EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON OKLAHOMA RANGELANDS

By

TIMOTHY ROYCE TUNNELL

Bachelor of Science

Texas Tech University

Lubbock, Texas

1994

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2002

EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON OKLAHOMA RANGELANDS

Thesis Approved:

Thesis Advisor

Dean of the Graduate College

EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON OKLAHOMA RANGELANDS

Thesis Approved:

Thesis Advisor

Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to thank Dr. Sam Fuhlendorf, Dr. Dave Engle and Dr. Terry Bidwell for their assistance throughout this study and for providing examples of "thinking outside of the box" to benefit not only wildlife, but producers and natural resources in general. Thanks go to Dr. Sam Fuhlendorf for providing the opportunity to be a part of this research.

This project could not have been accomplished without the input and invaluable skills of a number of people, employees and students alike associated with Oklahoma State University. Special thanks go to the following: Ken Nelson, Chris Stansberry, John Weir, and Charlie Worthington for helping with all aspects of the study and providing hands-on real world experience that is best taught through example and application. I would also like to thank Oklahoma State University for the funding, facilities, and the opportunity to complete this degree. Thanks also go to Rod and Jami Huck and the Shaw brothers for their friendship and support through the years.

I would like to give a special thanks to my wife Susan for her continuous support, encouragement, and invaluable input throughout this project and for many more "projects" in the years to come. I love you! Thanks to all my family and friends. Finally, I would like to thank my parents Hank and Sherry Tunnell for their guidance, encouragement, confidence, and support through the years.

TABLE OF CONTENTS

Chapter | Page

I. EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON TALL- AND MIXED-GRASS PRAIRIES 1

Abstract 1
Introduction 2
Study Area 6
Methods 9
Results and Discussion 12
Conclusions 16
Literature Cited 19

APPENDICES 35

APPENDIX A--Plant species composition for the Oklahoma State University Research Range (OSURR) (tallgrass site) and the Marvin Klemme Range Research Station (MKRRS) (mixed-grass site) 36

APPENDIX B--Patch level angle of obstruction (AOB) means and standard errors (se) for the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001 46

APPENDIX C-- Functional group patch means (n=3) and standard errors (SE) of grass and forb canopy cover, bare ground, and litter cover for the Oklahoma State Research Range (OSURR) for 1999, 2000, and 2001 47

APPENDIX D--Functional group patch means (n=2) and standard error (SE) for control and patch burn treatments at the Marvin Klemme Range Research Station (MKRRS) for 1999, 2000, and 2001 48

LIST OF TABLES

Table Page

Chapter I

1. Livestock performance, average daily gain (ADG) and gain/ha, mean and standard error (se) for yearling steers for 1998, 1999, 2000, and 2001 for the Oklahoma State University Research Range (OSURR) and the Marvin Klemme Range Research Station (MKRRS)..........24

2. Mean and standard error (SE) of grass and forb canopy cover, litter cover, and bare ground by pasture for Oklahoma State University Research Range (OSURR where n=3 and 1999=pretreatment) and Marvin Klemme Range Research Station (MKRRS where n=2 and 1998=pretreatment) for 1999, 2000, and 2001. 26

3. Pasture level Angle of Obstruction (AOB) (degrees) means and standard error (se) for the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001. 27

4. .Patch heterogeneity index and standard error (SE) of Angle of Obstruction (AOB), litter, and bare ground at the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001........28

LIST OF FIGURES

Figure Page

Chapter I

1. This study was conducted at the following two sites, the Oklahoma State University Research Range (OSURR) Payne County, Oklahoma in the tallgrass prairie and the Marvin Klemme Range Research Station (MKRRS) Washita County, Oklahoma located in mixed-grass prairie...... 29

2. Study pasture layout and location for the tallgrass site located at the Oklahoma State University Research Range (OSURR) 21 km southwest of Stillwater, Oklahoma 30

3. Study pasture layout and location for the mixed-grass site located at the Marvin Klemme Range Research Station (MKRRS) 15 km southwest of Clinton, Oklahoma.. 31

4. Oklahoma State University Research Range (OSURR) patch layout within a pasture and burning regime. Dates within each patch indicate the burn season and year. Solid lines represent barbed wire fence around the perimeter of pasture and dotted lines represent each individual "unfenced" patch. The pasture sizes ranged from 46 ha to 73 ha with each patch within a pasture ranging from 8 to 15 ha. Patch Heterogeneity Index (PHI) was calculated as the standard deviation of the 6 patches within each pasture... 32

5. Marvin Klemme Range Research Station (MKRRS) patch layout within a pasture and burning regime. Dates within each patch indicate the burn season and year Solid lines represent barbed wire fence around perimeter of pasture and dotted lines represent each individual "unfenced" patch. The pasture sizes ranged from 41 ha to 58 ha, with each patch within a pasture ranging from 5 to 12 ha. Patch Heterogeneity Index (PHI) was calculated as the standard deviation of the 8 patches within each pasture... 33

6. Angle of obstruction (AOB) measured by recording angles from a position (pivot point) perpendicular to the soil surface (90°) to the top of the nearest obstructing vegetation (<90°) and systematically sampled in eight cardinal

directions using a digital level. The digital level was permanently fixed in the center of a 2.54cm x 2.54cm x142.4cm board 34

CHAPTER I

EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON TALL- AND MIXED-GRASS PRAIRIES

Abstract

Traditional rangeland management for livestock promotes spatial homogeneity of rangelands by encouraging uniform livestock distribution. We investigated patch burning, an alternative approach to range management that promotes spatially variable livestock distribution on an annual basis but promotes uniform distribution over a period of several years. This approach is patterned after the bison-fire interaction model that has been used successfully on the Tallgrass Prairie Preserve near Pawhuska, Oklahoma. The result is a shifting mosaic of disturbance patches that promotes biodiversity. Our objective was to determine the effects of this management approach on livestock production and habitat composition and structure in tallgrass prairie and mixed-grass prairie in Oklahoma. We evaluated the role of heterogeneity by comparing two treatments, patch burn and no burn. In the patch burn treatment, one-third (tallgrass) and one-quarter (mixed-grass) of the pasture was burned annually, one-sixth or one-eighth was burned in the fall and again in the spring. Yearling steers were moderately stocked from December through September. Livestock weights were used to assess livestock performance. Canopy cover by plant species, and bare ground and litter cover were estimated each fall in 1999, 2000, and 2001 to assess treatment effects on vegetation composition. Habitat structure was evaluated by angle of obstruction. Cattle performance did not differ between treatments at either site. Vegetation composition and habitat structure were more spatially variable (heterogeneous) in the patch burn treatment at the tallgrass site. The effects of the patch burn treatment were less apparent at the mixed-grass site because of greater inherent heterogeneity as a function of climate and production potential of the site. We conclude that patch burning has the potential to enhance or maintain biological diversity without reducing livestock production.

Introduction

Over the past 100 years, Great Plains grasslands that have not been converted to row-crop agriculture have been managed primarily for livestock production (Lauenroth et al. 1999). Most of the technologies applied to grasslands were intended to reduce the variability associated with rangeland ecosystems and livestock grazing patterns. Traditional practices such as rotational grazing, improving water distribution, and brush and weed control have focused on improving or maintaining livestock production by promoting the most productive warm-season grasses (Holecheck et al. 2001; Vallentine 2001). However, these practices reduce the heterogeneity of grasslands and promote landscapes that are more similar to pastures than prairies.

Certain rangeland management practices can simplify the structure and composition of grasslands by promoting warm-season grasses and reducing less palatable plants. This type of management has been effective for the stocker-cattle enterprises, however, landscapes dominated by highly productive warm-season grasses are not conducive to year round cow-calf enterprises that dominate most rangelands in the Great Plains. Forage quality on simplified rangelands is insufficient to support cattle during most of the year without substantial supplementation and low forage quality in the dormant season increases expenses from supplementation reducing net-profits of cow-calf enterprises. Livestock production enterprises could benefit from management that promotes a diversity of forages that can be utilized during different seasons to maintain a more stable nutritional balance throughout the year.

Most rangeland management practices (i.e. brush and weed management, fertilization, and grazing systems) are designed to increase livestock production by promoting dominance of a few key forage species. These management practices have created homogeneous agricultural landscapes that are generally not economically or ecologically supported by data. Rangeland practices that attract livestock to lightly used or unused area reduce spatial heterogeneity and increase forage harvest efficiency (Hooper et al. 1969; Samuel et al. 1980; Holechek et al. 2001; Vallentine 2001). As a result, management that distributes livestock evenly often reduces inherent heterogeneity associated with topoedaphic features and livestock behavior (Bailey et al. 1998).

Livestock make a series of decisions, which influence grazing distribution and the plant community. For example, livestock attempt to find the most desirable area for grazing, predator avoidance, thermal regulation, and water (Senft et al. 1987; Stuth 1991). Grazing animals congregate at preferred locations and avoid use of non-preferred areas. The repeated use of preferred locations can lead to over utilization of individual forage species, plant communities, or both and eventual decline of rangeland condition (Pinchak et al. 1991).

Management of livestock distribution is based on the goal of maximizing utilization without degrading any portion of the managed area (Gillen et al. 1984). Factors that result in poor or uneven grazing distribution of rangeland include distance from water, rugged topography, diverse vegetation, wrong type of livestock, pests, and weather (Holechek et al. 2001). Each factor has been the focus of research aimed at securing more uniform utilization of the rangeland in order to increase livestock production. Consequently, intensive grazing management (i.e. grazing systems) and broad-scale applications of brush and weed control that have been used to promote even livestock utilization have also contributed to reducing much of the inherent variability (i.e. heterogeneity) associated with rangeland habitats (Fuhlendorf and Engle 2001).

Practices that promote uniform livestock distribution have been the focus of over 60 years of grazing management research. Typical rangeland management practices for example cross fencing, herbicide application, and brush control intend to maximize production of dominant forage grasses and reduce spatial variability of resources inherent to rangeland landscapes. Various methods are used to improve livestock grazing distribution. Distribution of water sources and other focal points such as salt and mineral, prescribed fire, herbicide and fertilizer applications, and grazing systems are a few methods used to create more uniform utilization (Valentine 1947; Ares 1953; Smith and Lang 1958; Duvall and Whitaker 1964; Anderson 1967; Martin and Ward 1970; Martin and Ward 1973; Wright 1974). However, minimal habitat variability and uniform utilization is a result of emphasizing grazing distribution in space and time (Fuhlendorf and Engle 2001).

Heterogeneity has been identified as a critical component of landscapes for wildlife habitat (Wiens 1974), vegetation structure (Fuhlendorf and Smeins 1999) and ecosystem function (Ludwig and Tongway 1995). The importance of heterogeneity suggests the need for a paradigm shift that recognizes the importance of heterogeneity of rangeland ecosystems and development of management strategies that can promote heterogeneity (Fuhlendorf and Engle 2001). An alternative approach to traditional rangeland management is an attempt to utilize grazing to enhance biological diversity and maintain ecosystem function and livestock production.

The overall objective of this study was to develop an innovative approach of rangeland management to alter patterns of livestock distribution through patch burning. Burning of local patches within a pasture is expected to result in increased grazing pressure on the burned patches, decreased grazing pressure throughout the rest of the pasture, and ultimately a spatio-temporal patchwork of patches in various stages of succession that promotes diversity of vegetation and wildlife (Steuter et al. 1990; Hamilton 1996; Fuhlendorf and Engle 2001). Using the patch burn approach to livestock management, the normal spatially patchy grazing behavior of livestock can be utilized to enhance biodiversity (Truett et al. 2001). This approach will provide wildlife habitat at a variety of scales and provide a means of maintaining the habitat over time (George and Zack 2001).

