total number of plants that were grazed (Table 3.1). In the burned portion of the patch treatment, 92% of the total plants were designated as having been grazed. This was not different compared to the unburned portions (42% and 53%), however it was statistically greater ($p \leq 0.10$) than the number grazed in the traditional full-burn pastures (35%). In 2007 and 2008, 67% and 37% of the sericea plants in the burned portion of the patch treatments were grazed, respectively.

Overall, the mean height of the grazed plants was lower in the burned portions of the patch treatment than in either of the unburned portions or the full-burn pastures (Table 3.1). Those plants that were grazed in the burned portions averaged 13.3 cm compared to 48.3 cm in the unburned portions of the patch treatment and 40.6 cm in the full-burn treatment.

The only statistically higher amount of sericea lespedeza biomass consumed ($p \leq 0.10$) was found in 2006 when cattle grazed 79.0% of the standing crop in the burned portion of the patch treatments compared to 2.0% in one of the unburned portions (Patch-Burn A). This higher percentage in Patch-Burn C did not differ from the other unburned area (Patch-Burn B) or the full-burn pastures.

Cummings et al. (2007b) found that sericea lespedeza increased in both patch-burn pastures and full-burn pastures, but sericea plants increased at only one-quarter of the rate (0.47%) in the patch treatment compared to the full-burn (1.95%). Over a 7-year period, these rates remained constant.

In this study, densities in the full-burn pastures remained fairly static (Table 3.1). Though not a significant change ($p \geq 0.10$), in the year a given portion was burned within the patch treatment, plant counts tended to double. Surprisingly, once the grazing pressure was shifted to another portion the next season, plant count began to drop. This trend then continued through the remainder of the cycle. At the conclusion of this 3-year cycle, results show that densities did not differ ($p \geq 0.10$) between treatments.

Likewise, Cummings et al. (2007b) found that by the third year following a patch-burn, the presence of sericea lespedeza was reduced. Because cattle focused their grazing on recently burned areas, continuous, non-selective grazing allowed for repeated foraging events on the most recently burned patch which maintained sericea lespedeza plants at young maturity levels.

Conclusions

While few significant results were realized from this study, the focused grazing that patch-burn grazing provides does appear to limit the ability of sericea lespedeza to expand. This concentration of cattle leads to more plants being grazed; consequently more biomass of this plant is utilized.

With the potential to produce upwards of 200 million seeds per acre, sericea lespedeza is a prolific seed maker. Each stem has the capability of producing 1000-1500 seeds, so biomass reduction certainly becomes an important aspect in the control of this plant (Ohlenbusch et al. 1999).

Patch-burn grazing is one potential tool that can be effectively used to decrease the amount of standing seed-producing crop. In any given year of a cycle, more individual plants are grazed and more standing biomass is utilized in the recently burned portion of a patch treatment compared, numerically, to traditionally-managed grazing systems because this system increases grazing pressure that is put on sericea lespedeza populations.

With increased pressure on the populations, plants are maintained at younger maturity levels providing for a possible opportunity to increase the efficacy of several commonly used herbicides. Once a portion of the patch treatment has been burned and intensively grazed, one could take advantage of the vulnerable state the plants are in and apply a selected herbicide. This could perhaps be done at a lower rate than what is traditionally used and lead to substantial economic benefits.

In summary, early identification of the plant and prevention of seed production is key to the long-term management and control of sericea lespedeza. An integrated approach of herbicide application and the fire-grazing interaction of patch-burn grazing in the current year burned patch could be a viable option for ranchers and land managers to use in accomplishing this goal.

Tables

Table 3.1 Sericea lespedeza utilization and density by treatment area, 2006-2008

Year	2006			
Treatment Area	A	B	C	
Treatment [1]	UB	UB	PB	FB
Total Plants Grazed, %	42.0 [ab]	53.0 [ab]	92.0 [a]	35.0 [b]
Grazed Height, cm	56.1	42.9	9.2	16.2
Ungrazed Height, cm	43.1	52.9	51.5	41.0
Biomass Utilization, %	2.0 [a]	18.0 [ab]	79.0 [b]	57.0 [b]
Density, plants / 0.25 m^2	2.9 [a]	3.2 [a]	8.4 [a]	8.3 [a]