Specifically, we compared the effects of patch burning and no burning under moderate grazing. We compared the effects of patch burning on two sites in Oklahoma, the Oklahoma State University Research Range (OSURR) and the Marvin Klemme Range Research Station (MKRRS) (Fig. 1). Our objectives were to examine 1) livestock performance (average daily gain and gain/ha), 2) grass, forb, litter cover, and bare ground, 3) the angle of obstruction, a measure of vegetation structure, and 4) variability (heterogeneity) of composition and structure in response to patch burning.

Study Area

The Oklahoma State University Research Range (OSURR) (Fig. 2) is part of the Oklahoma Agricultural Experiment Station system and is located approximately 21 km southwest of Stillwater, Oklahoma (36^{O}22'N; 99^{O}04'W, elev. 280 m). Average annual precipitation for the area is 830 mm. Mean monthly temperature is highest for July (27 ^{O}C) and lowest for December (4 ^{O}C). Major range sites on the study area are shallow prairie, loamy prairie, eroded prairie, and sandy savannah (Henley et al. 1987;McCollum et al. 1999).

The OSURR is classified as tallgrass prairie with some local communities representative of cross timbers vegetation including post oak [*Quercus stellata* Wang.] and eastern redcedar [*Juniperus virginiana* L.]. Dominant grasses include little bluestem [*Schizachyrium scoparium* (Michx.) Nash], big bluestem [*Andropogon gerardii* Vitman], indiangrass [*Sorghastrum nutans* (L.) Nash], switchgrass [*Panicum virgatum* L.], tall dropseed [*Sporobolus asper* (Michx) Kunth.], sideoats grama [*Bouteloua curtipendula* (Michx) Torr.] and Scribner's dicanthelium [*Dicanthelium oligosanthes* (J.A. Schultes) Gould]. The dominant forbs include western ragweed [*Ambrosia psilostachya* DC], heath aster [*Aster ericoides* L.], and annual broomweed [*Amphiachyris dracunculoides* (DC.) Nutt].

The management units at the OSURR have all been burned historically to minimize the encroachment of eastern redcedar (McCollum et al. 1999). Previous stocking rate research at the site was used to set the stocking rate at 3 ha per steer for the nine-month grazing period (December to September) for 1999, 2000, and 2001 (Gillen et al. 1991; Gillen et al. 2000).

The Marvin Klemme Range Research Station (MKRRS) (Fig. 3) is also part of the Oklahoma Agricultural Experiment Station and located approximately 15 km south of Clinton, Oklahoma in the Rolling Red Plains Resource Area of the southern Great Plains (35^{O}25'N; 99 ^{O}05'W, elev. 490 m). Average annual precipitation is 770 mm, ranging from 510 mm to 820 mm (Gillen et al. 2000). Mean monthly temperature is highest for July (28 ^{O}C) and lowest for January (9 ^{O}C). The 600 ha research station is largely rolling uplands cut by several steep drainages with many rock outcrops and bare areas. Soils are highly erosive and primarily classified as a Cordell silty clay loam with a depth of 0.25 m to 0.360 m over solid siltstone (Moffatt and Conradii 1979; Gillen et al. 2000).

Vegetation of the MKRRS is typical of the mixed-grass prairie with variable dominant species dependent upon topoedaphic effects and land use. The dominant species are a mixture of mid- and shortgrasses including sideoats grama, blue grama [*B. gracilis* (H.B.K) Lag.], hairy grama [*B. hirsuta* Lag.], buffalograss [*Buchloe dactyloides* (Nutt) Engelm.], silver bluestem [*Bothriochloa laguroides* (DC.) Herter], and purple threeawn [*Aristida pupurea* Nutt.]. The tallgrasses little bluestem, big bluestem, and indiangrass are present but less abundant. There is also a high diversity of herbaceous forbs. The dominant forbs include western ragweed, annual broomweed, and Texas croton [*Croton texensis* (Klotzch) Muell. Arg]. Woody plant species on the site include smooth sumac [*Rhus glabra* L.] and sand plum [*Prunus angustifolia* Marsh.] in isolated portions of the landscape, as well as the widely distributed sub-shrub broom snakeweed [*Gutierrezia sarothrae* (Pursh) Britt & Rusby).

The area has not been burned in the last ten years and prescribed fire is not commonly used in the area. Livestock have grazed the area since the turn of the century at stocking rates that have been estimated at moderately heavy to heavy from 1965 to 1989 (Gillen et al. 2000; Fuhlendorf et al. 2001). Each pasture was stocked at 4 ha per steer for the nine-month grazing period of 1998, 1999, 2000, and 2001. Steers stocked from April through September in 1998 and 1999 consist of pretreatment data.

Methods

Experimental Design

We used a completely randomized design to evaluate the effects of livestock performance, vegetation cover and structure, and vegetation cover and structural heterogeneity at the pasture level (large scale) of a patch burn system compared to a continuously grazed system with no burning. Replicated grazing-fire treatments were established at the OSURR (n=6) and MKRRS (n=4). The treatments included: 1) burning of spatially distinct patches within a treatment unit and free access by moderately stocked cattle (patch burn) and 2) no burning with free access by moderately stocked cattle (control).

Each experimental unit consisted of a pasture, which was divided into 6 (OSURR) (Fig. 4) or 8 (MKRRS) (Fig. 5) distinct patches. Each patch was delineated at the corners by permanent markers (t-posts) designed to facilitate ecological monitoring, but not to interfere with livestock or wildlife behavior and distribution. Patch size differed between the two sites because of the expected rate of recovery following patch burning. At the OSURR, one-sixth of the experimental unit was burned each spring (March to April) and one-sixth each fall (September to October) of 1999, 2000, and 2001 (Fig. 4). At the MKRRS site, one-eighth of each pasture was burned each spring (March to April) and one-eighth each fall (September to October) of 1999, 2000, and 2001 (Fig. 5). The burning regime used in this study will result in a 3-year complete pasture burning cycle at the OSURR site and 4-year complete pasture burning cycle at MKRRS.

Livestock Performance

Pastures were moderately grazed with mixed-breed yearling steers for each year of the study. Steers for each pasture were permanently identified and randomly assigned to each treatment pasture. Steers were weighed individually with 1 kg resolution on electronic scales at the beginning (December 1), mid-season (April 1), and end (September 1) of the grazing season for each year of the study at both sites. However, the grazing period for 1998 and 1999 at the MKRRS site was from April 1 to September 1 and is reported as pretreatment data. For the beginning and ending weights, steers were gathered in the afternoon at each unit, restricted from feed and water overnight, and weighed early the next morning. For the mid season weight, steers were gathered at each unit and restricted from feed and water for approximately one hour, weighed and then returned to the pastures.

Vegetation Composition

Vegetation was sampled in late August to early September of 1999, 2000, and 2001 at both sites. For each patch (Fig. 4 and 5) within each pasture, we recorded canopy cover by species (Daubenmire 1959) and presence of each vascular plant species (Appendix A) within 30, 0.1 m^2 quadrats. Species were combined into two functional groups grass and forbs, and all analyses were performed at the functional group level. Average cover for each patch was calculated by summing the percent canopy cover values for all species of grasses and forbs and the values for bare ground and litter in each patch. The average canopy cover of grasses and forbs and the average percent cover for bare ground and litter for each patch was then used to calculate the average cover of each functional group for the pasture.

Vegetation Structure

The angle of obstruction (AOB) was used to measure vegetation structure (Kopp et al. 1998; Harrell et al. 2001). At each quadrat sampled for species canopy cover, AOB was measured by recording angles (0° to 90°) to the top of the nearest obstructing vegetation and systematically sampled in eight cardinal directions from a pivot point at the soil surface using a digital level (Fig. 6) (Harrell and Fuhlendorf 2002). From these eight angles, we calculated an average AOB providing a structural measurement of the vegetation at each sampling point. AOB of each pasture was determined by calculating the average AOB for each patch within that pasture. Patch averages were then used to calculate the pasture average AOB.

Heterogeneity

Heterogeneity was indexed using the standard deviation between the average patch level AOB measurements (Appendix B), the patch level bare ground measurements and the patch-level litter measurements (Appendix C and D) within each pasture (Fig. 4 and 5). The Patch Heterogeneity Index (PHI) allows for a measure of variability among patches within each pasture to quantify heterogeneity.

Statistical Analyses

Statistical differences for livestock performance (average daily gain and gain per hectare), percent cover (grass, forb, bare ground, and litter), vegetation structure (angle of obstruction), and patch heterogeneity at the pasture level were assessed using t-tests ($\alpha=0.05$) to evaluate within year treatment differences (SAS 1988). Livestock performance, vegetation composition, vegetation structure (AOB), and Patch Heterogeneity Index were compared between treatments within each sample year and not across years.

Results and Discussion

Livestock Performance

There were very few differences in livestock performance. Differences in post-treatment data were the same as pre-treatment data at both sites for each year of the study. Livestock performance, measured by average daily gain (ADG) and gain/ha (kg/ha), did not differ ($P<0.05$) between treatments for any of the grazing periods for all three years of the study at the OSURR (Table 1). At the MKRRS site, the only effect of patch burning on livestock performance was a greater ($P<0.05$) average daily gain (ADG) in the patch burn treatment for the December to September sampling period during the 1999 to 2000 grazing season (Table 1). Overall, this study indicates that patch burning does not decrease livestock performance in the tallgrass and the mixed-grass prairie.

The literature has long recommended that uniform livestock distribution is important to maintain livestock production and range condition (Bell 1973; Holechek 2001; Valentine 2001). In fact, much research has been conducted to develop techniques to promote uniform distribution (Anderson 1967; Savory 1988; Hart et al 1993). These approaches have assumed that uniform distribution is required within a single year and the concept of a shifting mosaic of vegetation composition and structure has never been evaluated (Fuhlendorf and Engle 2001).

Vegetation Composition

Pretreatment data showed no difference in grass, forb, litter, and bare ground for MKRRS (1998) (Table 2) or OSURR (1999) (Table 2). At the OSURR, grass cover in the patch burn treatment was less ($P<0.05$) than the control treatment in 2000 only. Forb cover did not differ ($P<0.05$) between treatments in any of the three years of the study. Litter cover was less ($P<0.05$) and bare ground was greater ($P<0.05$) in the patch burn treatment in 2000 and 2001 (Table 2) after one-third of the pasture had been burned each year.

At the MKRRS, grass and litter canopy cover and percent bare ground remained unchanged between treatments for 1999, 2000, and 2001 (Table 2). In 2000, forb cover was greater ($P<0.05$) in the patch burn treatment compared to the control, however forb canopy cover was not different in 2001 (Table 2).

In 2001, two-thirds of the pasture had been burned at the OSURR and five-eighths of the pasture had been burned at the MKRRS with no difference between treatments in grass cover. This lack of an effect on grass cover is supported by the lack of a negative effect on livestock performance at either site. The only effect on forb cover was an increase in cover for the patchburn treatment in 2000 at the MKRRS site.

The effects on bare ground and litter were variable from the OSURR site and the MKRRS site. From 1999 to 2001, litter cover accumulated by 20 percent in the control while litter cover was maintained at a lower level and only increased by approximately 5 percent in the patch burn at the OSURR site. On the other hand, bare ground was lower and decreased by 4 percent in the control and was higher and increased by approximately 9 percent in the patchburn treatment at the OSURR site from 1999 to 2001 (Table 2). Conversely, litter and bare ground remained unchanged between treatments for each year at the MKRRS site (Table 2). Greater bare ground and less litter may be critical for some wildlife species, while less bare ground and more litter (i.e. cover) may be required for other species. Through patch burning and moderate grazing, habitat for a variety of species that require varying degrees of structure, bare ground and cover can be available in the same landscape (i.e. management unit) or maintained at appropriate levels to meet the habitat needs of many species.

Vegetation Structure

Pretreatment data at the OSURR (1999) had no difference ($P<0.05$) in Angle of Obstruction (AOB) (Table 3). Pretreatment data (1998) for the MKRRS site were not collected, but data for 1999 shows no differences in AOB (Table 3) after one eighth of each patch burn pasture had been burned the previous spring. At the OSURR, AOB was less ($P<0.05$) in the patch burn treatment in 2000 and 2001, when compared to the control treatment (Table 3). The lower AOB in the patch burn treatment indicates that patch burning creates more openness within the canopy at the pasture level compared to a more closed canopy in the control pastures in the tallgrass prairie. However, at the MKRRS, AOB was greater ($P<0.05$) in the patch burn treatment only in 2001 (Table 3). The higher AOB in the patch burn treatment indicates that patch burning is creating a more closed canopy at the pasture level compared to a more open canopy in the control pastures in the mixed-grass prairie. The higher AOB is most likely due to greater forb cover, which contributed most of the vegetation structure at this site.

Heterogeneity

The Patch Heterogeneity Index (PHI) of patch AOB means, patch litter cover means, and patch bare ground means for 1999, 2000 and 2001 at both sites are found in Table 4. Pretreatment data (1999) show there was no difference ($P<0.05$) in the PHI for AOB, litter cover, or bare ground at the OSURR site. Although pretreatment (1998) data was unavailable for the MKRRS, 1999 data indicated no difference ($P<0.05$) in the PHI for AOB, litter cover, or bare ground after one eighth of the pasture had been burned the previous spring (Table 4).

At the OSURR, the PHI of AOB and litter cover were greater in the patch burn treatment ($P<0.05$) compared to the control treatment for 2000 and 2001 (Table 4). Although there were no differences ($P<0.05$) between treatments in

1999 (pretreatment), variability greatly increased in 2000 and 2001 after burning two-thirds of the pasture, one-third each year at the OSURR. More variation was detected between patches within the pastures of the patch burn treatment at the OSURR, which indicates the patch burn pasture becomes more open with more structural variability between patches, thus increasing heterogeneity. The greater PHI for the patchburn treatments indicates higher variability within the patchburn management units compared to the control management units at the OSURR site. The PHI of bare ground remained unchanged for all three years of the study at the OSURR (Table 4). Conversely, at the MKRRS, there were no differences ($P<0.05$) in PHI for AOB and bare ground between treatments for 1999, 2000, or 2001 (Table 4). The PHI of litter cover was only greater ($P<0.05$) in the patch burn treatment compared to the control treatment for 2000 (Table 4). The variable vegetation composition and structure (i.e. heterogeneity) associated with a shifting mosaic can help provide the basic needs (i.e. food and cover) of a wide variety of wildlife species (Weins 1974;Holechek 2001) and consequently, a shifting mosaic has been described as critical to the structure and function of grassland ecosystems (Hamilton 1996; Truett et al 2001)

Conclusions

The differences observed in the vegetation at the OSURR were not as evident at the MKRRS. The primary reason for no treatment effect at MKRRS can be attributed to the inherent heterogeneity that occurs at the mixed-grass site. In addition, fires were less effective because of climate, productivity, and timing. These factors affect fuel load and continuity of the fires, which in turn influence the success of a prescribed fire in mixed-grass prairie and the ability of a fire to attract livestock. The mixed-grass prairies do not produce as much biomass as compared to more productive tallgrass prairies. Consequently, the effects of the fire-grazing interaction on composition and structure of mixed-grass vegetation are less than tallgrass prairie based primarily on the fact that forage production values are reduced at the mixed-grass site because of precipitation patterns and soil depth (Moffatt and Conradii 1979; Henley et al. 1987).

Patch burning is a contradiction of traditional management that leads to the idea of heterogeneity versus homogeneity, where management for one has the potential to eliminate the other. This can be looked at from the perspective of wildlife versus livestock where management for heterogeneity could maintain, if not, benefit both wildlife and livestock and the vegetational components of tall and mixed-grass prairies. Through patch burning, we expected livestock to preferentially graze recently burned patches that are rotated across the landscape (i.e. management unit) over a period of several years where livestock are given free access to the entire management unit. This management approach will result in focal disturbances that are intense within a matrix of undisturbed vegetation, thus creating a shifting mosaic in vegetation composition and structure within the grassland (Steuter et al 1990; Hamilton 1996; Fuhlendorf and Engle 2001) through the effects of the fire and grazing interaction. A shifting mosaic has been described as critical to the structure and function of grassland ecosystems (Hamilton 1996; Truett et al 2001) and the variable vegetation composition and structure (i.e. heterogeneity) associated with a shifting mosaic can help provide the basic needs (i.e. food and cover) of a wide variety of wildlife species (Weins 1974;Holechek 2001). Additionally, our data suggests that managing for a shifting mosaic of vegetation composition and structure through patch burning can also maintain livestock performance in the tall and mixed-grass prairies of Oklahoma.

Our data indicate that patch burning increased variation, or heterogeneity, within the vegetation components of tallgrass prairie and maintained variation within a mixed grass prairie without decreasing livestock gains or grass canopy cover. These observations suggest that uniform distribution of livestock under moderate stocking rates was not critical for livestock production as long as the uneven distribution was shifting and not constant from year to year. In fact, the only significant effect on livestock was an increase in ADG following the implementation of the patch burn treatment during one year at the mixed-grass site. The lack of an effect on livestock production is important because the heterogeneity associated with patch burn treatments may be important for wildlife habitat and ecosystem function of rangelands (Fuhlendorf and Engle 2001). Understanding the effect of heterogeneity on grasslands and wildlife is critical to maintaining long-term sustainability of grasslands and this awareness should guide future management decisions of native grassland ecosystems (Lauenroth et al 1999;Truet et al 2001).

Literature Cited

Anderson, E.W. 1967. Grazing Systems as methods of managing the range resources. J. Range Manage. 20: 383-388.

Ares, F.N. 1953. Better cattle distribution through the use meal-salt mix. J. Range Manage. 6: 341-346.

Bailey, D.W., B. Dumont, and M.F. WallisDeVries. 1998. Utilization of heterogeneous grasslands by domestic herbivores: Theory to management. Ann. Zootech. 47: 321-333.

Bell, H.M. 1973. Rangeland management for livestock production. University of Oklahoma Press. Norman, OK.

Daubenmire, R.F. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33: 43-64.

Duval V.L. and L.B. Whitaker. 1964. Rotation burning: A forage management system for longleaf pine-bluestem ranges. J. Range Manage. 17:322-326.

Fuhlendorf, S.D. and F.E. Smeins. 1999. Scaling effects of grazing in a semi-arid grassland. J. Veg. Sci. 10:731-738.

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

Fuhlendorf, S.D., H. Zhang, T.R. Tunnell, D.M. Engle, and A. F. Cross. 2001. Effects of grazing on restoration of southern mixed prairie soils. Ecological Restoration (In Press)

George, T.L. and S. Zack. 2001. Spatial and temporal considerations in restoring habitat for wildlife. Res. Ecol. 9:272-279.

Gillen, R.L., W.C. Krueger, and R.F. Miller. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. J. Range Manage. 37:549-553.

Gillen, R.L., F.T. McCollum, M.E. Hodges, J.E. Brummer, and K.W. Tate. 1991. Plant community responses under short duration grazing in tallgrass prairie. J. Range Manage. 44: 124-128.

Gillen, R.L., J.A. Eckroat, and F.T. McCollum III. 2000 Vegetation response to stocking rate in southern mixed-grass prairie. J. Range Mange.53:471-478.

Hamilton, R.G.1996. Using fire and bison to restore a functional tallgrass prairie landscape. Transactions of the North American Wildland and Natural Resource Conference 61:208-214.

Harrell, W.C., S.D. Fuhlendorf, and T.G. Bidwell. 2001. Effects of prescribed fire on sand shinnery oak communities. J. Range Manage. 54:685-690.

Harrell, W.C. and S.D. Fuhlendorf. 2002. Evaluation of habitat structural measures in a shrubland community. J. Range Manage. (In Press)

Hart, R.H., J. Bission, M.J. Samuel, and J.W. Waggoner Jr. 1993.Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. J.Range Manage. 46:81-87

Henley, J.R., D.Gelnar, and R.E. Mayhugh. 1987. Soil survey of Payne County Oklahoma. USDA Soil Conservation Service, Stillwater, Oklahoma.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 2001. Range management principles and practices. Prentice-Hall, Inc., Upper Saddle River, NJ.

Hooper, J.F., J.P Workman, J.B. Grumbles, and C.W. Cook. 1969. Improved livestock distribution with fertilizer: a preliminary economic evaluation. J. Range Manage. 22:108-110.

Kopp, S.D., F.S. Guthery, N.D. Forrester, and W.E. Cohen. 1998. Habitat selection modeling for Northern Bobwhites on subtropical rangeland. J. Wildl. Manage. 62: 881-902.

Lauenroth, W.K., I.C. Burke, and M.P. Gutmann. 1999.The structure and function of ecosystems in the central North American grassland region. Great Plains Res. 9:223-259.

Ludwig, J.A. and D.J. Tongway. 1995. Spatial organization of landscaped and its function in semi-arid woodlands, Australia. Landscape Ecol. 10: 51-63.

Martin, S.C. and D.E. Ward. 1970. Rotating access to water to improve semidesert cattle range near water. J. Range Manage. 23:22-26.

Martin, S.C. and D.E. Ward. 1973. Salt and meal-salt help distribute cattle use on semidesert range. J. Range Manage. 26:94-97.

McCollum, F.T. III, R.L. Gillen, B.R. Karges, and M.E. Hodges. 1999. Stocker cattle response to grazing management in tallgrass prairie. J. Range Manage. 52: 120-126.

Moffatt, H.H. and A.J. Conradii. 1979. Soil survey of Washita County Oklahoma. USDA Soil Conservation Service, Stillwater, OK.

Pinchak, W.E., M.A. Smith, R.H. Hart, and J.W. Waggoner, Jr. 1991. Beef cattle distribution patterns on foothill range. J. Range Manage. 44:267-275.

Samuel, M.J., F. Rauzi, and R.H. Hart. 1980. Nitrogen fertilization of range: yield, protein content, and cattle behavior. J. Range Manage. 33:119-121.

SAS Institute Inc. 1988. SAS procedures guide, release 6.03 edition. SAS Institute, Inc. Cary, NC.

Savory, A. 1988. Holistic resource management. Island Press, Covelo, CA.

Senft, R.L., M.B. Coughenour, D.W. Bailey, L.R. Rittenhouse, O.E. Sala, and D.M. Swift. 1987. Large herbivore foraging and ecological hierarchies. BioSci. 37:789-799.

Smith, D.R. and R.L. Lang. 1958. The effect of nitrogenous fertilizers on cattle distribution on mountain range. J. Range Manage. 11:248-249.

Steuter, A.A., C.E. Grygiel, and M.E. Biondini. 1990. A synthesis approach to research and management planning: the conceptual development and implementation. Nat. Areas J. 10: 61-68.

Stuth, J.W. 1991. Foraging behavior. In J.W. Stuth and R.K. Heitschmidt (ed), Grazing management: an ecological perspective. Timber Press, Portland, OR.

Truett, J.C., M.P. Phillips, K. Kunkel, and R. Miller. 2001. Managing bison to restore biodiversity. Great Plains Res. 11:123-144.

Valentine, K.A. 1947. Distance from water as a factor in grazing capacity of rangeland. J. Forest. 45:749-754.

Vallentine, J.F. 2001. Grazing management. Academic Press, Inc. San Diego, CA.

Wiens, J.A. 1974. Habitat heterogeneity and avian community structure in North American grassland birds. Am. Mid. Nat. 91: 195-213.

Wright, H.A. 1974. Range burning. J. Range Manage. 27: 5-11.