Year	2007			
Treatment [1]	UB	PB	UB	FB
Total Plants Grazed, %	23.0 [a]	67.0 [a]	33.0 [a]	29.0 [a]
Grazed Height, cm	46.3	12.8	52.2	51.9
Ungrazed Height, cm	38.4	24.8	46.4	68.7
Biomass Utilization, %	15.0 [a]	43.0 [a]	3.0 [a]	24.0 [a]
Density, plants / 0.25 m^2	5.7 [a]	6.4 [a]	7.2 [a]	4.6 [a]

Year	2008			
Treatment [1]	PB	UB	UB	FB
Total Plants Grazed, %	37.0 [a]	28.0 [a]	35.0 [a]	23.0 [a]
Grazed Height, cm	18.0	38.9	53.5	53.7
Ungrazed Height, cm	27.7	61.1	90.0	73.2
Biomass Utilization, %	37.0 [a]	38.0 [a]	40.0 [a]	24.0 [a]
Density, plants / 0.25 m^2	12.2 [a]	5.0 [a]	6.0 [a]	6.4 [a]

[1] Treatment: UB – Unburned, PB – Patch-burn grazed, FB – Full Burn
* Means followed by the same letter in the same row are not significantly different ($p \geq 0.10$)

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Appendix A - Pasture & Treatment Layouts

Figure A.1 Layout of the KSU Bressner Range Research Unit

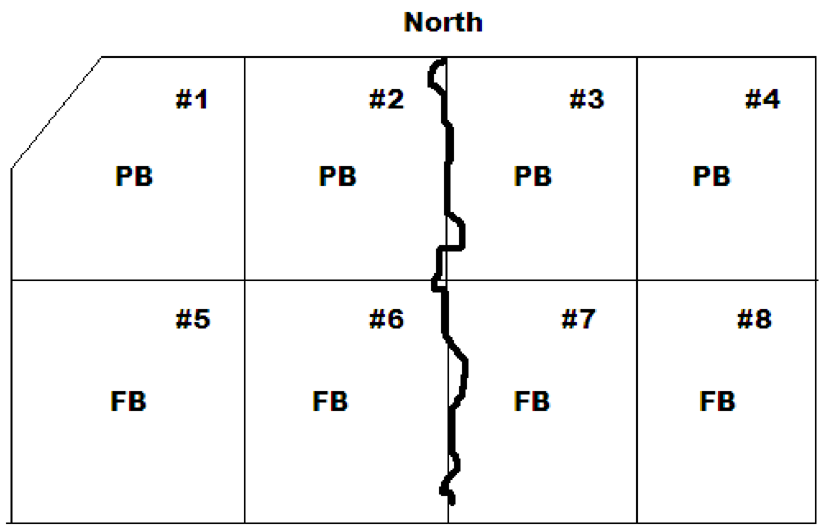
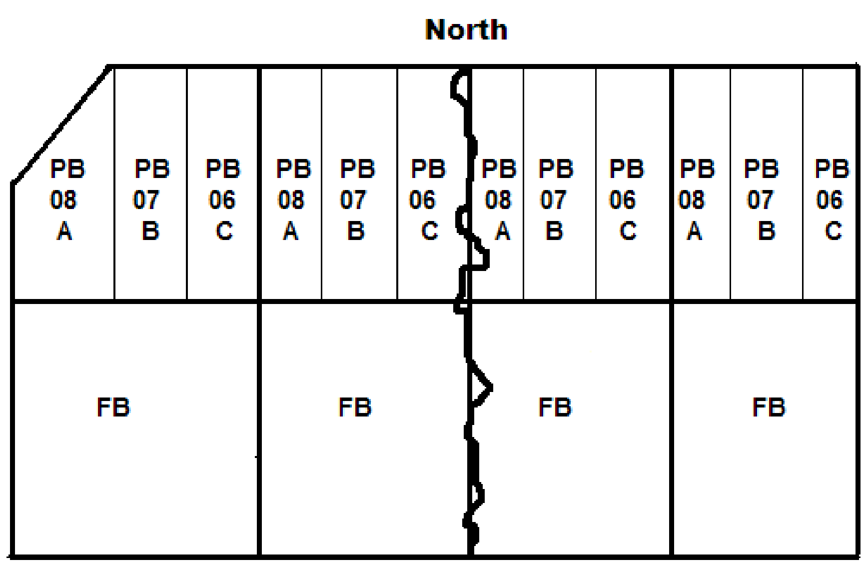