Table 1. Average daily gain (ADG) and gain/ha, mean and standard error (SE) of yearling steers for 1998, 1999, 2000, and 2001 for the Oklahoma State University Research Range (OSURR) and the Marvin Klemme Range Research Station (MKRRS).

Year and Treatment	Ave. initial weight (kg)	ADG (kg)			Gain/ha (kg/ha)		
		(Dec.-Mar.)	(Apr.- Sep.)	(Dec.-Sep.)	(Dec.-Mar.)	(Apr.-Sep.)	(Dec.-Sep.)
OSURR							
1998-1999							
Control	248	0.05 (0.02)	1.00 (0.05)	0.58 (0.02)	1.87 (1.02)	52.22 (2.80)	54.10 (2.09)
Patchburn	242	0.05 (0.02)	0.87 (0.05)	0.51 (0.03)	2.22 (0.88)	44.16 (3.08)	46.38 (3.66)
1999-2000							
Control	178	-0.002 (0.02)	0.96 (0.07)	0.50 (0.05)	-0.18 (1.01)	40.29 (4.19)	40.25 (5.06)
Patchburn	180	-0.05 (0.01)	0.97 (0.05)	0.48 (0.03)	-1.75 (0.39)	41.66 (3.64)	39.91 (4.02)
2000-2001							
Control	224	-0.18 (0.04)	0.79 (0.07)	0.36 (0.06)	-7.94 (1.88)	42.58 (3.73)	34.63 (5.58)
Patchburn	225	-0.15 (0.01)	0.75 (0.04)	0.34 (0.03)	-6.63 (0.38)	40.91 (2.38)	34.28 (2.70)

Table 1. Continued

Year and Treatment	Ave. Initial weight (kg)	ADG (kg) (Dec.-Mar.)	ADG (kg) (Apr.-Sep.)	ADG (kg) (Dec.-Sep.)	Gain/ha (kg/ha) (Dec.-Mar.)	Gain/ha (kg/ha) (Apr.-Sep.)	Gain/ha (kg/ha) (Dec.-Sep.)
MKRRS							
1998*							
Control	231			0.76 (0.02)			33.80 (1.45)
Patchburn	231			0.78 (0.03)			36.14 (0.56)
1999*							
Control	211			0.80 (0.01)			29.79 (0.50)
Patchburn	209			0.83 (0.03)			28.15 (2.88)
1999-2000							
Control	238	0.23 (0.05)	0.94 (0.05)	0.61 (0.002)**	6.23 (1.85)	30.59 (0.88)	36.82 (3.86)
Patchburn	241	0.26 (0.03)	0.96 (0.03)	0.64 (0.001)	7.61 (0.66)	33.64 (1.85)	41.25 (1.20)
2000-2001							
Control	186	0.17 (0.04)	0.74 (0.01)	0.46 (0.02)	5.26 (1.67)	23.34 (1.55)	28.60 (3.22)
Patchburn	194	0.18 (0.04)	0.76 (0.01)	0.48 (0.02)	5.90 (0.99)	25.60 (0.31)	31.50 (0.68)

* grazing period April 1 thru Aug 31.

**values are significantly different at α=0.05

Table 2. Mean and standard error (SE) of grass and forb canopy cover, bare ground, and litter cover by pasture for Oklahoma State University Research Range (OSURR where n=3 and 1999=pretreatment) and Marvin Klemme Range Research Station (MKRRS where n=2 and 1998=pretreatment) for, 1999, 2000, and 2001.

	Grass (%)				Forb (%)				Litter (%)				Bare Ground (%)			
OSURR	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001
Control	N/A	63.21 (0.63)	69.80* (3.19)	51.56 (8.05)	N/A	31.37 (3.91)	34.41 (2.61)	30.39 (2.37)	N/A	26.66 (8.51)	36.69* (0.60)	46.19* (1.30)	N/A	5.49 (1.32)	2.55* (0.59)	1.26* (0.20)
Patch-burn	N/A	59.63 (3.31)	57.27* (2.58)	38.02 (1.03)	N/A	27.04 (4.06)	38.64 (4.05)	34.81 (3.70)	N/A	23.98 (2.61)	25.54* (0.68)	28.90* (1.53)	N/A	5.80 (1.53)	9.20* (2.12)	15.18* (2.89)
MKRSS																
Control	33.12 (1.82)	30.10 (1.64)	44.31 (1.27)	31.46 (5.57)	4.20 (0.63)	22.91 (1.37)	24.11* (1.26)	21.54 (1.91)	11.60 (1.19)	23.70 (10.70)	24.38 (1.09)	33.00 (1.18)	23.93 (2.05)	21.52 (2.28)	22.71 (0.15)	22.21 (1.24)
Patch-burn	42.45 (1.70)	33.40 (5.42)	42.00 (1.48)	34.12 (1.51)	6.84 (0.80)	25.64 (0.12)	32.34* (1.07)	28.14 (4.48)	15.93 (1.08)	23.24 (6.19)	24.28 (0.42)	26.34 (3.00)	18.12 (1.77)	16.62 (0.27)	19.68 (2.64)	22.28 (0.42)

*Means within each year are significantly different at α=0.05.

Table 3. Pasture level Angle of Obstruction (AOB) (degrees) means and standard error (SE) for the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001.

	AOB (degrees)		
	1999	2000	2001
OSURR			
Control	84.69 (1.31)	87.79 (0.72) *	85.14 (0.62) *
Patchburn	84.29 (0.81)	82.34 (0.13) *	77.11 (1.62) *
MKRRS			
Control	55.30 (5.52)	54.21 (3.92)	57.65 (0.26) *
Patchburn	54.49 (1.97)	57.35 (0.70)	64.48 (1.61) *

*Means within each year for each site are significantly different at $\alpha=0.05$.

Table 4. Patch heterogeneity index and standard error (SE) of Angle of Obstruction (AOB), litter, and bare ground at the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001.

	AOB			Litter			Bare Ground		
OSURR	1999	2000	2001	1999	2000	2001	1999	2000	2001
Control	4.48 (1.40)	2.46* (0.70)	3.70* (0.33)	5.20 (1.72)	4.54* (0.91)	3.03 * (0.18)	6.29 (1.26)	4.93 (1.41)	4.82 (1.59)
Patchburn	2.75 (0.38)	9.91* (1.65)	14.37* (1.04)	4.09 (0.48)	16.53* (0.59)	16.52* (1.23)	3.65 (0.80)	6.87 (1.18)	7.91 (1.40)
MKRRS									
Control	5.51 (1.72)	6.28 (0.39)	5.84 (1.79)	6.35 (3.09)	7.73* (0.71)	7.64 (2.10)	8.58 (1.53)	7.89 (0.04)	8.07 (1.42)
Patchburn	8.54 (0.74)	9.14 (4.58)	4.77 (0.99)	11.76 (5.15)	13.13* (0.61)	8.98 (1.09)	10.43 (1.43)	10.98 (2.44)	8.07 (0.68)

*Means within each year are significantly different at α=0.05.

Fig. 1. This study was conducted at the following two sites, the Oklahoma State University Research Range (OSURR) Payne County, Oklahoma and the Marvin Klemme Range Research Station (MKRRS) Washita County, Oklahoma.

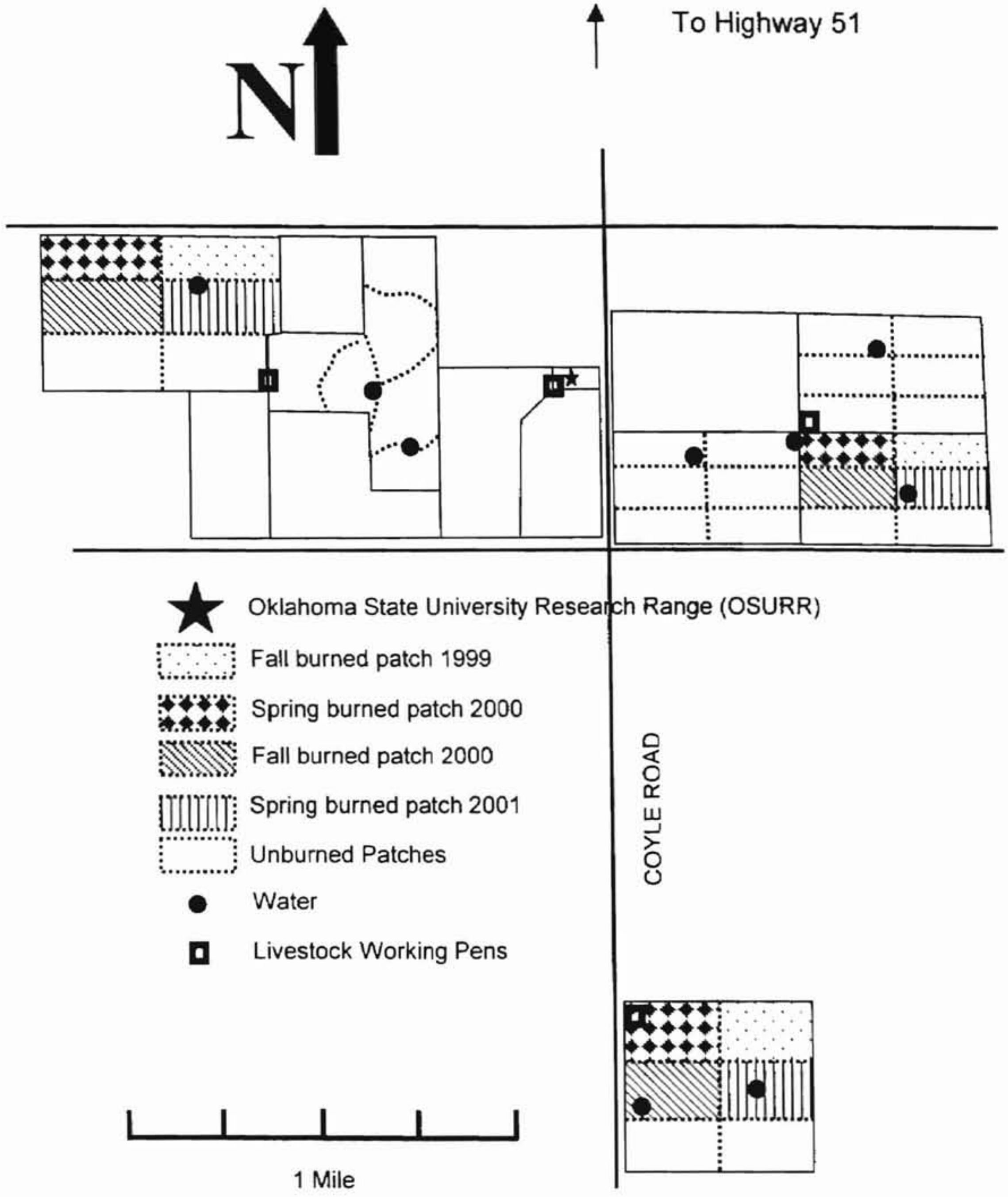

Fig. 2. Study pasture layout and location for the tallgrass site located at the Oklahoma State University Research Range (OSURR) 21 km southwest of Stillwater, Oklahoma.

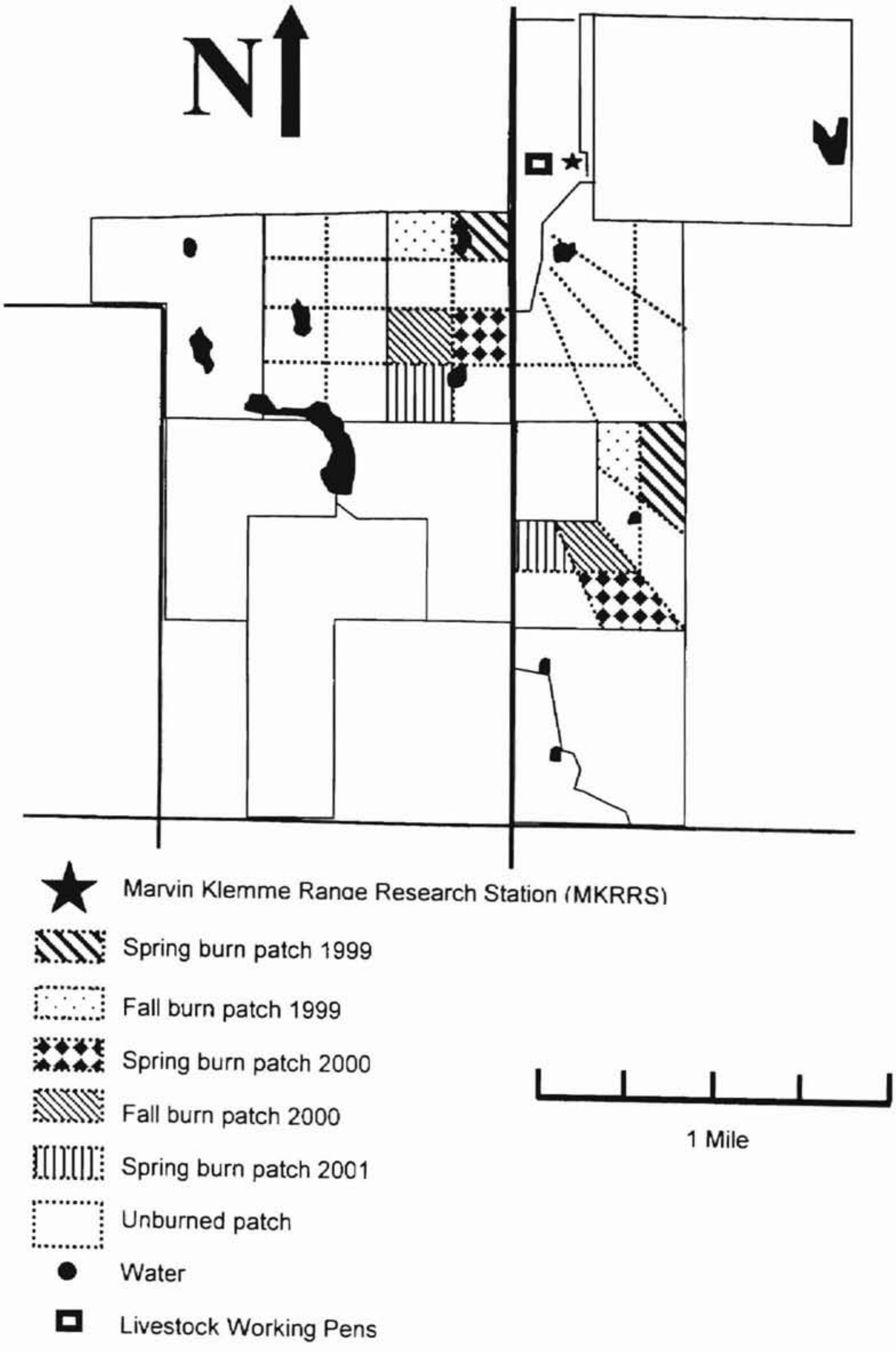

Fig. 3. Study pasture layout and location for the mixed-grass site located at the Marvin Klemme Range Research Station (MKRRS) 15 km southwest of Clinton, Oklahoma.

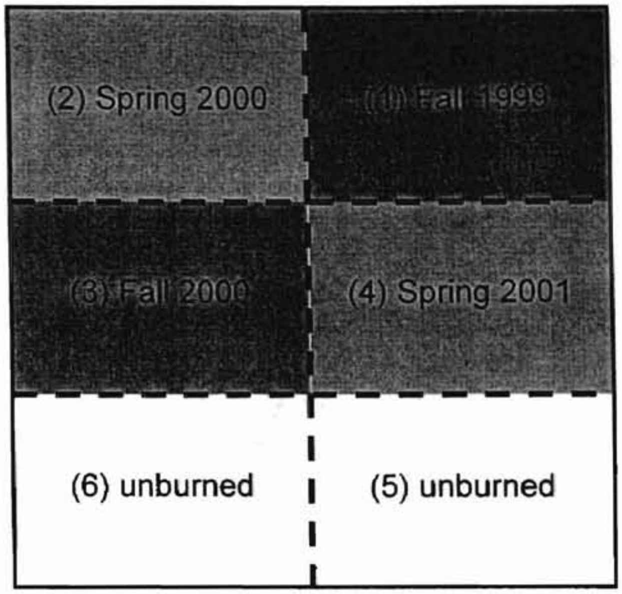

Fig. 4. Oklahoma State University Research Range (OSURR) patch layout within a pasture and burning regime. Dates within each patch indicate the burn season and year. Solid lines represent barbed wire fence around the perimeter of pasture and dotted lines represent each individual "unfenced" patch. The pasture sizes ranged from 46 ha to 73 ha with each patch within a pasture ranging from 8 to 15 ha. The Patch Heterogeneity Index (PHI) was calculated as the standard deviation of the 6 patches within each pasture.

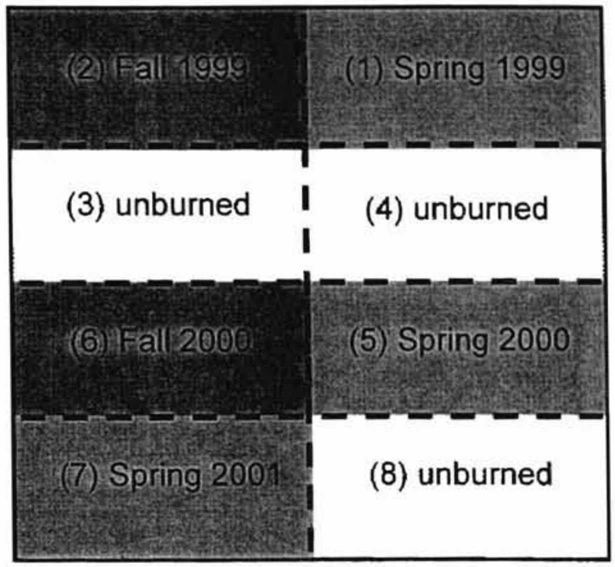

Fig. 5. Marvin Klemme Range Research Station (MKRRS) patch layout and burning regime of each pasture. Dates within each patch indicate the burn season and year Solid lines represent barbed wire fence around perimeter of pasture and dotted lines represent each individual "unfenced" patch. The pasture sizes ranged from 41 ha to 58 ha, with each patch within a pasture ranging from 5 to 12 ha. The Patch Heterogeneity Index (PHI) was calculated as the standard deviation of the 8 patches within each pasture.

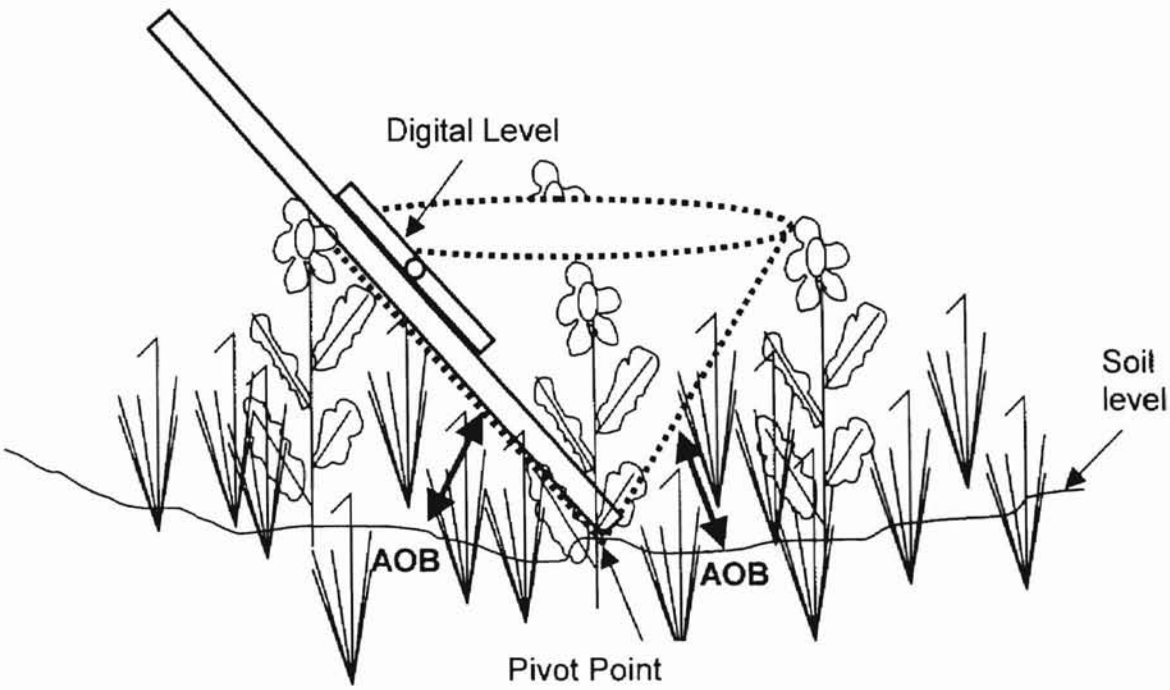

Fig. 6. Angle of obstruction (AOB) measured by recording angles from a position (pivot point) perpendicular to the soil surface (90°) to the top of the nearest obstructing vegetation (<90°) and systematically sampled in eight cardinal directions using a digital level. The digital level was permanently fixed in the center of a 2.54cm x 2.54cm x142.4cm board.

APPENDICIES

Appendix A. Plant species composition for the Oklahoma State University Research Range (OSURR) (tallgrass site) and the Marvin Klemme Range Research Station (MKRRS) (mixed-grass site).

OSURR (Tallgrass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
SCSC	*Schizachyrium scoparium* (Michx.) Nash	Little bluestem	Scsc	N	P	W	C_4
ANGE	*Andropogon gerardii* Vitman	Big bluestem	Tall	N	P	W	C_4
PAVI	*Panicum virgatum* L.	Switchgrass	Tall	N	P	W	C_4
SONU	*Sorghastrum nutans* (L.) Nash	Indiangrass	Tall	N	P	W	C_4
ARPU	*Aristida pupurea* Nutt.	Purple threeawn	Mid	N	P	W	C_4
ARLO	*Aristida oligantha* Michx.	Annual threeawn	Mid	N	A	W	C_4
BOCU	*Bouteloua curtipendula* (Michx.) Torr.	Sideoats grama	Mid	N	P	W	C_4
BOSA	*Bothriochloa laguroides* (DC.) Herter	Silver bluestem	Mid	N	P	W	C_4
DIOL	*Dicanthelium oligosanthes* (Schult.) Gould	Scribner panicum	Mid	N	P	C	C_3
PAFL	*Paspalum floridanum* Michx.	Florida paspalum	Mid	N	P	W	C_4
SPAS	*Sporobolus asper* (Michx.) Kunth	Tall dropseed	Mid	N	P	W	C_4
SCPA	*Schedonnardus paniculatus* (Nutt.) Trel.	Tumblegrass	Mid	N	P	W	C_4
CHVE	*Chloris verticulata* Nutt.	Tumble windmill grass	Mid	N	P	W	C_4
TRFL	*Triden flavus* (L.) Hitchc.	Purple top	Mid	N	P	W	C_4
VARYE	*Elymus virginicus* L.	Virginia wildrye	Mid	N	P	C	C_3
CARYE	*Elymus canadensis* L.	Canada wildrye	Mid	N	P	C	C_3
SEGE	*Setaria geniculata* (Lam.) Beauv.	Knotroot bristlegrass	Mid	N	P	W	C_4
DICO	*Digitaria cognata* (Schult.) Pilger	Fall witchgrass	Mid	N	P	W	C_4
SPCR	*Sporobolus cryptandrus* (Torr.) Gray	Sand dropseed	Mid	N	P	W	C_4
ERSP	*Eragrostis spectabilis* (Pursh) Steud.	Purple lovegrass	Mid	N	P	W	C_4
ANVI	*Andropogon virginicus* L	Broomsedge bluestem	Mid	N	P	W	C_4
MUSC	*Muhlenbergia schreberi* Gmel.	Nimbleweed	Mid	N	P	W	C_4

Appendix A. Continued.