Figure A.2 Layout of patch-burn grazing and full-burn treatments



Appendix B - Represented Soils and Ecological Range Sites

SOIL NAME [1]	ASSOCIATED RANGE SITE(S) [1]
Bates loam, 1 to 3% slopes	Loamy Upland
Dennis silt loam, 1 to 3% slopes	Loamy Upland
Eram – Collinsville complex, 5 to 15% slopes	Clay Upland / Shallow Sandstone
Eram silty clay loam, 3 to 7% slopes	Clay Upland
Kenoma silt loam, 1 to 3% slopes	Clay Upland
Lula – Dwight complex, 0 to 1% slopes	Loamy Upland / Sodic Claypan
Lula silt loam, 0 to 1% slopes	Loamy Upland
Niotaze – Stephenville complex, 4 – 25% slopes	Savannah
Ringo – Sogn complex, 5 to 15% slopes	Clay Upland / Shallow Limstone
Ringo silty clay loam, 3 to 8% slopes	Clay Upland
Summit silty clay loam, 1 to 3% slopes	Loamy Upland
Verdigris silt loam, channeled	Loamy Lowland
Woodson silt loam, 0 to 1% slopes	Clay Upland

[1] Swanson & Googins 1977 and NRCS 2008

Appendix C - Site Precipitation

Table C.1 Growing season precipitation (cm) for Woodson County, KS, 2006-2008 [a]

Year	2006	2007	2008	30-year Avg. [b]
Month				
April	11.86	8.89	9.68	9.70
May	8.00	14.15	18.57	12.73
June	4.70	44.60	25.65	14.38
July	9.98	22.50	11.74	11.13
August	8.13	1.60	14.76	10.02
September	2.72	2.95	17.96	11.56
Total	45.39	94.69	98.36	69.52
Departure from 30-year	-24.13	+25.17	+28.84	------
Departure from 30-year, %	-34.71	+36.21	+41.48	------
Annual	70.36	129.72	141.10	106.98

[a] Knapp 2009

[b] 30-year average based on 1971-2000 data

Appendix D - Observed Plant Species

GRASSES [1]

Barnyardgrass (*Echinochloa muricata* (Beauv.) Fernald)

Big bluestem (*Andropogon gerardii* Vitman)

Blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Greenm.)

Broomsedge bluestem (*Andropogon virginicus* L.)

Buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.)

Common wildrye (*Elymus canadensis* L.)

Common Witchgrass (*Panicum capillare* L. [=*P.barbipulvinatum* Nash))

Crabgrass (*Digitaria sanguinalis* (L.) Scop. [=*Syntherisma sanguinale* (L.) Dulac.)])

Eastern gamagrass (*Tripsacum dactyloides* L.)

Fall witchgrass (*Digitaria cognata* (Schult.) Pilg.)

Hairy grama (*Bouteloua hirsuta* Lag.)

Indiangrass (*Sorghastrum nutans* (L.) Nash)

Japanese brome (*Bromus japonicus* Thunb.)

Kentucky bluegrass (*Poa pratensis* L.)

Knotroot bristlegrass (*Setaria parviflora* (Poir.) Kerguélen)

Little bluestem (*Schizachyrium scoparium* (Michx.) Nash [=*Andropogon scoparius* Michx.])

Lovegrass (*Eragrostis cilianensis* (All.) E. Mosher [=*E. megastachya* (Koel.) Link])

Paspalum (*Paspalum setaceum* Michx. [=*Paspalum stramineum* Nash])

Prairie cordgrass (*Spartina pectinata* Bosc ex Link)

Prairie junegrass (*Koeleria macrantha* (Ledeb.) Schult.)

Prairie threeawn (*Aristida oligantha* Michx.)

Purpletop (*Tridens flavus* (L.) Hitchc.)