OSURR (Tallgrass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
ECCR	*Echinochloa crusgalli* (L.) Beauv.	Barnyard grass	Mid	I	A	W	C_4
COCY	*Coelorachis cylindrica* (Michx.) Nash	Joint tail	Mid	N	P	W	C_4
PAAN	*Panicum anceps* (Michx.)	Beaked panicum	Mid	N	P	W	C_4
BOHI	*Bouteloua hirsuta* Lag.	Hairy grama	Short	N	P	W	C_4
BUDA	*Buchloe dactaloydes* (Nutt.) Engelm.	Buffalograss	Short	N	P	W	C_4
BOGR	*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.	Blue grama	Short	N	P	W	C_4
BRJA	*Bromus japonicus* Thunb.	Japanese brome	Mid	I	A	C	C_3
CYDA	*Cyndon dactylon* (L.) Pers.	Bermudagrass	Intro	I	P	W	C_4
OWBL	*Bothriochloa ischaemum*	Plains bluestem	Intro				C_4
JUNC	*Juncus* spp.	Rush	GL	N	P	C	C_3
CARX	*Carex* spp.	Sedge	GL				C_3
PLPA	*Plantago patagonica* Jacq.	Plantago	Forb	N	A	C	C_3
ANPA	*Antennaria parlinii* Fern.	Largeleaf pussytoes	Forb	N	P	C	C_3
ERST	*Erigeron annuus* (L.) Pers.	Daisy fleabane	Forb	N	A	C	C_3
CRTX	*Croton texensis* (Kl.) Muell.Arg.	Texas croton	Forb	N	A	W	C_3
GUDR	*Amphiachyris dracumculoides* (DC.) Nutt.	Annual broomweed	Forb	N	A	W	C_3
COCA	*Conyza canadensis* (L.) Cronq.	Mare's tail (horseweed)	Forb	N	A	W	C_3
EUMA	*Euphorbia marginata* Pursh.	Snow-on-the-mountain	Forb	N	A	W	C_3
CRCA	*Croton captiatus* Michx.	Woolly croton	Forb	N	A	W	C_3
ACVI	*Acalypha virginica* L.	Three-seeded mercury	Forb	N	A	W	C_3
CHFA	*Cassia fasciculata* (Michx.) Greene	Partridge pea	Legume	N	A	W	C_3
DITE	*Diodia teres* Walt.	Poor joe	Forb	N	A	W	C_3
AMBI	*Ambrosia bidentata* Michx.	Lanceleaf ragweed	Forb	N	A	W	C_3
GAPU	*Gallardia pulchella*	Indian blanket	Forb	N	A	W	C_3
ECAN	*Echinacea pallida* (Nutt.) Nutt.	Black samson	Forb	N	P	C	C_3

Appendix A. Continued

OSURR (Tallgrass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
PSTE	*Psoralea tenuiflora* (Pursh) Rydb.	Slimflower scurfpea	Leg.	N	P	W	C_3
ACLA	*Achillea millefolium* L.	Common yarrow	Forb	N	P	C	C_3
PHPI	*Phlox pilosa*	Prairie phlox	Forb	N	P	C	C_3
BAAU	*Baptisia australis* (L.) R. Br.	Blue wild indigo	Legume	N	P	C	C_3
RYTE	*Strophostyles leiosperma* (T. and G.) Piper	Slick seed wildbean	Forb	N	P	C	C_3
GUSA	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby	Broom snakeweed	Forb	N	P	W	C_3
LIPU	*Liatris punctata* Hook.	Dotted gayfeather	Forb	N	P	W	C_3
LEVI	*Lespedeza virginica* (L.) Britt.	Slender lespedeza	Legume	N	P	W	C_3
ACAN	*Acacia angustissima*	Prairie acacia	Legume	N	P	W	C_3
PEPU	*Dalea purpurea* Vent.	Purple prairie clover	Legume	N	P	W	C_3
RACO	*Ratibida columnaris* (Nutt.) Woot. and Standl.	Prairie coneflower	Forb	N	P	W	C_3
SAAZ	*Salvia azurea* Lam.	Pitcher sage	Forb	N	P	W	C_3
SOMI	*Solidago missouriensis* Nutt.	Missouri goldenrod	Forb	N	P	W	C_3
PAJA	*Paronychia jamesii* T. and G.	James nailwort	Forb	N	P	W	C_3
RUHI	*Rudbeckia hirta* L.	Black eyed Susan	Forb	N	P	W	C_3
HECA	*Heterothera canescens*	Gold aster	Forb	N	P	W	C_3
AMCA	*Amorpha canescens* Nutt. ex Pursh	Leadplant	Legume	N	P	C	C_3
GRSQ	*Grindelia squarrosa* (Pursh) Dun.	Curly-cup gumweed	Forb	N	A	W	C_3
OXST	*Oxalis stricta* L.	Yellow wood sorrel	Forb	N	P	W	C_3
ERLO	*Eriogonum longifolim*	Wild buckwheat	Forb	N	P	W	C_3
PHHE	*Physalis heterophylla* Nees	Groundcherry	Forb	N	P	W	C_3
SORI	*Solidago rigida* L.	Stiff goldenrod	Forb	N	P	W	C_3
DEIL	*Desmanthus illinoensis* (Michx.) MacM. ex Robins and Fern.	Illinois bundleflower	Legume	N	P	W	C_3
VEBA	*Vernonia baldwinii* Torr.	Ironweed	Forb	N	P	W	C_3
TECA	*Teucrium canadense* L.	American germander	Forb	N	P	W	C_3
GUVI	*Guara villosa*	Woolly guara	Forb				C_3
APCA	*Apocyrum cannabinum* L.	Hemp dogbane	Forb	N	P	W	C_3

Appendix A. Continued.

OSURR (Tallgrass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
HEMO	*Helianthus mollis* Lam.	Ashy sunflower	Forb	N	P	W	C_3
SOLE	*Solanum elaeagnifolium* Cav.	Silver-leaf nightshade	Forb	N	P	W	C_3
KRLA	*Krameria lanceolata* Torr.	Trailing ratney	Forb	N	P	W	C_3
AMPS	*Ambrosia cumanensis* Kunth in H.B.K	Western ragweed	Forb	N	P	W	C_3
ARLU	*Artemisia ludoviciana* Nutt.	Louisiana sagewort	Forb	N	P	W	C_3
ASER	*Aster ericoides* L.	Heath aster	Forb	N	P	W	C_3
HENI	*Hedyotis nigricans* (Lam.) Fosb.	Prairie bluets	Forb	N	P	W	C_3
NELU	*Neptunia lutea* (Leavenw.) Benth.	Yellow neptune	Legume	N	P	W	C_3
LISU	*Linum sulcatum* Riddell	Yellow prairie flax	Forb	N	A	C	C_3
ASSY	*Asclepias syriaca* L.	Common milkweed	Forb	N	P	W	C_3
PHVI	*Physalis virginiana* P. Mill.	Virginia groundcherry	Forb	N	P	W	C_3
RUHU	*Ruellia humilis* Nutt.	Wild petunia	Forb	N	P	W	C_3
SOCR	*Solanum carolinense* L.	Horsenettle	Forb	N	P	W	C_3
THIS	*Cirsium undulatum* (Nutt.) Spreng.	Wavyleaf thistle	Forb	N	P	W	C_3
ASVI	*Asclepias viridis* Walt.	Antelopehorn	Forb	N	P	W	C_3
SOCA	*Solidago canadensis* L	Tall goldenrod	Forb	N	P	W	C_3
CALY	*Calyopsus berlandieri* Spach	Evening primrose	Forb	N	P	W	C_3
MOPE	*Monarda pectinata* Nutt.	Spotted beebalm	Forb	N	P	W	C_3
HEMA	*Helianthus maximiliani*	Maximilian sunflower	Forb	N	P	W	C_3
SCUN	*Schrankia nuttallii* (Britt. & Rose) Standl.	Sensitive briar	Legume	N	P	W	C_3
LECU	*Lespedeza cuneata* (DuMont) G. Don	Sericea lespedeza	Legume	I	P	W	C_3
AMBL	*Euphorbia prostata* Ait.	Prostrate spurge	Forb	I	A	W	C_3
MELU	*Medicago lupulina* L.	Black medic	Forb	I	A	W	C_3
CUPE	*Cuscata pentagona* Engelm.	Field dodder	Parasite	N	A	W	C_3

Appendix A. Continued.

OSURR (Tallgrass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
CODR	*Cornus drummondii* C.A. Mey.	Rough dogwoood	Shrub	N	P	W	C_3
RUCO	*Rhus copallina* L.	Winged sumac	Shrub	N	P	W	C_3
SYOR	*Symphoricarpos orbiculatus* Moench	Buckbrush	Shrub	N	P	W	C_3
RHGL	*Rhus glabra* L.	Smooth sumac	Shrub	N	P	C	C_3
PRAN	*Prunus gracilis* Engelm. and Gray	Sand plum	Shrub	N	P	W	C_3
RUOK	*Rubus oklahomus*	Blackberry	Shrub				C_3
DIVI	*Diospyros virginiana* L.	Persimmon	Shrub	N	P	C	C_3
CERE	*Celtis reticulata* Torr.	Hackberry	Tree	N	P	C	C_3
PRMX	*Prunus mexicana* Wats.	Mexican plum	Tree	N	P	C	C_3
ULMA	*Ulmus americana* L.	American elm	Tree	N	P	C	C_3

Appendix A. Continued.

MKRRS (Mixed-Grass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
SCSC	*Schizachyrium scoparium* (Michx.) Nash	Little bluestem	Scsc	N	P	W	C_4
ANGE	*Andropogon gerardii* Vitman	Big bluestem	Tall	N	P	W	C_4
PAVI	*Panicum virgatum* L.	Switchgrass	Tall	N	P	W	C_4
SONU	*Sorghastrum nutans* (L.) Nash	Indiangrass	Tall	N	P	W	C_4
ARLO	*Aristida oligantha* Michx.	Annual threeawn	Mid	N	A	W	C_4
ARPU	*Aristida pupurea* Nutt.	Purple threeawn	Mid	N	P	W	C_4
BOCU	*Bouteloua curtipendula* (Michx.) Torr.	Sideoats grama	Mid	N	P	W	C_4
BOSA	*Bothriochloa laguroides* (DC.) Herter	Silver bluestem	Mid	N	P	W	C_4
SEGE	*Seteria geniculata* (Lam.) Beauv.	Knotroot bristlegrass	Mid	N	P	W	C_4
CHVE	*Chloris verticulata* Nutt.	Tumble windmill grass	Mid	N	P	W	C_4
ELSM	*Elytrigia smithii* (Rydb.) Nevski	Western wheatgrass	Mid	N	P	C	C_3
ELCA	*Elymus canadensis*	Canada wildrye	Mid	N	P	C	C_3
SCPA	*Schedonnardus paniculatus* (Nutt.) Trel.	Tumblegrass	Mid	N	P	W	C_4
DIOL	*Dicanthelium oligosanthes*	Scribners panicum	Mid				C_3
SPAS	*Sporobolus asper* (Michx.) Kunth	Tall dropseed	Mid	N	P	W	C_4
SPCR	*Sporobolus cryptandrus* (Torr.) Gray	Sand dropseed	Mid	N	P	W	C_4
TRAL	*Tridens albescens* (Vasey) Woot & Standl.	White tridens	Mid	N	P	W	C_4
TRFL	*Tridens flavus* (L.) Hitchc.	Purple-top	Mid	N	P	W	C_4
TRMU	*Tridens mutica*	Slim tridens	Mid				C_4
BOGR	*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.	Blue grama	Short	N	P	W	C_4
BOHI	*Bouteloua hirsuta* Lag.	Hairy grama	Short	N	P	W	C_4
BUDA	*Buchloe dactaloydes* (Nutt.) Engelm.	Buffalograss	Short	N	P	W	C_4
ERPI	*Erioneuron pilosum* (Buckl.) Nash	Hairy erionneuron	Short	N	P	W	C_4

Appendix A. Continued.