Scribner's panicum (*Dichanthelium oligosanthes* (J.A. Schultes) Gould var. *scribnerianum* (Nash) Gould [=*Panicum oligosanthes* J.A. Schultes var. *scribnerianum* (Nash) Fernald])

Sedge (*Carex* spp.)

Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)

Switchgrass (*Panicum virgatum* L.)

Tall dropseed (*Sporobolus compositus* Merr. [=*Sporobolus asper* (Michx.) Kunth])

Tall Fescue (*Festuca arundinacea* Schreb.)

Tumblegrass (*Schedonnardus paniculatus* (Nutt.) Trel.)

Windmill grass (*Chloris verticillata* Nutt.)

Winter bentgrass (*Argostis hyemalis* (Walt) B.S.P.)

Yellow Foxtail (*Setaria pumila* (Poir.) Roem.& J.A. Schultes [=*Setaria glauca* (L.) Beauv.])

FORBS [1]

Annual broomweed (*Gutierrezia dracunculoides* DC.)

Aromatic aster (*Symphyotrichum oblongifolium* (Nutt.) G.L. Nesom)

Ashy sunflower (*Helianthus mollis* Lam.)

Baldwin ironweed (*Vernonia baldwinii* Torr.)

Field bindweed (*Convolvulus arvensis* L.)

Blue wild indigo (*Baptisia australis* L.)

Catclaw sensitive briar (*Mimosa nuttallii* (DC.) B.L. Turner)

Clammy ground cherry (*Physalis heterophylla* Nees)

Daisy fleabane (*Erigeron strigosus* Muhl. Ex Willd.)

False boneset (*Brickellia eupatorioides* (L.) Shinners [=*Kuhnia eupatorioides* L.])

False indigo (*Amorpha fructicosa* L.)

Fringeleaf ruellia (*Ruellia humilis* Nutt.)

Green antelopehorn (Asclepias viridis Walt.)

Heath aster (*Symphyotrichum ericoides* (L.) G.L. Nesom [=*Aster ericoides* L.])

Hemp dogbane (*Apocynum cannabinum* L.)

Horsenettle (*Solanum carolinense* L.)

Illinois bundleflower (*Desmanthus illinoensis* (Michx.) MacMill. ex B. L. Robinson & Fernald)

Korean lespedeza (*Kummerowia stipulacea* (Maxim.) Makino [=*Lespedeza stipulacea* Maxim.])

Lanceleaf ragweed (*Ambrosia bidentata* Michx.)

Missouri goldenrod (*Solidago missouriensis* Nutt.)

Narrowleaf bluet (*Hedyotis nigricans* (Lam.) Fosberg)

Painted euphorbia (*Euphorbia cyathophora* Murray)

Pale poppy mallow (*Callirhoe alcaeoides* (Michx.) A. Gray)

Pitcher Sage (*Salvia azurea* Michx. ex Lam. [=*Salvia pitcheri* Nutt.])

Plains wildindigo (*Baptisia bracteata* Muhl. ex Ell. var. *leucophaea* (Nutt.) Kartesz & Gandhi)

Purple poppy mallow (*Callirhoe involucrate* (T. & G.) A. Gray)

Purple prairie-clover (*Dalea purpurea* Vent.)

Sawtooth sunflower (*Helianthus grosseserratus* Martens)

Sericea lespedza (*Lespedeza cuneata* (Dumont) G. Don)

Sessile-leaf tickclover (*Desmodium sessilifolium* (Torr.) T. & G.)

Showy partridgepea (*Chamaecrista fasciculata* (Michx.) Greene var. *fasciculata* [=*Cassia chamaecrista* L.])

Slender lespedeza (*Lespedeza virginica* (L.) Britton)

Smooth-seed wildbean (*Strophostyles leiosperma* (T. & G.) Piper)

Spotted spurge (*Euphorbia maculata* L. [=*E. suprina* Raf.])

St. John's-wort (*Hypericum perforatum* L.)

Stiff goldenrod (*Solidago rigida* L.)

Tall goldenrod (*Solidago Canadensis* L.)

Toothed spurge (*Euphorbia dentata* Michx.)

Trailing wildbean (*Strophostyles helvula* (L.) Ell.)

Violet lespedeza (*Lespedeza violacea* (L.) Pers.)

Virginia copperleaf (*Acalypha virginica* L.)

Western ragweed (*Ambrosia psilostachya* DC.)

Western yarrow (*Achillea millefolium* L.)

White prairieclover (*Dalea candida* Michx. ex Willd.)

Whorled milkweed (*Asclepias verticillata* L.)

Wild strawberry (*Fragaria virginiana* Duchesne)

Wild violet (*Viola nephrophylla* Greene [=*Viola pratincola* Greene])

Wooly verbena (*Verbena stricta* Vent.)

Yellow woodsorrel (*Oxalis stricta* L. [=*Xanthoxalis bushii* Small, X. *cymosa* Small])

WOODY PLANTS [1]

Blackberry (*Rubus* spp.)

Leadplant (*Amorpha canescens* Pursh)

New Jersey tea (*Ceanothus herbaceus* Raf.)

Smooth sumac (*Rhus glabra* L.)

[1] Haddock 2005 and Stubbendieck et al. 1994

Appendix E - Photos

Figure E.1 Transition state of bare ground, forbs, and low amounts of standing biomass and litter 1 year after treatment (1-YAT)

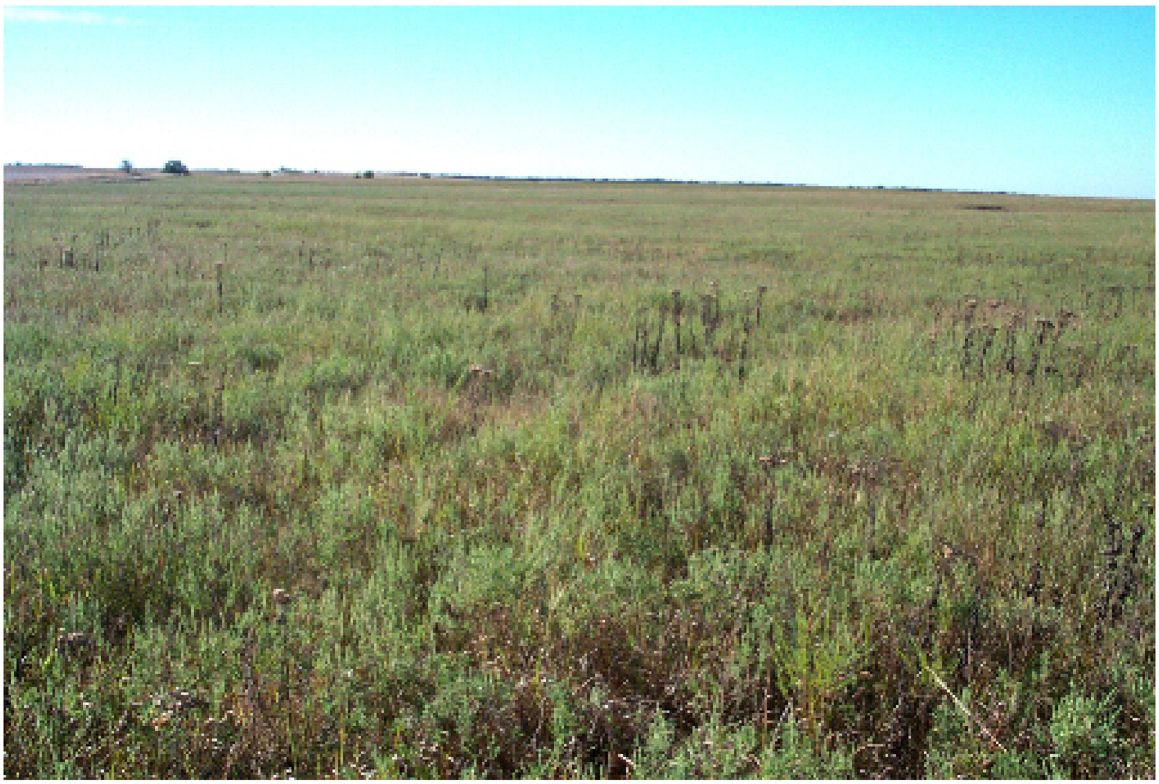


Figure E.2 Modified step-point frame used in botanical composition collections

Figure E.3 Frame (0.25 m^2) and measuring tape (30.5 m) used in sericea lespedeza monitoring