MKRRS (Mixed-Grass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
VUOC	*Vulpia octoflora*	Six-weeks fescue	Intro	I	A	C	C_3
BRTE	*Bromus tectorum* L.	Cheatgrass	Intro	I	A	C	C_3
CYDA	*Cyndon dactylon* (L.) Pers.	Bermudagrass	Intro	I	P	W	C_4
Plains	*Eragrostis intermedia* Hitchc.	Plains lovegrass	Intro	N	P	W	C_4
JUNC	*Juncus tenuis*	Rush	GL				C_3
CARX	*Carex* spp.	Sedge	GL	N	P	C	C_3
ACAN	*Acacia angustissima*	Prairie Acacia	Legume	N	P	W	C_3
AMPS	*Ambrosia psilostachya* DC.	Western ragweed	Forb	N	P	W	C_3
ARLU	*Artemisia ludoviciana* Nutt.	Silver sage (wormwood)	Forb	N	P	W	C_3
ALCA	*Allium canadense* L.	Wild onion	Forb	N	P	W	C_3
Astrag	*Astragalus mollissimus* Torr.	Woolly loco	Forb	N	P	W	C_3
CEAM	*Centaurea americanca*	Basket flower	Forb	N	A	W	C_3
ERAN	Eriogonum annuum	Buckwheat	Forb	N	A	W	C_3
CNTE	*Cnidoscolus texanus*	Bullnettle	Forb	N	P	W	C_3
Cheno	*Chenopodium album* L.	Lambsquarter	Forb	I	A	W	C_3
PODO	*Polansia dodecandra*	Clammy weed	Forb	N	A	C	C_3
CALA	*Calylophus lavandulifolius* or *serrulatus*	Calyophus	Forb	N	P	W	C_3
SILA	*Silphium laciniatum* L.	Compass plant	Forb	N	P	W	C_3
Cory	*Coreopsis lanceolata* or *Thelesperma megapotamicum*	coreopsis or Rayless thelesperma	Forb	N	A	W	C_3
CRTX	*Croton texensis* (Kl.) Muell.Arg.	Texas croton	Forb	N	A	W	C_3
GRSQ	*Grindelia squarrosa* (Pursh) Dun.	Curly-cup gumweed	Forb	N	P	W	C_3
DAEN	*Dalea enneandra*	Big-top dalea	Legume	N	A	W	C_3
PHIN	*Phyla incisa*	Texas frogfruit	Forb	N	P	W	C_3
ASER	*Aster ericoides* L.	Heath aster	Forb	N	P	W	C_3
HECA	*Heterothera canescens*	Gold aster	Forb				C_3
HENI	*Hedyotis nigricans* or *H. humifsa* or *H. crassifolia*	Prairie bluets	Forb	N	P	W	C_3
HEDR	*Hedeoma drummondii*	Drummonds hedeoma	Forb	N	A	W	C_3

Appendix A. Continued.

MKRRS (Mixed-Grass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
HETE	*Heliotropium tenellum* (Nutt.) Torr.	Pasture heliotrope	Forb	N	A	W	C_3
LAAM	*Lamium amplexicaule* L.	Henbit	Forb	I	A	C	C_3
SOCR	*Solanum carolinense* L.	Horsenettle	Forb	N	P	W	C_3
DEIL	*Desmanthus illoensis* (Michx.) Macm.	Illinois bundleflower	Legume	W	N	P	C_3
VEBA	*Vernonia baldwinii* Torr.	Ironweed	Forb	W	N	P	C_3
KRLA	*Krameria lanceolata* Torr.	Range ratney	Forb	W	N	P	C_3
AMCA	*Amorpha canescens* (Nutt.) Pursh	Leadplant	Leg.	C	N	P	C_3
LIPU	*Liatris punctata* Hook.	Dotted gayfeather	Forb	W	N	P	C_3
THPE	*Thymophylla pentachaeta* or *dysoddia*		Forb	W	N	A	C_3
COCA	*Conyza canadensis* (L.) Cronq.	Mares Tail	Forb	W	N	A	C_3
MEOL	*Mentzilla oligosperma*	Stickleaf mentzilla	Forb	W	N	P	C_3
ASSY	*Asclepias syriaca* L.	Common milkweed	Forb	W	N	P	C_3
TECA	*Teucrium canadense* L.	American germander	Forb	W	N	P	C_3
MOPE	*Monarada pectinata* Nutt.	Spotted beebalm	Forb	W	N	A	C_3
CANU	*Carduus nutans* L.	Musk thistle	Forb	W	I	B	C_3
OXST	*Oxalis stricta* L.	Yellow woodsorrel	Forb	W	N	P	C_3
PARO	*Palafoxia rosea*	Rose palafoxia	Forb	W	N	A	C_3
PAJA	*Paronychia jamesii* or *P. lindeimeri*	James nailwort	Forb	W	N	P	C_3
SAAZ	*Salvia azurea* Lam.	Pitcher sage, blue sage	Forb	W	N	P	C_3
PLNT	*Plantago rhodosperma* or *P. aristata*	Woolly plantain	Forb	C	N	A	C_3
EUPR	*Euphorbia prostrata* Ait.	Prostrate spurge	Forb	W	N	A	C_3
PEPU	*Petalostemon purpureum* (Vent.) Rydb.	Purple prairie clover	Legume	W	N	P	C_3
ANPA	*Antennaria parlinii* Fern.	Pussytoes	Forb	C	N	P	C_3

Appendix A. Continued.

MKRRS (Mixed-Grass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
RACO	*Ratibida columnaris* (Sims) D. Don	Prairie coneflower	Forb	W	N	P	C_3
RYTE		Peavine	Forb				C_3
PSTE	*Psoralea tenuiflora* Pursh	Slimflower scurfpea	Leg.	W	N	P	C_3
SCRE	Scutellaria resinosa Torr.	Skullcap	Forb	W	N	P	C_3
SCUN	*Schrankia uncinata* Willd.	Catclaw Sensitive briar	Leg.	W	N	P	C_3
LYGO	*Lygodesmia texana* (T. & G.) Greene	Texas skeleton weed	Forb	W	N	P	C_3
ASSU	*Aster subulatus* Michx. Var *ligulatus* Shinners	Slender aster	Forb	W	N	A	C_3
EUMA	*Euphorbia marginata* Pursh.	Snow-on-the-mountain	Forb	W	N	A	C_3
SOLE	*Solanum elaeagnifolium* Cav.	Silver-leaf Nightshade	Forb	W	N	P	C_3
SOMI	*Solidago missouriensis* Nutt.	Missouri goldenrod	Forb	W	N	P	C_3
HEAN	*Helianthus annuus* L.	Common sunflower	Forb	W	N	A	C_3
ASPR	*Aster praealtus* Poir.	Tall aster	Forb	W	N	P	C_3
TAPA	*Talinum paviflorum*		Forb	W	N	P	C_3
THTE	*Thamnosa texannum*	Dutchman's britches	Forb				C_3
ACVI	*Acalypha virginica* L.	Three-seeded mercury	Forb	W	N	A	C_3
TRRA	*Tragia ramosa* Torr.	Catnip noseburn	Forb	W	N	P	C_3
VEBI	*Verbena bipinnatifida* Nutt.	Dakota vervain	Forb	W	N	A	C_3
PAQU	*Parthenocissus quinquefolia*	Virginia creeper	Vine	W	N	A	C_3
VIVI	*Vicia villosa* Roth.	Hairy vetch	Legume	C	I	A	C_3
GUSA	*Guiterrezia sarothrae* (Pursh) Britt. & Rusby	Broom snakeweed	Forb	W	N	P	C_3
GUDR	*Amphiachyris dracunculoides* (DC.) Nutt.	Annual broomweed	Forb	W	N	A	C_3
SMBO	*Smilax bona-nox* L.	Green brier	Vine	C	N	P	C_3

Appendix A. Continued.

MKRRS (Mixed-Grass Site)

Code	Scientific Name	Common Name	Func. Group	Origin	Life	Season	Path
MIBO	*Mimosa borealis* Gray.	Fragrant mimosa	Legume	W	N	P	C_3
OPLI	*Opuntia* spp.	Prickly pear	Forb	C	N	P	C_3
PRAN	*Prunus angustifolia* Marsh.	Chichasaw plum	Shrub	C	N	P	C_3
RHTR	*Rhus trilobata* Nutt.	Skunkbush sumac	Shrub	C	N	P	C_3
RHGL	*Rhus glabra* L.	Smooth sumac	Shrub	C	N	P	C_3
YUGL	*Yucca glauca* Nutt.	Yucca	Forb	C	N	P	C_3
ULAM	*Ulmus americana* L.	American Elm	Tree	C	N	P	C_3
SADR	*Sapindus saponaria* L.	Western soapberry	Tree	C	N	P	C_3

Appendix B. Patch level angle of obstruction (AOB) means and standard errors (SE) for the Oklahoma State University Research Range (OSURR) (n=3) and the Marvin Klemme Range Research Station (MKRRS) (n=2) for 1999, 2000, and 2001.

OSURR	Angle of Obstruction (AOB)		
Control			
Patch	1999	2000	2001
1	78.75 (3.56)	86.73 (1.54)	85.50 (2.26)
2	83.60 (2.71)	86.87 (3.01)	84.69 (3.53)
3	85.04 (2.78)	88.73 (1.27)	85.00 (1.75)
4	84.16 (3.21)	89.17 (0.83)	83.25 (3.09)
5	84.85 (1.98)	86.52 (1.74)	85.36 (0.78)
6	86.22 (1.78)	88.70 (0.65)	87.05 (1.59)
Patchburn			
Patch	1999	2000	2001
1	83.75 (0.79)	79.76 (1.19)	81.70 (1.34)
2	86.29 (1.91)	63.68 (3.81)	86.14 (1.34)
3	82.46 (1.11)	89.54 (0.46)	78.93 (3.04)
4	84.10 (2.95)	87.16 (1.47)	48.85 (4.22)
5	82.59 (0.69)	87.81 (1.18)	80.35 (2.29)
6	86.54 (1.05)	86.07 (1.59)	86.67 (3.33)
MKRRS	Angle of Obstruction (AOB)		
Control			
Patch	1999	2000	2001
1	58.17 (0.56)	53.74 (7.08)	60.16 (1.01)
2	62.99 (4.09)	59.64 (2.57)	61.90 (3.95)
3	55.17 (5.12)	56.26 (8.01)	60.92 (10.05)
4	52.95 (9.58)	46.31 (3.43)	56.46 (3.06)
5	53.77 (9.97)	57.35 (6.75)	59.17 (1.98)
6	51.74 (7.86)	55.25 (2.20)	52.47 (0.005)
7	50.34 (8.80)	49.61 (7.23)	54.46 (4.55)
8	55.35 (0.91)	55.48 (5.89)	55.70 (5.51)
Patchburn			
Patch	1999	2000	2001
1	48.22 (8.98)	51.86 (5.31)	63.82 (4.17)
2	56.01 (2.94)	51.75 (8.68)	64.91 (0.01)
3	46.71 (4.84)	57.51 (1.31)	63.11 (2.18)
4	56.59 (7.52)	48.37 (4.18)	66.04 (1.43)
5	58.64 (4.20)	49.71 (1.51)	66.92 (0.71)
6	52.40 (0.09)	66.70 (5.83)	67.93 (2.43)
7	64.91 (2.44)	65.35 (9.09)	55.14 (3.75)
8	61.57 (8.65)	67.59 (6.03)	67.95 (4.53)

Appendix C. Functional group patch means (n=3) and standard errors (SE) of grass and forb canopy cover, bare ground, and litter cover for the Oklahoma State Research Range (OSURR) for 1999, 2000, and 2001.

Control	Grass (%)			Forb (%)			Bare Ground (%)			Litter (%)		
Patch	1999	2000	2001	1999	2000	2001	1999	2000	2001	1999	2000	2001
1	59.74	68.60	48.95	20.84	38.08	36.19	5.12	1.61	1.16	29.64	38.61	46.16
	(4.83)	(10.75)	(5.29)	(3.18)	(1.51)	(4.76)	(2.36)	(0.68)	(0.58)	(9.16)	(3.27)	(1.88)
2	60.51	67.09	51.13	26.33	31.49	26.48	6.84	3.21	3.20	20.19	35.68	45.80
	(2.95)	(4.79)	(3.90)	(4.26)	(7.03)	(2.29)	(2.79)	(1.98)	(2.62)	(6.73)	(3.34)	(3.54)
3	62.92	80.60	59.87	27.31	31.25	26.55	3.65	1.66	1.18	23.45	38.41	47.24
	(9.52)	(13.27)	(12.60)	(4.85)	(6.85)	(6.37)	(0.21)	(1.78)	(0.83)	(9.83)	(1.78)	(2.49)
4	65.23	78.67	49.07	33.18	31.57	33.83	3.05	0.85	0.93	32.59	38.28	45.88
	(8.22)	(7.23)	(11.32)	(5.02)	(4.42)	(2.98)	(1.47)	(0.52)	(0.60)	(11.67)	(3.42)	(1.99)
5	73.26	62.03	51.01	42.21	41.00	30.21	8.95	5.87	0.93	25.49	34.28	44.09
	(7.31)	(3.72)	(9.83)	(11.11)	(2.85)	(4.25)	(5.04)	(2.30)	(0.23)	(6.02)	(2.78)	(1.81)
6	57.60	61.53	49.33	38.34	33.09	29.05	5.34	2.11	0.17	28.60	34.86	48.00
	(2.81)	(8.13)	(7.63)	(10.57)	(6.42)	(5.50)	(2.99)	(1.08)	(0.03)	(8.23)	(1.96)	(1.35)
Patchburn	**Grass (%)**			**Forb (%)**			**Bare Ground (%)**			**Litter (%)**		
Patch	**1999**	**2000**	**2001**	**1999**	**2000**	**2001**	**1999**	**2000**	**2001**	**1999**	**2000**	**2001**
1	62.80	57.50	45.03	27.61	46.23	29.43	10.11	20.31	8.40	24.80	4.16	28.20
	(4.21)	(3.32)	(1.89)	(3.92)	(7.71)	(0.37)	(3.06)	(2.12)	(2.37)	(4.58)	(0.11)	(1.97)
2	63.14	35.97	38.29	27.06	43.85	41.93	3.53	21.56	11.17	27.71	5.31	24.77
	(5.20)	(3.77)	(3.93)	(4.73)	(2.62)	(4.59)	(1.22)	(2.85)	(3.15)	(2.67)	(0.30)	(1.55)
3	60.19	66.39	22.48	23.66	35.50	53.26	6.11	1.29	30.70	25.34	33.04	13.71
	(7.23)	(8.78)	(0.71)	(5.16)	(2.51)	(13.78)	(2.12)	(0.43)	(7.91)	(2.86)	(1.37)	(3.11)
4	63.57	67.98	25.17	29.22	29.14	31.51	6.59	5.52	36.79	22.47	39.58	10.90
	(7.50)	(3.21)	(1.73)	(4.18)	(8.97)	(2.50)	(3.17)	(4.12)	(7.32)	(2.86)	(1.46)	(0.67)
5	46.39	69.33	56.61	33.26	41.59	31.86	3.90	5.74	3.26	23.07	35.76	44.90
	(1.92)	(7.05)	(1.69)	(5.14)	(7.16)	(4.46)	(1.05)	(3.72)	(1.58)	(4.50)	(2.46)	(1.75)
6	61.67	46.42	40.57	21.46	35.54	20.88	4.54	0.80	0.77	20.48	35.41	50.90
	(5.64)	(6.33)	(3.25)	(4.93)	(6.47)	(3.91)	(1.38)	(0.45)	(0.72)	(1.71)	(4.11)	(5.34)

Appendix D. Functional group patch means (n=2) and standard error (SE) for control and patch burn treatments at the Marvin Klemme Range Research Station (MKRRS) for 1999, 2000, and 2001.

Control	Grass			Forb			Bare Ground			Litter		
Patch	1999	2000	2001	1999	2000	2001	1999	2000	2001	1999	2000	2001
1	31.07	51.10	26.85	28.83	17.82	20.03	13.98	17.32	24.90	27.79	28.38	34.22
	(9.93)	(5.13)	(4.95)	(5.56)	(2.98)	(5.95)	(4.16)	(0.35)	(4.27)	(18.64)	(0.12)	(6.25)
2	34.65	58.82	26.07	17.64	21.75	20.00	15.95	17.30	17.68	28.55	30.38	39.18
	(8.18)	(1.55)	(7.43)	(1.24)	(0.58)	(0.13)	(5.43)	(9.67)	(5.12)	(16.49)	(10.58)	(4.78)
3	28.09	37. 52	34.48	14.58	31.54	16.82	25.90	22.78	16.50	24.77	21.47	33.83
	(1.93)	(8.68)	(16.92)	(0.77)	(0.57)	(0.02)	(4.07)	(6.65)	(1.17)	(12.23)	(3.50)	(2.30)
4	28.46	44.14	33.25	26.92	23.21	21.74	20.41	25.32	23.27	28.49	24.07	33.65
	(5.38)	(7.47)	(11.25)	(2.59)	(8.37)	(7.93)	(1.71)	(4.35)	(7.53)	(12.19)	(1.67)	(3.85)
5	35.50	43.79	35.28	20.07	29.97	26.61	19.58	19.28	14.72	19.37	27.90	36.57
	(15.61	(5.52)	(11.68)	(3.67)	(3.20)	(3.37)	(15.30)	(8.22)	(0.85)	(3.01)	(6.03)	(2.93)
6	27.13	38.20	30.27	20.61	22.24	21.67	24.64	22.33	20.83	18.52	18.10	38.27
	(0.50)	(5.10)	(8.30)	(2.02)	(7.17)	(1.82)	(6.22)	(4.43)	(5.00)	(4.55)	(2.57)	(1.33)
7	39.15	43.28	35.38	24.19	22.12	20.14	17.87	25.28(	33.27	21.45	21.04	18.03
	(7.52)	(4.32)	(14.78)	(2.93)	(0.65)	(2.77)	(4.95)	2.58)	(5.20)	(6.30)	(8.33)	(5.53)
8	24.75	37.63	30.08	29.26	24.22	25.29	28.98	31.78(	26.52(	20.09	23.68	30.23
	(4.37)	(8.60)	(1.21)	(2.56)	(2.18)	(2.52)	(0.19)	4.38)	8.18)	(12.63)	(8.25)	(3.87)

Appendix D. Continued

Patchburn	Grass			Forb			Bare Ground			Litter		
Patch	1999	2000	2001	1999	2000	2001	1999	2000	2001	1999	2000	2001
1	25.84	38.85	31.98	28.41	28.30	24.52	28.66	28.50	25.82	7.57	11.00	20.13
	(4.17)	(0.32)	(4.78)	(5.31)	(4.87)	(0.08)	(2.10)	(1.37)	(2.78)	(2.95)	(1.10)	(0.80)
2	33.83	21.80	31.03	28.03	37.64	27.07	14.51	40.77	32.25	19.78	6.37	20.08
	(1.12)	(3.60)	(10.70)	(3.87)	(0.03)	(10.30)	(3.70)	(9.83)	(7.45)	(2.43)	(0.20)	(4.48)
3	27.92	49.12	24.20	28.53	30.70	30.12	18.16	14.28	22.70	21.82	31.93	28.88
	(6.99)	(6.18)	(1.20)	(9.11)	(7.00)	(3.18)	(6.94)	(2.48)	(0.60)	(7.73)	(2.23)	(10.12)
4	27.73	31.65	32.08	32.52	29.61	29.71	13.98	20.10	20.95	22.93	21.83	30.05
	(2.83)	(7.22)	(1.08)	(5.10)	(9.67)	(2.37)	(7.98)	(8.40)	(4.25)	(4.59)	(0.60)	(1.02)
5	43.13	37.63	49.07	21.45	33.34	26.85	7.30	17.32	12.67	29.08	12.33	29.43
	(15.6)	(5.10)	(0.13)	(15.11)	(1.40)	(2.05)	(2.70)	(0.95)	(1.80)	(12.92)	(0.43)	(0.40)
6	31.72	44.34	27.53	22.81	40.12	29.29	21.50	8.98	29.68	25.96	37.53	21.98
	(10.2)	(10.53)	(2.83)	(5.68)	(0.48)	(3.01)	(1.71)	(0.02)	(1.65)	(10.17)	(2.37)	(8.58)
7	40.87	48.24	27.33	23.39	31.90	33.25	13.19	15.33	22.07	26.74	36.53	24.25
	(1.14)	(5.80)	(0.50)	(4.62)	(1.80)	(9.48)	(1.22)	(3.43)	(5.17)	(6.53)	(2.27)	(7.48)
8	41.98	64.35	49.68	19.20	27.10(	24.34	9.62	12.17	12.12	38.07	36.72	35.93
	(11.2)	(2.28)	(7.35)	(2.60)	2.00)	(10.06)	(0.38)	(2.60)	(0.08)	(16.51)	(2.78)	(2.10)

Vita

Timothy Royce Tunnell 2

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF PATCH BURNING ON LIVESTOCK PERFORMANCE AND WILDLIFE HABITAT ON OKLAHOMA RANGELANDS

Major Field: Plant and Soil Sciences

Biographical:

Personal Data: Born in Brownfield, Texas, on 11 September 1968, the son of Hansford R. and Sherron K. Tunnell.

Education: Graduated from Eisenhower High School, Lawton, Oklahoma in May 1987. Received a Bachelor of Science degree in Wildlife Management from Texas Tech University, Lubbock, Texas in May 1994. Completed the requirements for the Master of Science degree in Plant and Soil Science, with a specialization in Rangeland Ecology and Management, at Oklahoma State University, Stillwater, Oklahoma in May 2002.

Work Experience: Employed as a Research Technician in Brush Management at the Texas A&M Agricultural Experiment Station in Vernon, Texas; worked as a Research Technician I at the Texas A&M Agricultural Experiment Station under the USDA-NRI grant entitled "Sustainable Management Strategies for Mesquite and Redberry Juniper Invested Rangelands"; employed as a full-time Senior Agriculturalist in the Department of Plant and Soil Sciences at Oklahoma State University while pursuing a MS degree in Rangeland Ecology and Management from 1998 to 2001; January 2002, employed by The Nature Conservancy as a Grassland Manager in the Nebraska Platte/Rainwater Basin Project Office.

Professional Memberships: Society for Range Management, The Wildlife Society.